Biodiversity and Land Condition in Tropical Savanna Rangelands

Technical Report

Tropical Savannas CRC
Cooperative Research Centre for Tropical Savannas Management

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Alaric Fisher[1]
Alex Kutt[2]

Tropical Savannas Cooperative Research Centre

and

[1]Department of Natural Resources, Environment & the Arts
PO Box 496, Palmerston, NT, Australia, 0810
email: alaric.fisher@nt.gov.au

[2]CSIRO Sustainable Ecosystems
Private Mail Bag PO, Aitkenvale, QLD, Australia 4814
email: alex.kutt@csiro.au
(previously: Qld Environmental Protection Agency, Townsville)

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Contents

1. Introduction

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 by an increasing expectation that Australian rangelands will be managed, by landholders and management agencies, in an ecologically sustainable fashion (eg. Anon 1996, ANZECC & ARMCANZ 1999); by requirements to report on the state of and trends in biodiversity at both national (eg. NLWRA 2002, Beeton *et al*. 2006) and regional scales (eg. Commonwealth of Australia 2002, NRMBNT 2005); 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. Such indicators include a number already used in monitoring “land condition” in the context of pastoral management, which are often combined and summarised in a simple “good” to “poor” 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. This project explores the relationship between “land condition” and biodiversity in a number of landtypes in the tropical savanna rangelands of northern Australia.

1.2 Biodiversity decline in rangelands

The rangelands[1] contain a substantial proportion and distinctive components of Australia’s biodiversity. They are also apparently not subject to the extreme disruption of habitat and ecological processes that are a characteristic of much of the more intensely settles, and agriculturally developed non-rangeland areas. Nevertheless, there has been substantial reduction in rangeland biodiversity since European settlement, and abundant evidence of ongoing decline. Evidence of loss and decline have been widely reviewed, along with discussion of factors responsible (eg. Lunney *et al.* 1994, Morton & Mulvaney 1996, James *et al*. 1999, Whitehead *et al*. 2001 (Background Paper 1), Woinarski & Fisher 2003). Although the extinction of 20 mammals species in the arid rangeland (McKenzie & Burbidge 2003) is the most widely quoted example, there have also been broad-scale losses or declines of many bird and plant species. Although some taxa, such as reptiles, may be more resilient to the changes underlying these losses, there is also a sparsity of historical and modern data on which to assess changes in their status (and most particularly for almost all invertebrate groups).

While the loss of biodiversity in rangelands is clearly related to environmental changes associated with European settlement and subsequent pastoral development, which disrupted the land management regime imposed by Aboriginal people for the previous tens of thousands

[1] There are a number of definitions of rangeland, but these are usually in the context of rainfall and landuse, such as “land where livestock are grazed extensively on native vegetation, and where rainfall is too low or erratic for agricultural cropping or improved pasture” (NRMWG 1996). The ‘standard’ delineation of rangelands in Australia (eg. NLWRA 2001, Fisher *et al.* 2004) includes the c. 75% of Australia outside the more-intensely developed south-western, southern and eastern coastal fringes (plus the Wet Tropics), which incorporates significant desert areas not used for pastoralism. In this report we are primarily concerned with rangelands under pastoral landuse.

of years, the precise nature of these changes and the relative importance of various threatening processes are less clear. Major factors include:

- changes in fire regimes, particularly a change in fire frequency, and a reduction in fine-scale patchiness associated with Aboriginal burning practices;
- a substantial increase in grazing pressure with the introduction of stock and feral grazers, which had both direct impacts on vegetation and indirect impacts on habitat quality for other biota and ecosystem functions;
- major changes to the spatial and temporal distribution of water in drier rangelands, ensuring that impacts associated with pastoral use were almost universal in many landscapes;
- spread of exotic predators;
- spread of introduced plants, including exotic pasture species;
- clearing of native vegetation.

These factors are likely to impact on biodiversity in a complex synergistic fashion (eg. Morton 1990) and their relative importance will vary between ecosystems and taxa. The fact that it is so difficult to disentangle these effects suggests that, while it may frequently be useful to monitor the extent or intensity of individual threatening processes (Saunders *et al.* 1998), this is unlikely to translate into a complete picture of trends in biodiversity status.

1.2.1 Biodiversity status in tropical savanna rangelands

While the tropical savanna (see Fig. 1, section 2.1) is generally incorporated into national delineation of “rangeland”, it represents a broad biogeographic realm separate from the arid and semi-arid region to the south, with a generally distinct biota. At least until very recently, it has also been generally regarded as more robust and intact than the arid rangelands, and largely immune to the negative impact on biodiversity observed elsewhere. Although c. 75% of the tropical savanna is subject to pastoral landuse (for cattle production), this is generally based on native pastures and has not involved obvious gross modification of the environment. There have been few known extinctions and these have been on the southern fringes of the region (McKenzie 1981).

However, there is accumulating evidence that this viewpoint is overly optimistic (Woinarski & Fisher 2003, Garnett *et al.* in press) and that there has been broad-scale historic or recent decline in many groups of species, which are likely to be ongoing. Documented declines include granivorous birds (Franklin 1999, Franklin *et al.* 2005), many medium sized mammals (Woinarski *et al.* 2001, Woinarski *et al.* 2006) and fire-sensitive plants (Bowman & Panton 1993, Russell-Smith *et al.* 1998). One of the best documented examples, in central Queensland (which is probably a good example of the ‘most-developed’ portion of the tropical savannas), showed a rapid change in the bird fauna following the introduction of pastoralism in 1870, but also a continuing loss equivalent to two species per decade (Woinarski & Catterall 2004).

The factors leading to these declines largely reprise those listed above (Garnett *et al.*, in press). Pastoral landuse is substantially implicated with, for example, the pattern of decline in granivorous birds correlated with the period and relative intensity of pastoralism (Franklin 1999, Franklin *et al.* 2005). A number of studies have demonstrated a direct or indirect impacts of pastoralism on a range of taxa (Landsberg *et al*. 1999, Fisher 2001, Woinarski *et al.* 2002, Woinarski & Ash 2002, Churchill & Ludwig 2004, Kutt & Woinarski 2007), and such impacts will continue or worsen as pastoral use is generally intensified in many savanna regions (Ash *et al.* 2006). Changes in fire regimes have had substantial impacts in the tropical savannas due to both increase and decrease in the frequency and/or intensity of fire (Russell-Smith *et al.* 2003, Williams *et al*. 2003, Crowley & Garnett 1998), and fire management is often inextricably linked to pastoral management.

1.3 The concept of "land condition" in rangeland management

"Land condition" is a widely-used concept in rangeland or pastoral land management, although the term is often poorly defined. The maintenance or improvement of land condition is seen as a basic goal of sustainable management, as land condition is a major factor influencing productivity.

Grazing Land Management (GLM) education packages (which are widely used in extension to pastoralists in northern Australia; eg. Chilcott *et al.* 2003) define land condition as *"the capacity of land to responds to rain and produce useful forage"*. Components of land condition include:

- soil condition: the capacity of the soil to absorb and store rainfall, store and cycle nutrients, provide habitat for seed germination and plant growth, and to resist erosion. Measured by the amount of ground cover, infiltration rate, and the condition of the soil surface;
- pasture condition: the capacity of the pasture to capture solar energy into green leaf, use rainfall efficiently, conserve soli condition, and to recycle nutrient. Measured by the types of perennial grasses present, their density and vigour;
- woodland condition: the capacity of the woodland to grow pasture, cycle nutrients and regulate groundwater. Measured by the balance of woody plants and pasture in different landtypes and locations in the landscape.

The GLM system classifies land condition into 4 broad categories:

Land condition	Features
Good or 'A'	▪ good coverage of perennial grasses dominated by species considered to be 3P grasses (perennial, productive & palatable) for that land type ▪ little bare ground (<30% in general) ▪ few weeds and no significant infestations ▪ good soil condition; no erosio and good surface condition ▪ no sign, or only early signs of woodland thickening
Fair or 'B'	Similar to 'A' but with one or more of the following: ▪ some decline in 3P grasses; increase in other species (les favoured grasses and weeds) ▪ increase in bare ground (>30% but <60% in general) ▪ some decline in soil condition; some signs of previous erosion and/or current susceptibility to erosion is a concern; ▪ some thickening in density of woody plants
Poor or 'C'	Similar to 'B' but with one or more of the following: ▪ general decline of 3P grasses; large amounts of less favoured species ▪ large increase in bare ground (>60% in general) ▪ obvious signs of past erosion and/or susceptibility currently high ▪ general thickening in density of woody plants
Very poor or 'D'	One or more of the following: ▪ general lack of any perennial grasses or forbs

	▪ severe erosion or scalding, resulting in a hostile environment for plant growth ▪ thickets of woody plants or weeds cover most of the area

Under this system, major indicators for land condition are:
- density and coverage of 3P grasses;
- levels of groundcover;
- condition of the surface soil;
- evidence of erosion;
- presence of weeds;
- woodland condition[2].

However, the GLM system also stresses that it is more important to use these indicators to assist in broad assessment of condition than to focus on describing critical values for each indicator.

Changes in land condition are generally related to grazing impacts, but may also be influenced by changes in fire regime, tree clearing, weed invasion or sowing pasture. Land condition also influences the susceptibility of land to change, and the ease with which change can be reversed. Thus, condition 'A' is relatively stable, and trends towards condition 'B' can be relatively easily remedied by management change. Land in condition 'B' is susceptible to a relatively rapid decline to condition 'C' and reversing this change may require major management change and take some time. Land in condition 'C is very susceptible to decline to 'D' condition, and this change may be very difficult to reverse. Land condition also determines the way country responds to seasonal conditions. Land in condition 'A' may have reduced cover after a series of dry years, but retains a good density of perennial grasses and will quickly recover after rain. Conversely, land in poor condition may have good cover after wet years, but still has a low density of perennial plants and poor water and nutrient capture by soil.

The GLM system encourages land managers to assess their property in terms of the land condition of each paddock and land type, and that such assessment (and ongoing monitoring) informs all aspects of their property management strategies. This system is amalgamated into other land management tools used in northern Australia, such as the "Stocktake" package[3].

Assessment of land condition under this sort of system is likely to be formalised in the Queensland State Rural Leasehold Strategy[4], whereby leases on grazing land will include land managements agreements, with maintenance or improvement in land condition as a performance indicator. The proportion of land in different land condition levels is also used as explicit Resource Condition Targets or Management Action Targets in some Natural Resource Management Plans of northern Australian NHT/NAP regions[5].

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[2] in this context, generally refers to 'thickening', or an increase in the density of (native) trees and shrubs, which can reduce pasture production.
[3] http://www2.dpi.qld.gov.au/stocktake/
[4] http://www.nrw.qld.gov.au/blueprint/rurallease/index.html
[5] eg. Northern Gulf Region – *LRCT2: 70% of the grazed landscapes of the Northern Gulf to be in either A or B condition by 2017*. (http://www.northerngulf.com.au/all.pdf -p42)

1. 3 Rangeland Monitoring

There are well-established procedures for assessing and monitoring "land condition" in Australian rangelands, with each jurisdiction having institutionalised monitoring programs (reviewed in NLWRA 2001 & Whitehead *et al.* 2001). Rangeland monitoring activities undertaken by each State / Territory are described briefly in Table 1.

Table 1. Summary of rangeland monitoring programs undertaken in each rangeland State & Territory in Australia. Adapted from NLWRA (2001); more detail can also be found in Whitehead *et al.* (2001; Background Paper 2) and jurisdictional reports to NLWRA (Andersen *et al.* (2001), Gould *et al.* (2001), Green *et al.* (2001), Karfs *et al.* (2001) and Watson *et al.* (2001)).

Jurisdiction	Rangeland monitoring activities
New South Wales	*Rangeland Assessment Program* ▪ 340 ground-based sites within 7 range types ▪ monitored annually, since 1989 ▪ attributes assessed at each site include species of vascular plant, biomass, frequency & composition of pasture species, soil surface characteristics; ▪ density of perennial chenopods and canopy cover of trees and shrubs measured in selected range types ▪ no operational remote sensing program
Queensland	*Transect Recording and Processing System (TRAPS)* ▪ 150 sites in woodland communities ▪ implemented in 1982, all sites have been reassessed at least twice ▪ attributes assessed include woody vegetation floristics, canopy cover, vegetation structure and dynamics, disturbance *QGRAZE* ▪ 350 sites in a range of pasture types ▪ commenced in 1991, aim for reassessment at least once every 5 years ▪ attributes assessed include herbaceous species frequency, frequency and size of woody species, amount of cover, pasture yield, soil surface condition, tree basal area *Grass Check* ▪ voluntary program for pastoral land managers ▪ components include photopoints, record of species present, estimates of forage availability, ground cover, cover of woody species. *Statewide Landcover & Trees Study (SLATS)* ▪ uses satellite imagery to regularly report extent, condition and trend of vegetation cover and landuse *Australian Grassland and Rangeland Assessment by Spatial Simulation (Aussie GRASS)* ▪ uses simulation modelling techniques to assess condition of Australian rangelands ▪ operates nationally on a 5km grid basis ▪ uses inputs of daily rainfall, climate, soil characteristics, vegetation characteristics, tree density and grazing pressure ▪ output is used to assess current seasonal conditions relative to historical conditions
South Australia	*Rangeland Monitoring Program* ▪ since 1990, assessed resource condition and established baseline monitoring over all pastoral leases ▪ includes 5500 photopoint monitoring sites, 20000 Land Condition Index sample points and assessment of 4500 paddocks ▪ no defined schedule for reassessment, although assessment is required every 14 years or when leases are renewed ▪ Land Condition Index is based on the rating of multiple sites into 3 disturbance classes, based on the presence & abundance of perennial plant species, level of grazing and browsing of palatable species, soil surface condition

Jurisdiction	Rangeland monitoring activities
Northern Territory	*Tier 1* ▪ photopoints located in each major paddock of all pastoral leases ▪ pastoral officers record composition and cover of dominant species and some soil attributes; pastoralists are encouraged to make annual photographs and records ▪ reassessed every 3-5 years *Regional Rangeland Monitoring Program (Tier 2)* ▪ satellite-based methods used to assess variation in land cover and condition ▪ Landscape Cover Change Analysis used in tropical savannas; ▪ Grazing Gradient analysis used in arid regions; this can be applied at local paddock or regional scales ▪ augmented by ground-based sites in some regions ▪ attributes at ground sites include floristic composition, cover, frequency of perennials, soil surface condition
Western Australia	*Western Australian Rangeland Monitoring System (WARMS)* ▪ c. 1600 fixed sites, in representative areas of specific pasture/vegetation communities ▪ commenced 1992 (although some monitoring sites have data back to 1970s) ▪ attributes assessed at grassland sites (northern WA) include frequency of all perennial species, crown cover of woody perennials, soil surface condition ▪ attributes assessed at shrubland sites (southern WA) include size and demography of all shrub species, soil surface condition ▪ grassland sites reassessed every 3 years; shrubland sites every 6 years ▪ remote-sensed assessments being trialled in some areas *Range Survey Program* ▪ subjective assessment of range condition along 75000 traverses at 1km intervals in many pastoral regions

Although there is some variation in methodology between these jurisdictional programs, most include plot-based assessment of vegetation cover, frequency of perennial plants, floristic composition (to varying levels of detail) and soil-surface condition. In some jurisdictions, there is a greater focus on the use of satellite imagery for condition assessment over large areas.

The Australian Collaborative Rangeland Information System (ACRIS; NLWRA 2001) was established in 2002 as a coordinating mechanism to bring together rangeland information from State, Territory and Commonwealth agencies, and provide integrated national reporting on rangeland condition (NLWRA 2001). The ability of this system to provide robust national reporting has been tested using selected pilot regions for key indicators including change in critical stock forage availability; change in landscape function; change in native plant species; change in cover; capacity for people to change (Bastin *et al.* 2005). ACRIS will produce a "State of Australian Rangelands" report by mid-2007[6].

1.5 Biodiversity Monitoring in Rangelands

There are no broad-scale, institutional programs to monitor biodiversity in rangelands analogous to the pastoral land condition monitoring programs (Whitehead *et al*. 2001, NLWRA

[6] http://www.environment.gov.au/land/management/rangelands/acris/challenges.html

2001, Day pers. comm.[7]). Information on biodiversity in rangelands is available through a number of sources:

- databases or "atlases" of distributional data for plant and animal species (including herbarium and museum records);
- systematic biological survey and inventory programs (which contribute to the above);
- in some cases, resampling of previous baseline surveys, providing direct evidence of change in biodiversity over time in limited areas;
- the national Bird Atlas project;
- monitoring programs for particular species or groups of organisms, particularly exploited species such as waterbirds or large macropods;
- categorisation of the status of threatened species, and research and/or monitoring programs for some of these species;
- monitoring of the distribution and/or density of pest animals and plants;
- local-scale biodiversity monitoring programs (particularly in conservation reserves);
- ecological studies of particular organisms or communities;
- ecological studies of processes influencing rangeland biota, such as grazing pressure, waterpoint distribution, fire, clearing.

In combination, these provide useful insight into the status of rangeland biodiversity, but such insight is extremely patchy, both spatially and taxonomically, and is inadequate to satisfy a requirement for robustly reporting on trends in biodiversity across the Australian rangelands.

Whitehead *et al* (2001) investigated the utility of the established pastoral monitoring programs to provide information about biodiversity condition or trends. There are some direct measures of biodiversity attributes recorded in the plot-based pastoral monitoring programs, generally relating to vegetation structure and floristics, and the large number of plots sampled means there is potentially substantial power to report on trends in these attributes. However, there were significant problems in the design of pastoral monitoring programs which reduced their utility for monitoring rangeland biodiversity, notably:

- the distributional bias of monitoring sites, at a broad-scale, with low representation of non-pastoral bioregions and habitats;
- the distributional bias of monitoring sites at a finer-scale, with a concentration of sites into dominant pasture types, and at moderate distances form waterpoints. As a result there are few monitoring sites in habitats with restricted distribution but often high importance for biodiversity, such as riparian zones, rugged rocky areas and ecotones;
- a lack of 'control' or 'benchmark' sites, where management-induced pressures;
- selective collection of data, with an emphasis on pastorally-important species and, in some cases, omission of the annual or ephemeral plant component

Whitehead *et al.* (2001) noted that it was widely assumed that there was a link between biodiversity and "land condition", or more specifically widely-used indicators of condition such as vegetation cover or landscape function analysis, but such relationships had not been extensively validated or calibrated. The importance in describing these linkages was additionally important in the context of increasing use of remote-sensing, which offers the opportunity to generalise condition assessment across broad scale, and incorporate landscape variation into the assessment. Such remote-sensed condition assessment can provide no direct information on biodiversity values or trends, but conceptually there are useful links between remote-sense measures of pasture condition and biodiversity attributes. Whitehead *et al.*

[7] as part of the development of the ACRIS State of Rangelands report in 2007, L. Day was commissioned by DEH to review State/Territory capacity to report on trends in rangeland biodiversity

(2001) recommended that substantial effort be put into studies that validate these often-proposed but poorly tested potential indicators of biodiversity status, and this was the prompt for the development of the current project.

1.6 Project Objectives

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. This was particularly in the context of land condition states (the ABCD scheme), which are widely understood and applied by pastoral land managers and management agencies within the tropical savannas; and land condition as defined by mapping based on remote sensing (eg. Karfs *et al*. 2000). We also sought to assess the value as surrogates for biodiversity health of some individual, commonly-used indicators for land condition (such as cover of bare ground or perennial grasses). This analysis was extended to consider whether other variables describing the habitat were usefully incorporated into this condition assessment.

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.

2. Biodiversity and Rangeland Condition - Methods

2. 1 Study area

The study focused on two important pastoral regions in northern Australia – the Victoria River District (VRD; Ord-Victoria bioregion; 17^{o}S 131^{o}E; mean annual rainfall at Victoria River Downs Station 640mm) in the Northern Territory and the Burdekin Rangelands (BR; Einasleigh Uplands bioregion; 19^{o}S 145^{o}E; mean annual rainfall at Greenvale 630mm) in Queensland (Fig. 1). 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). A general description of the BR can be found in McCullough & Musso (2004) and of the VRD in Stewart *et al.* (1970).

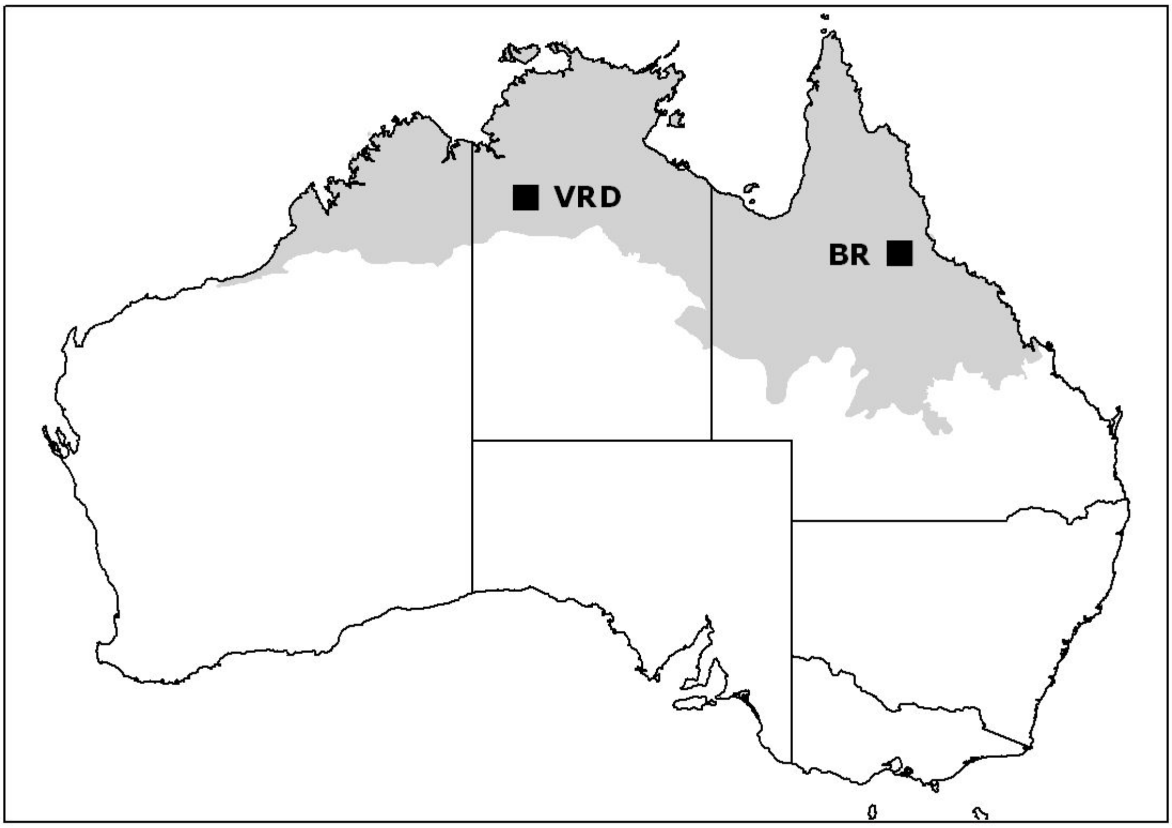

Figure 1. General location of study sites in the Victoria River District (VRD) and Burdekin Rangelands (BR). The extent of the tropical savannas in northern Australia is shaded.

2. 2 Selection of sample sites

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 this study, “good” and “poor” condition sites in each location were chosen based on land condition mapping from satellite imagery (see below), and sites were carefully selected to be otherwise similar in soil type, topography and vegetation.

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 (located in the BR; O'Reagain *et al.* 1996) 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 (Kutt *et al*. 2004). 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 can be considered 'intermediate' in resilience to stocking pressure.

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* spp. and *Aristida* spp. A total of 56 sites were sampled on one property on cracking-clay soils (vertosols), which were grasslands dominated by Aristida latifolia, C. fallax, D. fecundum and mixed annual grasses, with a very sparse low trees layer of Rosewood and Nutwood *Terminalia* spp, Bauhinia *Bauhinia cunninghamii* and Desert Bllodwood *Corymbia terminalis*.

In the BR, we sampled 36 sites on 3 properties on sedimentary chromosols, with a mosaic 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. A further 48 sites on 5 properties were on basalt soils (ferrosols), with a mixed eucalypt (*Eucalyptus* sp. Stannary Hills (G.W. Althofer 402), *Corymbia dallachiana* and *C. erythrophloia*) open woodland and an understorey of *Bothriochloa* spp., *Themeda triandra*, *H. contortus* and *C. fallax*. In the Wambiana trial, 16 sites were in Box (*Eucalyptus brownii)* and 8 sites in *Ironbark (E. melanophloia)* woodland, with an understorey similar to that of the sedimentary sites.

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 (Karfs *et al*. 2000) of a time series of satellite imagery from the 10 years preceding sampling (an example is given in Fig 2.). Aerial and ground inspection of potential sites was made to ensure that condition mapping had not been influenced buy other factors (such as gross difference in canopy cover or soil type). 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, and validated 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", "poor"), equivalent to the A, B, C condition classes used in the GLM system. Examples of sites from each landtype in each condition class are shown in Fig. 3. We did not attempt to sample "very poor" or D condition sites for several reasons: the area of land in this condition in the study area is small; there is little debate that this condition is highly undesirable, both form production and biodiversity perspectives; and this would have required an undesirable reduction in the amount of replication within condition classes.

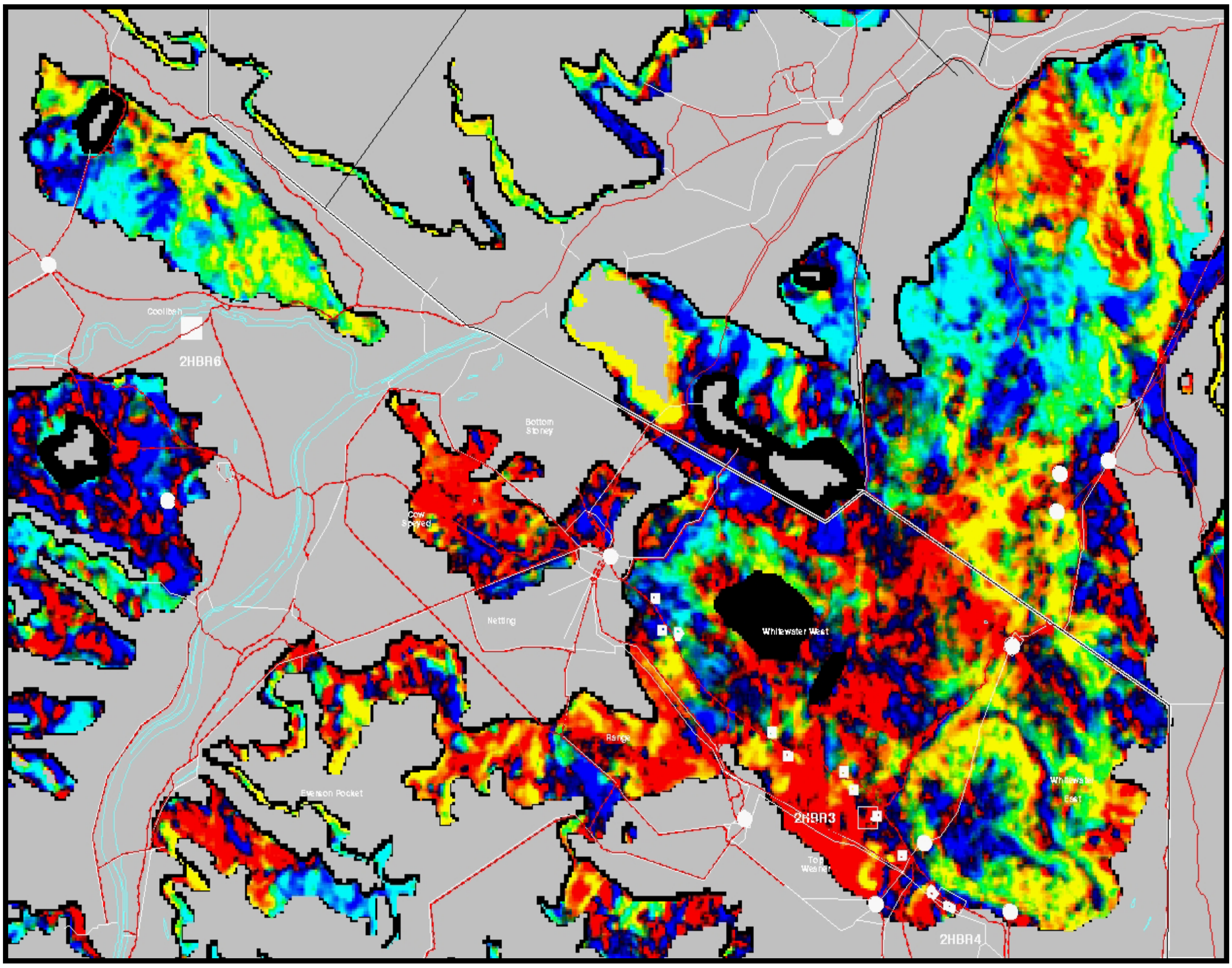

Figure 2. Example of a condition trend map derived from cover-change analysis using satellite imagery (Karfs *et al*. 2000). The coloured portion of the map shows areas of the "NT loam" landtype on kandasols in the VRD region. Colours indicate level and trend of plant cover in the time period analysed: green = high & stable; cyan = high & increasing; yellow = high & decreasing; blue = low & increasing; red = low & decreasing.

Figure 3 (next pages). Example sites from each landtype, in each condition class (photos: A. Fisher & A. Kutt).

NT Loam
"good" (A)

NT Loam
"intermediate" (B)

NT Loam
"poor" (C)

NT Clay
“good” (A)

NT Clay
“intermediate” (B)

NT Clay
“poor” (C)

QLD Basalt
“good” (A)

QLD Basalt
“intermediate” (B)

QLD Basalt
“poor” (C)

QLD Sedimentary "good" (A)

QLD Sedimentary "intermediate" (B)

QLD Sedimentary "poor" (C)

QLD Alluvial
“good” (A)

QLD Alluvial
“intermediate” (B)

QLD Alluvial
“poor” (C)

2.3 Sample methods

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. Canopy structure (canopy height and crown cover at 4 height intervals) and tree basal area were measured at 2 diagonal corners of the site (using clinometer for height, and Bitterlich gauges for crown cover and basal area). Additional 'habitat' variables were measured at each site, relating to substrate, recent grazing pressure (tracks, dung and defoliation) and fire history. Further details of sample methods are given in Appendix 1.

2.4 Analysis

The raw biodiversity data from this study consists of a list of species recorded from each site, with an abundance measure for each species. Within each major group (plants, ants, birds, reptiles, mammals), species were also allocated to functional groups (Table 2, Appendix 3). A number of summary variables were derived from this data:

- total species richness (of major taxa and functional groups)
- Shannon-Wiener diversity (of major taxa and some functional groups)
- total relative abundance (of major taxa and functional groups). For plants, abundance included cover and frequency.

For convenience, these summary variables are hereafter referred to as "biodiversity variables"

Table 2. Groupings of species within major taxonomic groups used in analyses.

Plants (life-forms)	tree shrub perennial grass facultative perennial grass annual grass perennial forb annual forb sedge
Plants (other groupings used in some analyses)	groundlayer plants (all except tress and shrubs) 3P grasses (palatable, productive, perennial: eg. Ash *et al.* 2001)
Ants (functional groups: Andersen 1990, 1995)	Cold Climate Specialist Cryptic Dominant Dolichoderinae Subordinate Camponotini Hot Climate Specialist Opportunist Generalized Myrmicinae Specialist Predator

Birds (foraging guild: Woinarski *et al.* 1988, Fisher 2001)	Aquatic Aerial Insectivore Foliage or Trunk Insectivore Foliage Insectivore / Nectarivore Nectarivore Ground or Low Undergrowth Insectivore Ground Insectivore / Granivore Ground Insectivore / Omnivore Granivore Frugivore Raptor
Reptiles	Scincid Varanid/Agamid Gekkonid Serpent (including pygopids)
Mammals	Dasyurids Murids Macropods (includes potoroids) Arboreal mammals Introduced mammals

In addition, there are a large number of "habitat variables" for each site describing ground cover characteristics and vegetation structure, as well as "disturbance variables" describing recent grazing pressure, distance to water, etc.

Species composition was examined by calculating a similarity matrix between all pairs of sites, using the Bray-Curtis association measure. Separate similarity matrices were calculated for each major taxonomic group, and some functional groups, within each landtype. In all cases, a square-root transformation of the abundance data was used. Multi-dimensional scaling was used to portray the relationship between sites for species composition in 2 dimensions.

Preliminary analysis showed that there significant biotic differences between two sample locations in the VRD loam landtype (although these were superficially similar landform, soil and vegetation), and between box- and ironbark-dominated sites in the Qld sedimentary and alluvial landtype (although these were mapped as a single vegetation type). A 'location' or 'vegetation' factor was therefore included in most analyses, and where this was significant results were derived separately for the 2 locations or vegetation types within the landtype. These secondary divisions are referred to as "sub-landtypes"

Four major analyses were carried out:

2.4.1 Comparison between condition classes.

ANOSIM (Clarke & Gorley 2001) was used to compare compositional similarity between the 3 condition classes, for each similarity matrix. This reported a global test for "condition" and also pairwise comparisons between each condition level. Two-way ANOSIM was used for NT loam, Qld sedimentary and Qld alluvial to separate the effects of condition and location or vegetation.

The mean for each biodiversity and habitat variable was calculated for each condition class within each landtype (and sub-landtype), as well as the mean abundance of all species occurring in at least 5 sites within the landtype. Comparisons between landtypes are generally illustrated graphically as box plots.

All biodiversity and habitat variables were initially compared between condition classes using Kruskal Wallis tests (KW; the non-parametric equivalent of one-way ANOVA). Differences were also tested using generalised linear modelling (GLZ), which was often more sensitive than KW tests. For most variables (that were counts, or analogous to counts), a Poisson error distribution and log link was used; otherwise a simple identity model was used. For relevant landtypes, "location" or "vegetation" was included as a second factor and, where there was a significant interaction term, the response to condition of the variable in each sub-type was considered separately.

The same procedure was carried out for the relative abundance of each individual species that occurred in sufficient sites (at least 5 sites for most taxa, but at least 10 sites for plants in Queensland landtypes).

In order to facilitate description, and comparison across landtypes and taxa, the relationship between condition classes for each variable was categorised into "response types". Four main responses are commonly used (eg Noy-Meir *et al.* 1989, Wilson 1990):

- **increaser**: highest value in poor and lowest in good sites
- **decreaser**: lowest in poor and highest in good sites
- **intermediate**: highest in intermediate sites
- **extreme**: lowest in intermediate sites

Examination of the responses of many variables/species suggested that it was sensible to discriminate further for intermediate- or extreme-type responses:

- **intermediate**: highest in intermediate sites (and good and poor approx. equivalent)
- **intermediate\increaser**: highest in intermediate sites, but high in poor and low in good sites
- **intermediate\decreaser**: highest in intermediate sites, but low in poor and high in good sites
- **extreme**: lowest in intermediate sites (and good and poor approx. equivalent)
- **extreme\increaser**: lowest in intermediate sites, but high in poor and low in good sites
- **extreme\decreaser**: lowest in intermediate sites, but low in poor and high in good sites

These categories are only applied if there is a significant condition effect (in KW or GLZ tests). Where there was no significant effect, the response was categorised as **neutral**. The nine response types are illustrated in Fig. 4.

In some of the summary descriptions, the 8 non-neutral responses were simplified back to 4 coarse types, with intermediate\increaser and extreme\increaser included in increaser, and intermediate\ decreaser and extreme\decreaser included in decreaser. In this case, the key aspect is that the variable is low in poor sites for decreasers, or low in good sites for increasers.

The response types for each variable were tabulated for comparison across landtypes (and sub-types). The number of species in each response type was calculated for each landtype, and this was expressed as a proportion of the total number of species occurring in sufficient sites for analysis. For species occurring across multiple landtypes, the number of responses in each broad type were counted and an assessment made of whether these responses were "consistent" (all non-neutral responses were of the same broad type) or "contradictory" (the same species had increaser and decreaser responses, or extreme and intermediate responses). This calculation may include different response types in subtypes within the same landtype.

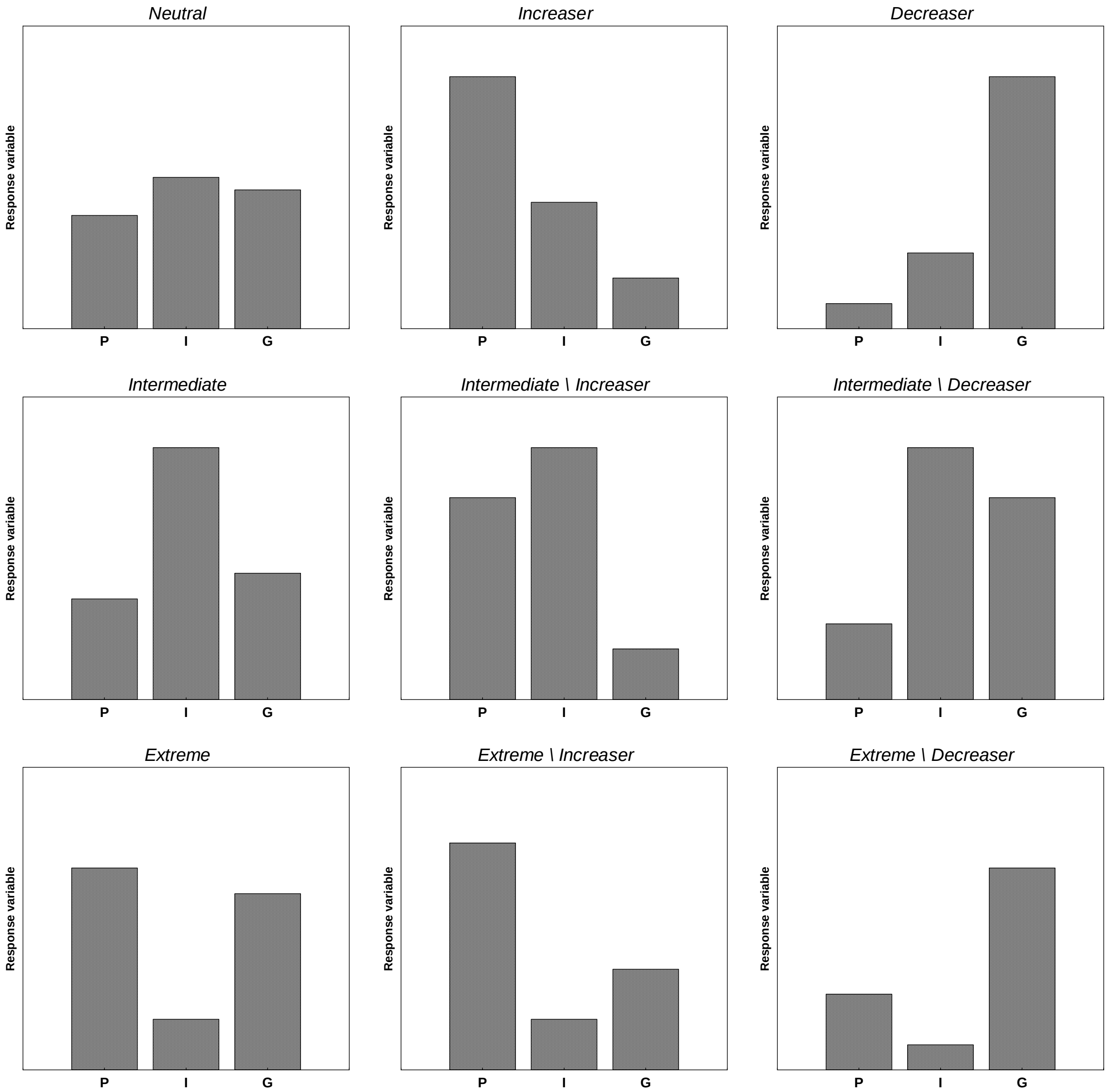

Figure 4. Graphical representation of the different response types to condition class (P=poor, I=intermediate, G=good). The response variable may be species richness, diversity, total cover, or abundance of a species.

2. 4.2 Condition variables as continuous predictors

The relationship between biodiversity variables and selected continuous variables that are important in describing land condition was tested using generalised linear modelling (GLZ). Cover of bare ground and total understorey cover were used as predictors in all landtypes; cover of 3P perennial grasses was used in Queensland landtypes and cover of all perennial grasses was used in NT landtypes (there is no consistent categorisation of perennial grasses as ‘3P’ in the Northern Territory). A backward stepwise process was used to select the minimum adequate model, and % deviance explained was calculated as a measure of model adequacy. The number of condition variables used was also expanded in NT landtypes to include perennial grass frequency and basal area, in order to test whether these performed better as predictors than perennial grass cover.

Predictive models were calculated for each biodiversity summary variable and for all individual species that occurred frequently enough in a landtype for analysis. Because of the large number of models (585 summary variable / landtype combinations and 836 species / landtype combinations) and the need to calculate each model twice (see below), generalised regression modelling (GRM) was used[8]. Although this may entail using a less desirable error structure than possible in GLZ, a check using randomly selected response variables showed little difference in result between GRM and GLZ. The adjusted R^2 of the regression was used as a measure of model adequacy.

The adequacy of models for each summary variable was tabulated for comparison across landtypes. For comparison between landtypes and taxa for species' models, results were tabulated as the proportion of analysable species for which there was a significant model, and the mean and range of deviance explained were calculated for each major taxonomic group in each landtype.

In order to assess which condition variables were most useful in predicting biodiversity attributes, the number of significant models in which each term appeared was tabulated.

2.4.3 Comparison between condition variables and other habitat variables as continuous predictors

A range of other habitat variables was recorded in each site. In order to select a small subset of variables for use in predictive modelling, vector fitting (Kantvilas and Minchin 1989; using the PCC and MCAO routines in PATN) was used to analyse which habitat variables were most strongly correlated to the ordination of sites by their species composition. This analysis was repeated for each major taxonomic group (plants, ants, birds, mammals and reptiles combined[9]), and the 3 or 4 habitat variables having the highest correlation and that were not strongly intercorrelated were selected. These variables were then used in all predictive models relevant to that taxonomic group.

The selected habitat variables were added to the condition variables in the predictive models described above, and the backward stepwise procedure repeated to give the minimum adequate model. Results were tabulated as described above. The 'improvement' in models due to the inclusion of habitat variables was assessed by comparing the adjusted R^2 between the condition and (condition+habitat) model for each variable.

2.4.4 Surrogacy and assemblage fidelity

In this context, surrogacy is a measure of the extent to which patterns amongst sites in the dataset for one set of taxa are similar to those in the datasets for other taxa. If there are strong similarities, it suggests that this taxa acts as a good surrogate for the others, and it would therefore be sufficient to monitor that taxa in order to gain a robust picture of what is happening to biodiversity more broadly (eg. Landres *et al.* 1988, Noss 1991). We assessed two measures of surrogacy across all sites and within each landtype.

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[8] we used the Statistica package for these analyses; the GRM routine can be implemented for multiple models far more efficiently then the GLZ one.
[9] it was necessary to combine these two groups because the richness of each, particularly mammals, in many sites was too low for effective ordination analysis

Richness and diversity

The total richness of plants, groundlayer plants, perennial grasses, ants, ant functional groups, vertebrates, birds, bird guilds, mammals, reptiles, and the Shannon diversity index for plants, ants, ant functional groups and vertebrates were compared between sites using Spearman rank correlation. The comparison was made across all sites and for each landtype separately.

Assemblage fidelity

Assemblage fidelity is a measure of the extent to which patterns in the overall species composition of sites coincide between different taxa (Faith & Walker 1996, Oliver *et al*. 1998). We assessed this by using Mantel tests to calculate the correlation between the compositional similarity matrices for vertebrates, birds, bird guilds, mammals and reptiles combined, ants, ant functional groups, plants and groundlayer plants.

3. Biodiversity and Rangeland Condition - Results

3.1 Pilot study

The results of the pilot study in the VRD region in 1999 are briefly summarised here; more detail is given in Appendix 2.

- 45 sites were sampled, approximately evenly split between 5 locations on different pastoral properties. The maximum distance between locations was about 100km.
- Numerical analysis of satellite data used in pastoral condition assessment was applied to classify sites into two broad condition classes – “good” and “poor”. There were approximately equal numbers of sites in each class at each location.
- A total of 235 plant, 73 bird, 32 reptiles and 50 ants species were recorded from all sites. Mammals and some invertebrate taxa (carabid beetles, centipedes, scorpions) occurred too sparsely to use in analysis.
- For each major taxon (and also functional group classifications), differences in species composition between locations obscured differences between condition classes (despite the fact that all sites were in the same vegetation type).
- In a two-way analysis, which removed the “location effect”, there was a significant effect of condition on composition of plants, all vertebrates, birds and bird guilds, but not ants or ant functional groups.
- the strength of this “condition effect” differed substantially between locations.
- in a simple comparison, there was no significant difference between condition classes for the total richness or abundance of any taxonomic or functional group, other than the % cover of perennial grasses, facultative perennial grasses and trees.
- a more complex analysis included location and canopy cover as explanatory variables, as well as condition. This showed complex condition/location interactions for a number of richness/abundance variables related to birds (but not plants or ants).
- A total of 123 plant, 49 vertebrate and 16 ant species occurred in sufficient sites for analysis of species-level responses. In a simple comparison, there was a significant difference between good and poor sites in the abundance of 3 bird and 19 plants species, but no ant species.
- A number of predictor variables were derived from satellite reflectance data used in pastoral condition assessment, based on the mean and coefficient of variation of reflectance (in pixels corresponding to sample sites) in annual imagery over 5 and 15 year time-periods.
- these “remote-sensed variables” had some predictive power for many biodiversity variables, including richness and abundance of vertebrates, birds and reptiles, richness of plants, and richness and cover of most plant lifeforms.
- remote-sensed variables also had significant predictive power for the abundance of 41-46% of plant, and vertebrate species (that were sufficiently frequent to analyse).
- However, most models using remote-sensed variables were quite weak and had complex interactions between terms.
- One way of visualising the response of species to condition was to place them within a “condition-space” diagram defined by mean and CV of reflectance values.
- The conclusion of the study was that linking biodiversity ‘health’ to land condition was very complex, and that the response of biota to condition was highly variable between taxa and locations (even in a single landtype).
- Variables describing condition derived from remote-sensing had some ability to predict the richness or abundance of many taxonomic groups and individual species

- The pilot study only considered a small number of sites in a single landtype, so broader sampling was needed to clarify many of these relationships.

3.2 Description of Flora and Fauna

A total of 519 plant, 136 bird, 26 mammal, 57 reptile and c. 300 ant species were recorded from the 216 sites sampled during the main study (a complete list of species is given in Appendix 3).

A summary of the total and site richness of each major taxon in each land type is given in Table 3[10]. Richness levels were broadly comparable across landtypes, except that clay sites in the NT had very low richness of ants and birds (a similar pattern, however, was not evident for resilient (basalt) landtypes in Queensland). Mammal richness was very low, and reptile richness was moderately low, at all sites. All landtypes in Queensland had higher mean richness of birds and reptiles than those in the NT. Mean site richness of ants was remarkably consistent across all landtypes (other than NT clay), while NT loam sites had relatively high plant richness.

Ordination of all sites by their species composition (using simple presence/absence data) showed that sites clearly separated according to landtype, for each major taxonomic group (Fig. 5[11]). Therefore, most analyses were conducted separately for each landtype, and then results compared across landtypes in a meta-analysis (rather than including landtype as a factor in an integrated analysis).

One feature of the biodiversity data was the large number of “rare” species (ie. those recorded from few sites; Table 4). For taxa other than mammals, 20-30% of the species from each landtype and in each taxon are recorded from only a single site; and 45-60% of species are recorded from less than 5 sites. Only 25-40% of species occurred in at least 10 sites. The relative proportion of species in each “rareness” class was quite consistent between landtypes – the exception was the NT clay landtype, which has relatively few ant species but also relatively few rare ant species. Mammal species were generally “rarer” than other taxa, with 82-100% of mammals in each landtype occurring in fewer than 10 sites. This implies that data for about half of the fauna and flora is too sparse to robustly determine whether there is any significant response to land condition for these individual species. It is also likely that the most sensitive species will occur at relatively few sites, exacerbating the difficulty of identifying such species through any statistical analyses. While mammals are often a focus for monitoring effort (either because they are more charismatic or there is genuine concern over species’ decline), they may be particularly difficult to adequately sample (requiring a larger number of sites and/or a greater effort per site).

3.3 Comparison of “habitat” variables between land condition classes

“Habitat” variables, in this sense, are features of the sites that are likely to be important for influencing fauna and/or flora composition, but should be independent of land condition. A general comparison between landtypes for mean habitat variables is given in Table 5, illustrating some differences between landtypes, which contribute to differences in their biota. The NT clay landtype supports a grassland (or very sparse woodland), so there is minimal

[10] All results tables are collected in section 9.
[11] All results figures are collected in section 10.

upper storey cover or basal area, and also has a high surface rock cover and no termite mounds. Woodlands in the NT loam landtype are generally lower, with a smaller tree basal area than those in Qld landtypes and a much lower proportion of standing dead trees and fewer fallen logs. Woodlands on Qld basalt soils had a taller canopy than other Qld landtypes, but a sparser mid- and shrub-layer, and also had few termite mounds.

The most marked difference between condition classes within a land type was for Queensland basalt sites (Table 6). In this landtype, good condition sites had taller canopy, higher live basal area, higher crown cover above 10m and more termite mounds. Poorer sites had higher basal area of dead trees, more logs and higher litter cover, while intermediate sites had the highest crown cover for mid-sized trees. A similar pattern of good condition sites having higher tree cover and basal area was observed in NT loam sites, although the effect was more muted, and good sites had higher litter cover. By contrast, mean basal area and crown cover of trees was higher in poor condition sites in the Qld alluvial landtype.

3. 4 Comparison of “grazing” variables between land condition classes

“Grazing” variables are those that are potential indicators of recent grazing pressure at the sample sites (dung, tracks, defoliation, distance to water). Distance to waterpoints may also be indicative of longer-term grazing history. These variables would be expected to vary significantly between condition classes, especially if current grazing regimes reflect longer-term grazing history.

The synthetic grazing index (combining dung, tracks and defoliation) showed a significant increaser response for all landtypes except NT clay.(Table 7) However, the relationship between condition class and all individual grazing variables differed between landtypes. Direct measures of recent grazing pressure (dung, tracks, defoliation) were clearly related to condition class for NT loam and QLD basalt sites, but this relationship was weaker, more poorly defined, or absent for other land types. This may arise because cattle grazing distribution at the time of sampling was atypical (eg. paddock was temporarily destocked). In NT clay and Qld alluvial sites there was relatively high defoliation levels in good sites (as well as poor sites) at the time of sampling, which may be related to selective grazing on preferred palatable species in these sites.

Interestingly, mean distance to water was only significantly different between condition classes for Qld basalt sites. This reflects the fact that difference in condition were generally most pronounced across fencelines (between paddocks and/or properties) and presumably arose because of different stocking rates and/or other grazing management systems at a paddock/property scale over at least moderate time-frames. Distance from water was invariant for the Qld alluvial sites, because these were in equally-sized experimental paddocks with different stocking histories. Sites in the NT clay land type were in large paddocks with a mean distance from water close to 3km for each condition class. Although piosphere effects are usually well-developed in this landtype (Fisher 2001), this observation suggest that development of areas of relatively poor condition through patch grazing is also important.

Mean distance from water (across all condition classes) within each landtype was much lower for Qld sites (basalt=1.3km, sedimentary=1.1km) than NT sites (clay=3.2km, loam=3.5km), reflecting the smaller properties and generally greater infrastructure development in Qld. There was also a significant difference in mean distance from water for sites within the two properties sampled within the NT loam landtype (1.8 and 5.2km).

3.5 Comparison of "pasture condition" variables between land condition classes

Pasture condition variables are those that are typically applied in pastoral monitoring schemes (and observationally by land managers) to assess the state of the ground layer – including cover of bare ground, total understorey cover and cover, frequency and/or basal areas of perennial grasses.

The NT landtypes clearly demonstrate the predicted relationship, with a very strong decreaser response for cover, frequency and basal area of perennial grass (Table 8). Patterns are less clearly defined for each Qld landtype, with an intermediate or increaser response for some perennial grass variables. This is attributable to the confounding effect of introduced pasture grasses (which are not present in NT sites), which have relatively high cover or frequency in poorer sites.

Total groundlayer cover and cover of bare ground do not necessarily have a simple relationship with condition, as poor condition sites may have a relatively high cover of annual plants.

3.6 Comparison of biodiversity variables between land condition classes

3.6.1 Species composition

Similarity between sites in species composition was summarised for each major group within each landtype by ordination (Fig 6), and ANOSIM was used to test whether condition class has a significant effect on composition (ie. whether sites in the same condition class are more similar to each other than to all other sites) (Table 9).

For NT loam, Qld sedimentary and Qld alluvial landtypes, there is a primary separation of sites on location (NT) or vegetation type (Box or Ironbark). The location effect in the NT loam landtype is pronounced for all taxa, particularly ants, although there is some overlap of locations for mammals/reptiles. The separation by vegetation type is also obvious for all taxa in Qld alluvial landtype, particularly for plants. The separation by vegetation type is also most obvious for plants in Qld sedimentary landtype, but there is no significant vegetation effect for mammals/reptiles, and the effect is subdued for ants and birds.

The strength of the effect of condition on composition varies between taxa and across landtypes. In general, the condition effect is most pronounced in Qld sedimentary and Qld basalt landscapes, moderate in NT loam and weak or absent in NT clay and Qld alluvial landtypes (except for plants in the latter). In most landtypes, the condition effect is most pronounced for plant composition, and weak (or absent) for reptile/mammal composition. However, in the Qld sedimentary landtype there is a very strong condition effect for vertebrates, which includes highly significant effects for both birds and reptile/mammal composition.

The pairwise comparisons between condition classes also reveal some difference between landtypes & taxa in the nature of the effects. In most cases a significant overall condition effect is accompanied by a significant difference between good and poor sites. However, for vertebrates in Qld sedimentary sites there is a less significant, or non-significant difference, between good and poor sites, and the strongest difference is between intermediate and other sites. Inspection of the ordinations shows that good and poor sites tend to group together. In NT loam sites there is generally no significant difference between intermediate and poor sites. However, for plants in NT clay and Qld basalt there is a stronger difference between intermediate and poor sites than good and intermediate.

In almost all cases, the condition effect was less pronounced when composition of a taxon was expressed in terms of functional groups. Ground layer plants gave very similar results to all plants (although they did give a stronger condition effect for the Qld sedimentary landtype). Ant functional groups and bird guilds both performed poorly in discriminating between landtypes compared to the full species composition of these groups.

3.6.2 Vegetation structure

Differences between condition classes for some aspects of vegetation structure (canopy height and structure and some measures of understorey cover) have already been described above (Tables 6 & 8). A more detailed comparison between condition classes for mean cover/ frequency of plant functional groups (lifeforms) is given in Table 10. More significant results are seen for cover variables than frequency variables, possibly because cover differences can be exaggerated by recent defoliation by cattle and/or seasonal variation in rainfall. Total understorey cover and perennial grass cover generally show a decreaser response, although this was not evident in Qld alluvial sites. Annual grasses and all forbs tend to show an intermediate or increaser response, although a decreaser response was observed in Qld basalt sites.

3.6.3 Richness and diversity – plants

Total plant species richness showed a subdued response to condition, that varied in form between landtypes (Table 10, Fig. 7). Richness was highest in poor sites for Qld sedimentary sites, and there was an intermediate/increaser response for NT loam sites. However, there was an intermediate/decreaser response for Qld basalt, and no relationship for NT clay landtypes.

Responses of plant functional groups (lifeforms) varied within and between landtypes (Table 10). Perennial grass richness had a decreaser or intermediate/decreaser response to condition for NT loam, Qld basalt and Qld alluvial landtypes, and no increaser response for any landtype. Annual grass richness had an intermediate, intermediate\increaser or increaser response for NT loam (one location), Qld basalt and Qld sedimentary landtypes, and no decreaser response for any landtype. Understorey forb richness also had an increaser response for VRD loam and Qld sedimentary landtypes, but an intermediate response for Qld alluvial (box only) and intermediate/decreaser response for Qld basalt sites. Responses for some lifeforms were entirely divergent between landtypes; facultative perennial grass richness had an increaser response for VRD loam (one location), decreaser for Qld basalt and extreme for Qld sedimentary sites.

Plant diversity (Shannon-Wiener) had an increaser response for NT loam and Qld sedimentary landtypes, but an intermediate/decreaser response for Qld basalt (Table 10). There was no significant difference between condition classes in plant diversity for NT clay or Qld alluvial sites.

Qld basalt sites were notable as richness and diversity of all plants, and richness of most plant groups, showed a decreaser or intermediate/decreaser response. The only group with an increaser response in this landtype was woody richness (trees and shrubs combined). By contrast, plant richness, diversity and most plant groups (other than perennial grasses) had an increaser or intermediate\increaser in *NT loam* sites, and there were also primarily increaser responses for Qld sedimentary sites. There was no significant response to condition for most plant variable at NT clay or Qld alluvial sites.

3.6.4 Richness and diversity – ants

There were significant effects of condition on ant species richness and Shannon-Wiener diversity for all landtypes other than Qld alluvial (Table 11, Fig. 7). There were strong decreaser responses for total richness and diversity in the resilient landtypes (NT clay and Qld basalt), but a strong increaser response for NT loam and a subdued extreme\increaser response for Qld sedimentary landtypes.

The increaser response for ant richness & diversity in NT loam sites was due to a pronounced increaser response for richness of the functional group Hot Climate Specialists, which also had a very high total frequency in poor sites. There was also an increaser response for richness of Generalised Myrmicinae in one NT loam location, and an increaser response for frequency of Dominant Dolichoderinae. By contrast, richness of Hot Climate Specialists had a decreaser response to condition in the resilient landtypes, and an extreme response in Qld sedimentary landtypes. There was also a decreaser response in resilient landtypes for richness of Subordinate Camponitini, and for richness of Dominant Dolichoderinae and Generalised Myrmicinae in NT clay and Qld basalt, respectively. An extreme or extreme\increaser response was seen in richness of Cryptic and Generalised Myrmicinae groups in Qld sedimentary sites.

There was no significant response to condition in the richness or frequency of the functional groups Cold Climate Specialist, Tropical Climate Specialist, Specialist Predator or Opportunist (which generally had few species and relatively low abundance in the sampled sites).

3.6.5 Richness and diversity – vertebrates

The total species richness of vertebrates had a strong decreaser response for Qld basalt, and a strong intermediate response for Qld sedimentary sites, but no significant response for the other landtypes (Table 12, Fig. 7). There was also an intermediate response for total vertebrate diversity in Qld sedimentary sites, but no significant effect for diversity in other landtypes.

3.6.6 Richness and diversity – birds

The total species richness and total diversity of birds similarly had a decreaser response for Qld basalt and an intermediate response for Qld sedimentary sites, but there was also an increaser response for bird richness in NT clay sites (Table 12). The same response for total bird abundance was seen for the Qld landtypes, but there were dissimilar responses for bird abundance in the two locations within the NT loam landtype.

The decreaser response in bird richness in Qld basalt sites is reflected in a similar response in richness within the *ground insectivore* and *nectarivore* functional groups. Functional groups that have an intermediate response in richness in Qld sedimentary sites are *aerial insectivore*, *granivore*, *ground insectivore* and *ground insectivore/omnivore*.

The response type for richness within the various bird functional groups is not necessarily consistent between landtypes. *Granivores* show an increaser trend in NT loam and clay and an intermediate one in Qld sedimentary sites. *Foliage insectivore/nectarivores* have a decreaser response in one NT loam location but an Intermediate response in the other, an increaser response in NT clay sites and an extreme\increaser response in Qld alluvial (Ironbark) sites.

There were more significant responses for the total abundance of various bird functional groups, although these responses are also variable across landtypes. Few functional groups have a consistent response in two landtypes, and none are consistent in 3 or more landtypes. *Foliage insectivore/nectarivores* have an increaser response for Qld alluvial and NT clay sites, but an intermediate or intermediate/increaser response in Qld sedimentary and a decreaser response for NT loam (one location). *Granivores* have an increaser response in the two NT landtypes, but an intermediate response in Qld sedimentary sites. *Foliage/trunk insectivores* have an intermediate or intermediate\increaser response for NT loam and Qld sedimentary sites, but an extreme\increaser response for NT clay. *Ground insectivores* have a decreaser response for VRD clay and VRD loam (one location), but an intermediate or intermediate\increaser response for the other NT loam location and Qld sedimentary sites.

3.6.7 Richness and diversity – reptiles

Total reptile richness has a marked decreaser response in NT loam sites, but no significant response in other landtypes except for an increaser response in Qld alluvial (Box) (Table 12). Reptile diversity had a decreaser response in both NT loam and Qld basalt landtypes, and an increaser response in Qld alluvial (Box). The decreaser response for NT loam is also seen for total reptile abundance, and there is an intermediate response for reptile abundance in Qld sedimentary (Ironbark) and alluvial (Ironbark) sites.

There are some significant responses to condition for reptile taxonomic/functional groups, but mostly for only one or two landtypes. Richness and abundance of varanids/agamids has a decreaser response in both Qld basalt and sedimentary landtypes, and agamid abundance a decreaser response in NT loam sites. Response type for skink richness is decreaser in NT loam, intermediate\decreaser in Qld basalt, extreme\decreaser in Qld sedimentary (box) and intermediate in Qld alluvial (Ironbark). Gecko richness has an intermediate/increaser response in Qld sedimentary sites, but an increaser one in Qld basalt and an extreme/decreaser one in NT clay sites.

3.6.8 Richness and diversity – mammals

There was no significant response of mammal richness, diversity or abundance to condition in most landtypes (Table 12). The three variables had a decreaser response for Qld basalt sites, mammal richness had an extreme response in Qld sedimentary (Box) sites and mammal diversity had an extreme/decreaser response in the Qld sedimentary (Box) landtype.

Murid richness and abundance had a decreaser response in NT clay and NT loam landtypes, and dasyurid richness and abundance also had a decreaser response in NT clay sites. Macropod richness and abundance had an intermediate response in Qld alluvial sites, but macropod richness had an extreme response in the Qld sedimentary (Box) landtype. There were no significant responses for individual taxonomic group variables for Qld basalt sites, despite the decreaser responses for total mammal diversity.

In summary, *Qld basalt* sites were notable for showing a decreaser response for many vertebrate variables, and *Qld sedimentary* sites for an intermediate response. There were very few significant vertebrate variables for *Qld alluvial* sites (which may at least partly reflect the smaller number of sites), while both NT landtypes had a small number of significant variables, with the form of response variable amongst taxa.

3.6.9 Individual species – plants

The response patterns of a total of 254 plant species were analysed, representing 48.6% of the recorded species. The response patterns of species in each landtype are tabulated in Table 13, and the proportion (of analysable species) falling into each response type is summarised in Tables 14 & 15. Comparisons between landtypes for each species can be made in Appendix 3.

Of the plant species that were sufficiently frequent to analyse, the proportion that show any significant response to condition is remarkably similar across most landtypes (49-53%). The exception is Qld alluvial, where only 17% of species had a significant response – which may reflect the smaller number of sites in this landtype.

However, the proportion of species in each response type is variable between landtypes. This is best illustrated at the coarse level of response (when responses are simply classed as increaser, decreaser, intermediate, extreme) (Table 22). Sensitive landtypes have relatively high proportions of increaser species (36% and 27% for NT loam and Qld sedimentary, respectively) compared to resilient landtypes (18% and 12% for NT clay and Qld basalt). Conversely, resilient landtypes have higher proportions of decreaser species (29% and 30% for NT clay and Qld basalt) and sensitive landtypes have fewer (14% and 10% for NT loam and Qld sedimentary). The proportion of species with an intermediate response is generally low and there are few species with an extreme response. The exception is in the Qld sedimentary sites, where 10% of species had an intermediate response and 8% and extreme one.

Of the 254 analysable species, only 124 (49%) occur in more than one landtype, 64 (25%) in at least 3 landtypes, 24 (9%) in at least 4 landtypes, and only 9 (4%) in all landtypes. A total of 163 species (64% of the total analysed) had a significant response to condition in at least one land type, but only 55 species (22%) had a significant response in two or more landtypes (most species occurring in several landtypes had non-significant (neutral) responses in some of these landtypes). Of the 55 species with a significant response in two or more landtypes, for only 8 species was the response entirely consistent across landtypes. Furthermore, for 27 of these species (49%) there was a contradictory response between landtypes (ie. increaser and decreaser response, or intermediate and extreme response).

The four species with a consistent decreaser response are all perennial grasses (*Sehima nervosum, Themeda triandra, Bothriochloa ewartiana, Eulalia aurea*). However, of the 14 species identified as “3P” grasses (in Queensland), only two have a consistent decreaser response, while 8 of these species have an increaser response in at least one landtype (or vegetation type / location).

Species with a consistent increaser response are woody forbs (*Malvastrum americanum, Sida spinosa, Tephrosia juncea*), while the sedge *Fimbristylis dichotoma* had a consistent intermediate response.

3.6.10 *Individual species – ants*

Response patterns were analysed for 33-64 ant species in the five separate landtypes (Table 16). It is not possible to compile a single list of ant species across all landtypes, as morphospecies “names” have not been standardised between all landtypes.

There was a significant response to condition for between 40% and 58% of species analysed in each landtype (Tables 17,18). Again, the proportion of species in each response type is variable between landtypes, although the pattern is broadly similar to that described for plants. Resilient landtypes had a relatively high proportion of decreasers (30% and 24%) and a lower proportion of increasers (5% and 13%), while sensitive landtypes had a low proportion of decreasers (17% and 7%) and a high proportion of increasers (33% and 19%). Qld sedimentary sites were notable for a particularly low proportion of decreaser ant species (7%) and relatively high proportions of ants with an intermediate (7%) or extreme (6%) response type. The proportion of species in each response type in Qld alluvial sites was similar to the sedimentary landtype.

19 ant species occur in more than one landtype and have been identified consistently across landtypes (taxa with specific names, rather than morphospecies letter). Only 5 of these species have a significant response in 2 or more landtypes (most species have a ‘neutral’ response in most landtypes) and only one species has a consistent response across landtypes – the increaser *Iridomyrmex pallidus*. The most widespread species – *Iridomyrmex sanguineus* – shows a decreaser, increaser or intermediate response in different landtypes, and has a contradictory response (increaser/decreaser) at 2 locations within one landtype.

All of the more speciose ant functional groups are represented within each major response type (decreaser, increaser, intermediate) (Table 19). There was a remarkably similar number of decreaser and increaser responses in each of the functional groups, with the exception of the *hot climate specialist* group, which had substantially more increaser responses – reflecting the preference of these species for areas of bare ground.

3.6.11 *Individual species – birds*

Response patterns for 87 bird species were analysed, which is 64% of all species recorded. Between 27% and 54% of analysed species in each landtype had a significant response to condition (Tables 20-22). There was a high proportion of increaser species (35%) in NT clay sites, but a low proportion (6%) in the Qld basalt sites. The NT clay sites had a low proportion of decreaser bird species (9%), while Qld basalt sites had a much larger proportion (20%). The Qld sedimentary sites also had a higher proportion of increaser (21%) than decreaser species (7%), and were remarkable for the high proportion of species with an intermediate response (28%). The NT loam sites had a similar pattern for birds as plants and ants, with more decreaser than increaser species, although it also had a relatively high proportion of intermediate species (13%).

Of the 87 species analysed, 69 (79%) occur in more than one landtype, 46 (53%) in at least 3, 21 (24%) in at least 4, and 9 (10%) in all 5. A total of 60 bird species (69%) had a significant response to condition in at least one landtype, but only 27 species (31%) in at least 2 landtypes. Five species had a consistent response across landtypes, whereas 9 species had a contradictory response in two or more landtypes.

Birds with a consistent response were the increasers: black-faced woodswallow, australian magpie and mistletoebird, and the decreasers: brown falcon and pale-headed rosella.

Apart from the guilds with very few species, each guild is represented within each major response type (decreaser, increaser, intermediate) (Table 23). However, there is a disproportionately high number of decreaser species in the *ground insectivore* and *foliage insectivore/nectarivore* guilds; and a disproportionately high number of increaser species in the *granivore* and (marginally) *foliage/trunk insectivore* guilds. The *raptor* and *aerial insectivore* guilds have relatively high numbers of species with an intermediate response.

3.6.12 Individual species – reptiles

Only 35 reptile species occurred in enough sites for analysis, although this is 87.5% of all species recorded. Between 21% and 58% of analysed species in each landtype had a significant response to condition (Tables 24-26). Most species recorded in Qld basalt sites had no significant response, and there was a small proportion of both increaser and decreaser species. There was also a high percentage of species with no response in NT clay sites, although 25% of species were increasers (and there were no decreasers). Qld sedimentary sites had the largest proportion of species with a significant response, with more increaser than decreaser species. There was a high proportion (40%) of decreasers and no increasers in NT loam sites.

Only 9 reptiles species had a significant response to condition in more than one landtype. Of these, four showed a consistent response across landtypes, while two species had contradictory responses (with decreaser and increaser responses in tow vegetation types within a landtype.

The skinks *Carlia munda* and *Cryptoblepharus virgatus* had consistent decreaser responses, while the gecko *Heteronotia binoei* had a consistent increaser response. The small skink *Menetia greyi* had a consistent intermediate response.

3.6.13 Individual species – mammals

Only 12 mammal species (60% of all recorded species) were sufficiently abundant in any landtype for analysis, and only 1 or 2 species in each landtype showed a significant response to condition (20% to 33% of analysed species) (Tables 27,28).

No mammals had a significant increaser response in any landtype, while one species (rufous bettong) had an intermediate response in both Qld sedimentary and alluvial sites. One or two species were decreasers in NT loam, NT clay and Qld basalt sites, and these were different species in each landtype. Other than the bettong, no species had a significant response in more than one landtype, so there were no contradictory responses for mammal species.

Decreaser species included the rodents *Pseudomys nanus* and *Rattus villosissimus*, the dasyurid *Sminthopsis macroura* and the eastern gray kangaroo.

3.7 Condition variables as continuous predictors

3.7.1 Biodiversity summary variables

Continuous variables commonly used to assess condition (bare ground cover, understorey cover and perennial grass cover) had significant predictive power for many biodiversity summary variables in most landtypes (Tables 29-31). However, most regression models were relatively weak (except for plant models where the response variable was closely related to one or more of the predictor variables). The predictive power of the models may have been improved by considering interactions and/or polynomial terms but, given the very large numbers of models tested, this was not attempted.

Condition variables explained between 7% and 16% of plant species richness and between 7 and 35% of plant species diversity in 3 landtypes, although there was no significant model for QLD sedimentary or alluvial landtypes (Table 29). Models were highly variable between landtypes in their strength in explaining total richness, cover or frequency of different plant lifeforms. For example, models for the cover and frequency of annual and perennial forbs were relatively good (>50% deviance explained) in NT loam sites, but much poorer in other landtypes

Predictive models for ant species richness and diversity were moderately strong (11% to 32% of deviance explained) in 4 landtypes, although there were no significant models for these variables in NT loam sites (Table 30). Models were highly variable amongst landtypes in their adequacy in explaining the richness and total abundance of ant functional groups, but were generally most robust for the *hot climate specialist* group.

Models were generally poor, but again variable between landtypes, in their adequacy in explaining the richness and diversity of all vertebrates, birds, reptiles or mammals (Table 31). The most robust models) were for the richness and abundance of birds in QLD sedimentary sites (29% and 39% or deviance explained; which also resulted in a reasonable model for total vertebrate richness) and the richness of reptiles in NT loam and alluvial landtypes (13% and 14% deviance explained). There were also some relatively robust models for the richness and/or abundance of vertebrate functional groups, such as the richness and abundance of dasyurids and murids in both NT landtypes; the abundance and/or richness of several bird guilds in QLD sedimentary sites; and the richness of geckos and skinks in QLD alluvial landtypes. Again, however, the strength of models was highly variable amongst landtypes for each response variable, and there were many variables for which there was no significant model.

3.7.2 Individual species

The continuous condition variables also had some predictive power for the relative abundance of individual species (Table 32). Excluding mammals (which had very few species) there were significant models for between 13% and 58% of species (that occurred in sufficient sites to analyse) in each taxonomic group and landtype. Across all landtypes, the proportion of species with a significant model was remarkably consistent between major taxonomic groups (31-39% of species), with the highest proportion for ants and plants, and the lowest for mammals and birds. The proportion of species in a group with significant models was generally higher for NT than QLD landtypes, with particularly high proportions for plants (58%) and birds (62%) in NT clay sites.

Although there were a large number of significant models, these models were generally weak, with the mean deviance explained (for each landtype and taxonomic group) ranging from 10.1 to 29.8% (Table 32). For plants, ants and birds, predictive power of models was generally greater in the more sensitive landtypes (NT loam, QLD sedimentary, alluvial) than the resilient ones (NT loam, QLD basalt).

3.7.3 Which condition variables are the best predictors – biodiversity summary variables

The number of times that each continuous condition variable (bare ground cover, total understorey cover, perennial grass cover) appeared in the predictive models for biodiversity summary variables is shown in Table 34. Across all landtypes, each of the three variables appeared in a moderate proportion of models for each of the major taxonomic groups. Perennial grass cover was the most frequently appearing term for 3 groups (plants, birds, reptiles); bare ground cover for 2 groups (ants and mammals) and total understorey cover for only 1 group (reptiles, equal with perennial grass cover). However, this pattern was not necessarily consistent between landtypes – for example, perennial grass cover was the most frequent term in models for plant variables in 3 landtypes, but bare ground cover was more frequent in the other 2 landtypes.

It is interesting to note that there was a disparity between the frequency of negative and positive parameter estimates for each variable for most taxonomic groups – for example, perennial grass cover was a positive term in all 11 models for mammals in which it appeared, but a negative term in 12 of 16 models for bird variables.

Potential refinement to the use of perennial grass cover as a predictor variable was tested for NT landtypes, where perennial grass frequency (loam and clay) and perennial grass basal area (clay only) were also quantified and tested in models (Table 35). In NT loam sites, cover appeared in many more models than frequency for plant variables, although the two variables were approximately evenly represented in models for other taxonomic groups. In NT clay sites, none of the 3 variables was clearly more useful than the others.

3.7.4 Which condition variables are the best predictors – individual species

The number of times that each continuous condition variable appeared in the predictive models for individual species is shown in Table 36. As for the summary variables, each of the three condition variables appeared in a moderate proportion of models for each of the major taxonomic groups. Across all landtypes, perennial grass cover was the most frequent term in models for plants, ants and mammals, while total understorey cover was most frequent in models for birds and reptiles. Again, this pattern was not always consistent across landtypes.

There was generally less disparity between the number of negative and positive parameter estimates for each variable / taxonomic group combination than noted above for the biodiversity summary variables.

There was no clear advantage in using either of the three perennial grass terms (cover, frequency, basal area) in predictive models for individual species in NT landtypes (Table 37).

3.7 Other habitat variables as continuous predictors

Vector fitting was used to test the correlation of condition and habitat variables with the ordination of sites by species composition (Table 38). The ranking of habitat variables by correlation coefficient varied considerably between landtypes, and between taxonomic groups, and the resultant selection of variables for use in predictive models is shown in Table 39. In general, models included a   The basal rea if dead trees was an important habitat variable in some Queensland landtypes, and the density of height of termite mounds also appeared to be a useful predictor variable.

It is also instructive to examine the correlation coefficients for the condition vectors within the ordination space for each taxonomic group in each landtype (Table 38). Condition variables generally have the highest correlation for plants and ants, and lowest for mammals and reptiles. Correlations between condition variables and species ordinations are particularly poor for the QLD basalt landtype, for all taxonomic groups. Within a taxonomic group, the condition variable with the highest correlation coefficient tends to vary between landtypes – for example, for ants the strongest condition vector is perennial grass frequency for both NT landtypes, soil cover for QLD sedimentary and perennial grass cover for QLD alluvial landtypes.

3.7.1 Condition and habitat models – biodiversity summary variables

There is generally a substantial improvement to models for biodiversity summary variables when habitat variables are included in addition to condition variables as predictors (Tables 40-42).

For plant summary variables (Table 40), there was an increase in deviance explained for 34 of the tested models as well as 20 additional models (for variables that had no significant model base don condition alone. The improvement on deviance explained was variable, although substantial in some cases (notably for total plant richness in QLD basalt sites).

For ant summary variables (Table 41), there was an improvement in deviance explained for 21 models, and an additional 24 significant models. With the inclusion of habitat variables, there were significant predictive models for richness, diversity and total abundance of ants in all landtypes (with total deviance explained between 14% and 52%).

For vertebrate summary variables (Table 42), there was an improvement in deviance explained for 29 models, and an additional 48 significant models. 19 of these additional models were for QLD basalt sites; models including habitat variables explained between 37% and 42% of the richness, abundance and diversity of birds in this landtype, and there were significant models for the richness and/or abundance of most bird guilds in this landtype. Inclusion of habitat terms brought some improvement t models for total richness, abundance and diversity of mammals and reptiles, although these models remained relatively weak (6% to 29% of deviance explained) and there were still no significant models in some landtypes.

3.7.2 Condition and habitat models – individual species

There was a substantial improvement in predictive models for individual species when habitat variables were included in addition to condition variables (Table 43). Across all landtypes, the proportion of species for which there was a significant model increased by 32% for birds, 27%

for plants, 24% for ants, 13% for mammals but only 4% for reptiles. Consequently, there were significant models for 62-65% of all plant, ant and bird species, and 40-44% of reptile and mammal species. The increase in the proportion of significant models occurred across all landtypes, but was markedly larger for QLD basalt.

There was also a general improvement in the strength of the predictive models, with mean total deviance explained ranging from 15.5% to 33.9% (excluding mammals). There is still some tendency for models to be weaker for the more resilient landtypes, although this is less marked than it was for models based only on condition variables. For a small number of species, the predictive models with habitat and condition variables explained a very high percentage of total deviance (up to 91%)

The summary figures presented in the Tables described above do not give a precise picture of the improvement in predictive models with the addition of condition variables, as the calculation of mean deviance explained included the additional models (with habitat variables as the only significant term). Additionally, the inclusion of up to 4 additional terms in any model will always lead to some increase in deviance explained. As an illustration, a more precise calculation of “model improvement” is given for the NT loam landtype (Table 44). For summary variables, the mean deviance explained after the inclusion of habitat predictors was between 26% (ants) and 86% (mammals) greater than with condition predictors only. For individual species, mean deviance explained was between 52% (mammals) and 101% (ants) larger with the more complete models. Improvement in the models resulted from the addition of few terms, with an increase in the mean number of terms of less than one for all models except ant summary variables, and a reduction in the mean number of terms for individual species of birds and reptiles.

3.7.3 Which habitat variables are the best predictors

This project did not seek to exhaustively examine the relative merits of a large range of habitat predictors. The number of times that each habitat variable tested here appeared as a significant term in the predictive models is summarised in Tables 45 and 46. In general, all habitat variables were useful in at least some models, and their relative importance varied both between landtypes and taxonomic groups.

For <u>summary biodiversity variables</u> (Table 45), foliage cover of tall trees and dung score were important habitat variables for most taxonomic groups in the QLD basalt landtype. Terms relating to vegetation density were important in most landtypes for a variety of taxa and distance to water or grazing index were significant in models for each taxonomic group in both NT landtypes.

For <u>individual species</u> (Table 46), litter cover appeared as a significant term in models for plant and ant species in most landtypes. Projective foliage cover was an important predictor for some plant, ant and bird species, but at different heights in different landtypes. Interestingly, termite mound height appeared as a significant term for 13 bird species in the QLD basalt landtype. Distance to water was a significant predictor variable for a large number of plant, ant and bird species in the NT loam landtype.

3.8 Surrogacy amongst components of biodiversity

3.8.1 Richness and diversity

Unsurprisingly, there was high correlation for richness where one dataset was a major subset of another (eg. between plants and ground layer plants, between vertebrates and birds), and there was generally a high correlation between richness and diversity within a taxon (Table 47). Outside these obvious relationships, correlations between taxa were generally weak (typically r<0.3) or non-significant[12]. Notably, across all sites there was a relatively strong correlation between richness of perennial grasses and richness of vertebrates, birds, bird guilds and reptiles. Bird richness was also relatively strongly correlated with reptile richness. 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.

Generally similar patterns were observed for individual landtypes (Table 47). There was a weak negative correlation between perennial grass richness and bird richness in *NT loam* sites, and between perennial grass richness and ant richness in *Qld sedimentary* and *Qld alluvial* sites. By contrast, ant richness was positively related to total plant richness and perennial grass richness in *NT clay sites*, and total plant richness was also weakly positively correlated with vertebrate and bird richness in this landtype. In the *Qld basalt* landtype, there was a relatively strong correlation between plant richness variables and richness of vertebrates and birds (although not mammals or reptiles). Ant richness and diversity were negatively correlated with richness and diversity of vertebrates and birds in *Qld sedimentary sites*.

3.8.2 Assemblage fidelity

Again unsurprisingly, there was strong assemblage fidelity between vertebrates and birds, and between plants and ground layer plants (Table 48). Ant functional groups and bird guilds were generally poor substitutes for the use of all bird and ants species in compositional analysis. 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.

Plant composition was most strongly related to bird (and vertebrate) composition in Qld basalt sites, moderately correlated in NT loam and Qld alluvial sites, but weakly correlated in NT clay and Qld sedimentary sites. Plant composition was relatively strongly correlated to ant composition in NT loam, NT clay and Qld alluvial sites, but weakly so in Qld basalt and Qld sedimentary landtypes. There was a relatively strong correlation between ant composition and bird composition in NT loam sites, a moderate correlation in all Queensland landtypes, and no significant relationship in NT clay sites. Ant composition was weakly correlated to mammal/reptile composition in NT loam, Qld basalt and Qld alluvial landtypes, and there was no significant relationship for Qld sedimentary sites. Quite unusually, there was a negative correlation between ant composition and mammal/reptile composition in NT clay sites[13]. There was generally a weak relationship between the bird composition and mammal/reptile

[12] It is important to note that, with a large number of sites, even a very small correlation can be significant. A correlation coefficient of 0.32 implies that the variation in one variable explains c. 10% of the variation in the second variable)
[13] This implies that sites that were more similar to each other in their ant composition tended to be less similar in their reptile/mammal composition.

composition, except for Qld basalt landtype. The NT clay and Qld sedimentary landtypes were notable for generally low assemblage fidelity between most taxa.

3.9 Other results

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; Appendix 4). 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.

Changes in land condition within the grazing trial at Wambiana over 5 years were accompanied by substantial changes in biodiversity (Kutt *et al.* 2004; Appendix 5). Some modifications to the biota were caused by the resumption of burning after 20 years of fire exclusion, and severe rainfall fluctuation over this period, emphasising how the larger shadow of management and climate can affect condition. 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.

4. Biodiversity Monitoring in Northern Australian Rangelands

4.1 Improved "biodiversity condition" assessment

The results of this project indicate that "land condition", as traditionally assessed in pastoral monitoring programs, is a useful but generally weak indicator for rangeland biodiversity. The analyses also showed that the predictive power of models for most biodiversity attributes were substantially increased by including habitat variables additional to those used to assess pastoral condition. A more sophisticated and useful rating of "habitat condition" or "biodiversity condition" for use in savanna rangelands may therefore combine a broader (or different) set of attributes than conventionally applied in pastoral "land condition" assessment. There have been a number of attempts to develop similar objective "habitat condition" assessment schemes in other parts of Australia, some of which are briefly reviewed below[14].

The Habitat Hectares approach, which was developed in Victoria (Parkes *et al.* 2003, DSE 2004) relies on a comparison of remnant vegetation to a 'benchmark' for the same vegetation type in a 'mature and long-undisturbed' site. In Victoria, the vegetation units used are Ecological Vegetation Classes (ECVs) and benchmarks have been generated for the majority of these using either existing vegetation known to be relatively undisturbed, or postulated values using historical information and knowledge of the effects of disturbance on similar vegetation types. The 'habitat score' of an area is made of components describing 'site condition' (large trees; tree canopy cover; understorey; lack of weeds; recruitment; organic litter; logs) and 'landscape context' (patch size, neighbourhood, distance to core area). Each of these component is scored relative to the benchmark for that ECV, and the contribution of each component to the total score is weighted. The final score may be multiplied by the area (in hectares) to give a total 'habitat hectare' score.

The Biodiversity Benefits Toolkit (Oliver 2004, Oliver *et al.* 2005) was developed in New South Wales to values terrestrial habitat and land use change scenarios. It uses 3 surrogate measures of species-level biodiversity: conservation significance (which scores the biodiversity value of a site in a regional context), landscape context (which scores the biodiversity value of the site according to its size and location in the wider landscape) and vegetation condition (which scores the degree to which critical habitat components for native plants and animals are present at the site). The site attributes used in the vegetation condition assessment were modified from those of the Habitat Hectares approach, and were similarly scored against the characteristics of a benchmark stand of the same vegetation type. The 3 components were combined into a Biodiversity Significance Score (with the greatest weighting given to vegetation condition) and this was multiplied by a Land Use Change Impact Score and the area to give a Biodiversity Benefits Index.

Biometric (Gibbons et al 2005[15]) is a tool used in NSW to assess the impacts on terrestrial bodiversity of applications for clearing or incentives within native vegetation. The steps within the decision-support system include a scheme for assessing "site value", base don ten condition variables: native plant species richness; native overstorey cover; native midstorey cover; native ground cover (grasses); native ground cover (shrubs); native ground cover (other); exotic plant cover; number of trees with hollows; proportion of overstorey species occurring as regeneration;

[14] much of this work has focused on aquatic environments and we do not consider these schemes here

total length of fallen logs. Each variable is scored on a 0-3 scale by reference against a benchmark, which is based on relatively unmodified examples of the same vegetation type. Scores for regional value and landscape value are also used in the tool.

The BioCondition tool (Eyre *et al*. 2006) was developed in Queensland and aims to provide "a measure of how well a terrestrial ecosystem is functioning for the maintenance of biodiversity values. It is concentrates on vegetation condition, which is defined in Queensland as "the structural, compositional and functional aspects of a mature and relatively undisturbed regional ecosystem important for the maintenance of biodiversity values"[16]. As in the schemes described above, BioCondition depends on scoring sites relative to benchmarks[17], in this case specific to each regional ecosystem (RE), with the reference sites being either "mature or long undisturbed" or "best on offer" (although benchmarks may be elicited from experts rather than based on measured sites; Low Choy *et al.* (2005)). Site-based condition attributes contributing to the BioCondition score are an elaboration of the approach of Parkes *et al.* (2003): recruitment of woody perennial species; native plant species richness; tree canopy cover; tree canopy height; shrub layer cover; native perennial grass cover; native perennial forb and non-grass cover; large trees; fallen woody material; weed cover; litter cover. Landscape attributes scored for each site are size of patch, context and connection for fragmented subregions; or distance to water for intact subregions. Each attribute is weighted and combined to give a total BioCondition score, which can be further simplified to a 1 ('good') to 4 ('poor') scale for biodiversity condition.

The application of each of these schemes to biodiversity condition assessment in tropical savanna rangelands has a number of limitations or caveats:

- They were initially developed for use in highly fragmented landscapes and for the assessment of the value of patches of remnant vegetation. The attributes used in the 'landscape context' portion of the assessment are generally not relevant to more intact rangeland landscapes;
- The use of benchmarks against which all attributes are assessed suggests that long-undisturbed sites represent an 'ideal' condition. This is a questionable approach in dynamic landscapes (McCarthy *et al.* 2004), such as tropical savannas where frequent disturbance by fire is the norm rather than the exception, and where the maintenance of spatial and temporal heterogeneity in otherwise relatively uniform vegetation types is likely to be an important factor in maintaining biodiversity (Woinarski 1999, Woinarski *et al.* 2005)
- Notwithstanding the previous point, it is unlikely to be practical to describe benchmarks for all vegetation units in the tropical savannas, particularly given that there is only coarse-scale mapping (eg. 1:1000000) of vegetation units across much of the savanna, and a lack of uniformity in mapping methods and community description.
- Furthermore, it is unclear what the appropriate scale is for describing the landscape units that would be used in condition assessment and benchmarking. The results of the current study demonstrated that there was substantial variation in many biodiversity attributes between two recognisable vegetation types within a single regional ecosystem (cf. Eyre *et al.* 2006), or even between locations (in the NT loam landtype) within what would be almost certainly mapped as a single vegetation unit at even fine scales.

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[15] http://www3.environment.nsw.gov.au/npws.nsf/content/biometric_tool
[16] Eyre *et al.* (2006) note however that the BioCondition score does not provide an index of habitat suitability for fauna.
[17] http://www.epa.qld/gov.au/nature conservation/biodiversity/BioCondition

- The current schemes focus on assessing vegetation condition, with an assumption that this is a good surrogate for other components of biodiversity. While the vegetation condition attributes include a number of habitat features that have shown (by the current and many other studies) to be important for a range of fauna, other attributes may be equally useful.

Although these are substantial issues, we recognise that the refinement of “biodiversity condition” assessment schemes will inevitably offer a significant improvement on the ability of conventional land condition assessment to provide information about the state of, or trends in, biodiversity. A recently-commenced project led by A. Kutt - *Biodiversity Management and Condition Assessment: a Toolkit for Queensland’s Tropical Rangelands* – seeks to explicitly test the utility of a biodiversity condition assessment in the Burdekin and northern Gulf regions. The biodiversity condition assessment method will be based on that used in BioCondition, but will attempt to incorporate attributes that better reflect ecological processes and disturbance regimes in the tropical savanna.

However sophisticated a site-based assessment of ‘habitat’ condition may be, there may be a disjunction between habitat suitability and the presence or abundance of species, due to factors that are not considered in the assessment (such as the density of predators; historical impacts on biota that are no longer reflected in habitat condition; complex spatial arrangement of vegetation units and condition states). This is largely an intractable problem, and emphasises the need to maintain direct monitoring of biota as at least an adjunct to habitat condition assessment.

4.2 Regional- and local-scale biodiversity monitoring programs

There has been increasing attention paid over the past decade to the need to develop achievable but effective monitoring programs for biodiversity in Australian rangelands. We summarise the outcomes from several attempts to develop and/or refine such frameworks below.

In a report to the National Land & Water Resources Audit (NLWRA), Whitehead *et al.* 2001 investigated an “adaptive framework for monitoring biodiversity in rangelands”. They concluded that a capable system would include a number of components:
- elements from the existing State and Territory pastoral monitoring programs (but ideally enhanced to better meet biodiversity monitoring objectives, by more comprehensive sampling of rangeland landscapes and grazing intensities and inclusion of control or benchmark sites)
- increased application of remote sensing and its improved linkage to both measures of landscape function and direct monitoring of biodiversity (accompanied by an emphasis on robust studies to validate these relationships)
- additional wildlife (flora ad fauna) surveys designed to repeat “landmark” surveys and validate surrogates or indicators;
- regular monitoring of populations of a range of selected species, emphasising those most sensitive to prevailing adverse processes or otherwise identified as good indicator species;
- explicit linkage of monitoring programs for Parks and Reserves to their equivalent on lands used for primary production (in order to better tease out management-induced change)

Whitehead *et al.* (2001) developed a minimum set of 11 indicators to provide a ”starting configuration for an ultimately useful scheme” (Table 49).

Table 49. Minimum set of indicators for a national rangelands biodiversity monitoring system, recommended by Whitehead *et al.* (2001).

a) Progress towards a comprehensive, adequate and representative (CAR) reserve system;

b) Trends in the extent of clearing of native vegetation;

c) Trends in landscape function metrics;

d) Trends in the cover of native perennial grass / ground layer vegetation;

e) Trends in the distribution and abundance of exotic plant species;

f) Trends in the distribution, abundance and condition of fire-sensitive plant species and communities;

g) Trends in the distribution and abundance of grazing-sensitive plants;

h) Trends in the distribution and abundance of susceptible mammals;

i) Trends in the distribution and abundance of susceptible birds;

j) Trends in the distribution and abundance of listed threatened species, and the distribution and condition of listed threatened communities;

k) Trends in the intensity of land use;

Smyth *et al.* (2003) reported on expert technical workshop that aimed to further develop or refine indicators, methods and tools for rangeland biodiversity monitoring. Some of the key papers from the workshop were also elaborated in a thematic issue of *Austral Ecology* (eg. Smyth & James 2004). The workshop described and reviewed a very large number of monitoring techniques for measuring attributes of introduced predators, wild harvesting, grazing, weeds, land surface change, plants, fauna and ecosystems. It also distinguished 5 scales for purpose, resolution and reporting of biodiversity monitoring. One outcome of the workshop was a large list of 51appropriate indicators for regional- and local-scale biodiversity reporting (Smyth *et al.* 2003, Table 4.2). Two other useful outcomes of the workshop were the development of some sets of guiding principles for biodiversity monitoring systems: the first more concerned with the process of developing a monitoring program (Table 50) and the second more of a conceptual model of how a monitoring system would be structured (Table 51). Table 50 emphasises that the form of the monitoring program will depend on the purpose, scope and scale, and these must be carefully considered in the development of the program. Table 51 emphasises the need for adequate regional resource information, that the indicator set should be diverse, and that reference areas are important.

Table 50. Guiding principles for development of a biodiversity monitoring system (from Smyth *et al.* 2003, section 5.3)

1. Include in the development process people with expertise in biodiversity management and monitoring. *(eg. NRM planners, regional land/bushcare coordinators*)
2. Identify what changes are happening in the environment that are of concern to biodiversity values. If there are many issues of concern try and prioritise them. (*eg.* *reduced extent of plant communities, degradation of land and inland water condition, loss & degradation of specific habitat attributes, e.g. understorey cover, water-edge vegetation, increased bare ground, tree hollows, favoured seed & nectar plants, declines in well-known fauna and plants. **OR** Include particular species you are concerned about? Are there areas or locations that you consider especially important? Can you identify areas that can serve as 'reference points'? Are changes more likely to happen at particular times?)*
3. Identify what factors are operating in the environment that may be driving these changes. *(eg. grazing, altered fire regimes, feral predators, exotic plant invasions, clearing. **OR** Are some pests or weeds a problem? Are there changes in land-use or management that might affect biodiversity? Are these factors and processes localised or do they operate throughout the region? Do they operate all the time, or only occasionally?).*
4. Identify who needs this information and why. Consider what sort of information product will be needed to allow land managers and decision makers to react to the change. *(eg. Commonwealth, State, Territory & local government NRM and biodiversity managers and planners, regulatory bodies, primary industry groups and landholders for internal management and decision-making. Primary industry groups, community groups, landholders and other parties who have commitments to externally demonstrating environment performance outside the enterprise OR Who does this affect? Who can take action in response to the information?)*
5. Decide on how often information will be needed to best meet the needs of users. *(eg. annually, biennially, every 5 years, every 25 years **OR** Do you need to monitor everything all the time? Do you need to change some monitoring in response to events like fire or drought? Will your monitoring allow enough time for responses?)*
6. Establish who will be responsible for collecting and managing the information and ensuring that it is available to the users. *(eg. State NRM govt agency for storage, analysis and uptake; environmental consultants, landcare, primary industry group, landholders for targeted data collection; Commonwealth, States & Territory for performance assessment, communication and funding. **OR** Who will analyse the information? Who will store and distribute the information and analyses?)*
7. With an understanding of issues of concern and client needs, establish what will be monitored and what techniques will be used to track change. (*Refer to list of most appropriate indicators and the best techniques for measuring them **OR** What information is already available? What additional information do you need?)*.
8. Doublecheck to make sure the indicators, techniques and reporting frequency selected will be able to detect the changes of concern. *(Refer to protocols for selecting sites, indicators, techniques, sampling regime, analysis, interpretation and reporting)*
9. Establish a process to review and improve the monitoring program to ensure it is providing the information required. *(eg. Identify performance criteria and indicators and then assess outcomes against performance targets every 5 years or as required. OR Have your needs or priorities changed?)*

Table 51. Guiding principles for designing an operation framework for regional biodiversity monitoring system (BMS) (from Smyth *et al.* 2003, Appendix F)

1. Whether the monitoring is for special circumstances or for general biodiversity values should be identified and the BMS for each designed differently. For example: ▪ Special places ▪ Regional matrix
2. A BMS should be supported by adequate digital and non-digital regional information resources sufficient to allow mapping of: ▪ Country types ▪ Land-use pressures ▪ Special places
3. A BMS should encompass a necessary and sufficient set of biodiversity values, including: ▪ Plant and animal dimensions, including structural and compositional components ▪ Ecosystem dimension to maintain and enhance ecosystem functioning
4. Indicators of a BMS should be a necessary and sufficient set that includes: ▪ Biotic response, environmental, pressure and landscape attributes ▪ Remote- and ground-based measurements. ▪ An appropriate range of sampling effort from opportunistic to systematic, and qualitative to quantitative ▪ Feedback on deliverable outcomes, operating constraints and assessment against a standard and credible protocol.
5. The set of monitoring sites should include areas with a range of biodiversity values and country types, and encompass: ▪ Areas that have special biodiversity values (e.g. threatened species or communities, or areas under special management) ▪ Reference areas that have high biodiversity value because they are under low pressure, for use as benchmarks to signal adverse change from natural variability ▪ Areas where biodiversity values are at-risk because of high pressure, and areas where land-use pressures are average

Although Smyth *et al.* (2003) detailed a large set of potential indicators for rangeland biodiversity, there was still a lack of clarity as to how a subset of these were best selected and implemented in an achievable and effective monitoring program, especially at regional scales and where scientific expertise was limited. Hunt *et al.* (2006) sought to develop a somewhat simplified indicator set, and undertook several case studies at regional and enterprise scale to test how biodiversity monitoring programs may practically be implemented.

The indicator sets of Hunt *et al.* (2006) for biodiversity monitoring at pastoral enterprise and regional scales are summarised in Table 52 and 53. At the latter scale, we have removed the distinction made by Hunt *et al.* (2006) between indicators for different reporting functions (regulatory& compliance, investment allocation), as there was substantial overlap.

Hunt *et al.* (2006) also provide some detailed examples of how monitoring programs may be developed at property and regional scales. At a property scales, examples are provided for 4 different scales and three levels of monitoring effort, depending on the management issues and resources and expertise available. A worked regional example is provided for the Burdekin Dry

Tropics region, which takes into account the explicit requirements for biodiversity monitoring established by Resource Condition targets and associated management actions in the regional Natural Resource management Plan. Key components in developing a regional biodiversity monitoring plan are:

1. **Obtain existing environmental mapping and biodiversity data for the region.**

   Usually some biophysical baseline mapping data exists for the region of interest. Existing baseline biodiversity and other ecological data, and information on land management regimes, land tenure and other cadastral data should be utilised in planning the monitoring program.

2. **Identify significant biodiversity components.**

   Using the existing information and expert knowledge that may be available identify significant biodiversity components in the region (e.g. significant ecosystems, significant species or threatened or declining species).

3. **Identify significant pressures.**

   for example: total grazing pressure
   invasive 'pasture' plants or weeds (i.e. introduced species)
   fire
   vegetation structural change (thickening or thinning)
   proliferation of water points
   feral predators.

4. **Select 'pressure' and 'management action' type indicators.**

   Pressure indicators are selected based on knowledge of significant pressures in the region, and are generally measured broadly across the region using landscape-scale surrogates. Management action indicators might include CAR reserve status, number of threatened species action plans, progress to best-practice pastoral management.,

5. **Select 'response-type' indicators.**

   Response indicators are selected based on knowledge of significant biodiversity components and to encapsulate as broad a range of taxa as possible. Many response indicators require direct measures of biota at the local scale, with careful stratification according to landtype and management regime to select monitoring sites. Monitoring response indicators may requires more specialised knowledge and greater investment than 'pressure-type' indicators, but are essential for a comprehensive biodiversity monitoring program.

It is not possible for this report to proscribe a detailed framework for a biodiversity monitoring program that can be applied ready-made to all regions in the tropical savannas. Effective biodiversity monitoring programs must be designed on a case-by-case basis for each region though consultation between relevant biodiversity experts and the land management agencies that will use the information. However, the development of the monitoring program should be informed by the principles described above, and the indicators listed here are the current "best-bet" options. In developing any monitoring program, it will always be tempting to rely on pressure-type indicators, or very simple response-type indicators such as "land condition", as they are generally tractable to measurement across broad landscape scales. As this project has demonstrated, however, the response of biodiversity to landuse effects are inevitably complex, and it is unreasonable to expect that a few simple surrogates to be adequately capture this complexity. Therefore, we emphasise the importance of incorporating response-type indicators into any biodiversity monitoring program, that these should encapsulate a broad a range of taxa as possible, and that they should be monitored at as comprehensive a range of sites as possible.

Table 52. Suggested indicators for biodiversity monitoring at the scale of a **pastoral enterprise** (modified from Hunt *et al.* 2006). Indicators are divided into 3 types; "response" indicators assess the biotic response of species, groups or ecosystem attributes to landuse impacts; "pressure" indicators assess landuse pressures or threatening processes that are likely to affect biodiversity; "management action" assess changes in land management for the benefit of biodiversity. The table also includes an assessment of **Feasibility** (the technical feasibility of using the indicator at this scale) and **Likelihood** (whether the level of resources and expertise are likely to be available at this scale), suggested by Hunt *et al*. (2006). Indicators marked with an asterisk are likely to be quantified at a regional scale, and need to be considered in this context.

Indicator description	Suggested techniques / notes	Indicator explanation	F	L
"Response" type				
Change in cover and structure of perennial terrestrial vegetation (pasture grasses / woody shrubs)	Photopoints / plots or transect counts / detailed demography / remote sensing	Broad indicator of a number of pressures. e.g. grazing, fire, flood, drought, weed invasion, land clearing.	High	Med.
Change in composition of perennial terrestrial vegetation (pasture species / shrubs / all)	Photopoints / plots or transect counts	Aimed at maintenance of pastorally productive plant species and habitat for other elements of biodiversity.	High	Med.
Change in composition of bird fauna (all or selected species)	Plot / transect counts	Different suites of birds are good indicators of different pressures, based on mobility/dispersal characteristics; some known to be sensitive to landuse impacts	Med.	Low
Change in composition of ant fauna	Pit trapping	Ants are a ubiquitous and diverse group, sensitive to disturbance at fine scales	Low	Low
Change in composition of mammal / reptile fauna	Pit/Elliott trapping; searches; counts; track counts; scat counts; hair tube	A direct measure of a components of biodiversity, some known to be sensitive	Med.	Low
Change in distribution or abundance of significant fauna species (eg. threatened spp. / waterbirds)	Specific monitoring programs	A direct measure of significant components of biodiversity	Low	Low
Effective recruitment in populations of special biota	Photopoints / plots or transect counts	Recruitment is key to persistence in species or ecosystems of high value.	Med.	Low
Change in landscape function measures	Area of bare ground, erosion / photopoints / transects / remote sensing	An indicator of long-term capacity of the landscape to support biota, although linkages poorly validated	Med.	Low
Riparian / aquatic condition	Rapid assessment techniques?	Important habits for many biota; indicates problems with sediment and nutrient loads	High	Med.
Abundance of macropods	Dung, transect counts / aerial survey / cull	may be an important component of total grazing pressure, as well as a readily	Med.	Med.

Indicator description	Suggested techniques / notes	Indicator explanation	F	L
	returns	sampled component of biodiversity		
"Pressure or threat" type				
Average stocking rates	Property records (by paddock)	Indicator of grazing pressure on the landscape / ecosystem	High	High
Distribution and abundance of feral herbivores	Plot or transect count / scat counts / aerial survey	Often a major & uncontrolled source of grazing pressure.	Med.	Low
Distribution and abundance of feral predators	Spotlight transect counts / scat or track counts	Predation may be a critical factor in the decline of many fauna species, and important management factor for some threatened species.	Med.	Low
Distribution and abundance of invasive weeds (terrestrial and aquatic)	Locality records / plot or transect counts	May be an important threatening process.	Med.	Low
Localised grazing pressure (on special / sensitive areas)	Track / dung counts / defoliation / photopoints	Specific to plant communities or fauna habitats that need some areas protected from grazing pressure (eg from rabbits).	Med.	Low
Density of artificial waterpoints* (by land type)	Station plans; GIS data compiled by state agencies (may be very inaccurate)	Surrogate of grazing pressure	High	Med
% of land area remote from water points* (by land type)	GIS analysis (from waterpoint & landtype mapping)	Availability of refuges for grazing-sensitive species	Med.	Low
Extent of clearing of native vegetation* (by land type)	Aerial photographs, satellite imagery; data compiled by agencies	Major threatening process. Can be enhanced with measures of patch size / connectivity / fragmentation	High	High
Frequency and extent of fire*	Annual fire mapping by agencies; Station records	May be major threatening process, but needs to be related to desirable fire regime for each landtype.	Med.	Med.
"Management action" type				
Infrastructure to protect special areas	Station records; reports to funding agencies	Fences to remove stock, fire breaks etc, are indicators of care for special areas and taxa.	High	High
Biodiversity-friendly grazing management strategies	Documented plans; records of implementation	An indicator that biodiversity conservation is a priority of management	Med	Low
Property environmental plans	Documented plans	Suggest that natural values have been documented	High	High

Table 53. Suggested indicators for biodiversity monitoring at a **regional** scale (modified from Hunt *et al.* 2006[18]). Indicators types and table structure as Table 52. Some of the Feasibility and Likelihood scores have been changed base don the authors' experience of tropical savanna regions.

Indicator description	Suggested techniques / notes	Indicator explanation	F	L
Response type				
Composition of perennial terrestrial vegetation	Photopoints / plot or transect counts	Direct measure of some components of biodiversity; relative proportion of increaser ad decreaser species indicates landuse impacts ; important resource for much biota	High	Med
Cover and structure of perennial terrestrial vegetation	Photopoints / plots or transect counts / detailed demography / remote sensing	Attribute of landscape function and habitat quality for other elements of biodiversity. Indicator of impacts of a number of pressures (e.g. grazing, fire, weed invasion and land clearing).	High	Med
Vegetation 'greenness' indices	Remote sensing	Indicates relative response of areas to rainfall, possibly an indicator of condition. Link to biodiversity not well validated.	High	Med
Abundance and distribution of aquatic and semi-aquatic vegetation	Greenline transects/photo points	Reflects the effect of changed flow regimes and indicates riparian vegetation and wetland health.	Med	Med
Composition and abundance of waterbird fauna	Plot / transect counts	Direct measure of some components of biodiversity. May be an indicator of wetland health more broadly.	High	Med
Composition of terrestrial bird fauna	Plot/transect counts	Direct measure of some components of biodiversity. Some species known to be sensitive to landuse pressures.	High	Low
Composition of terrestrial fauna	Pit/Elliott trapping; searches; counts; track counts; scat counts; hair tube	Direct measure of some components biodiversity. Some species known to be sensitive to landuse pressures.	High	Low
Composition of aquatic invertebrate fauna	Micro-netting and volume sampling	Direct measure of some components biodiversity. Some species/groups are sensitive indicators of aquatic and riparian habitat condition	Med	Low

[18] The simplification of the table from that in Hunt *et al.* (2006) also reflects discussions with Lynn Day and the development of a list of indicators that she used in background research for the ACRIS 2007 Tracking Changes report.

Indicator description	Suggested techniques / notes	Indicator explanation	F	L
Kangaroo abundance	Dung and/or transect counts/aerial survey/culling returns	May be a significant component of grazing pressure. Important to monitor exploited species.	High	High
Status of threatened species and ecological communities	Specific monitoring programs, usually by agencies	Important component of biodiversity. May be an indicator that pressures are ameliorated in wider landscape.	Med	Med
Status of particular 'icon' plant species	Specific monitoring programs, usually by agencies	May be useful surrogates for broader biodiversity components, or clearly demostrate impacts of landuse pressures. May be chosen because eof community concern, interest or knowledge	High	Med
Riparian / aquatic condition	Rapid assessment programs; possibly remote sensing	Important habits for many biota; may be an indicator for landuse pressures elsewhere in the catchment	Med	Med
Landscape pattern change	Site-based assessment; possibly at broad scales using remote sensing	Indicates potential loss of landscape function and habitat degradation. Link to biodiversity requires validation.	Med	Low
Pressure type				
Distribution and abundance of feral carnivores	Spotlight transect counts/scat or track counts	Major threatening process for some fauna, including threatened species	Med	Low
Density and abundance of feral herbivores	Plot or transect count/dung counts/aerial survey	Often a major & uncontrolled source of grazing pressure.	High	Med
Distribution and abundance of significant weed species (includes ecologically significant exotic species that are not currently classified as weeds)	Locality records/plot or transect counts	May be an important threatening process	High	Med
Extent of clearing of native vegetation (area and proportion by vegetation type)	Remote sensing, aerial photography, clearing applications.	Habitat loss is a major threatening process	High	High
Landscape pattern metrics (patch sizes, connectivity)	GIS analysis of coverages for vegetation types, land clearing, etc.	Elaboration of indicator above to include fragmentation and connectivity	High	Med
Fire frequency and extent	Annual fire mapping from remote sensing	Examine role of fire in changing habitat elements of landscape	High	High
Land tenure change	Mapping, databases of State agencies	Gross indicator of change in landuse pressures.	High	Med

Indicator description	Suggested techniques / notes	Indicator explanation	F	L
Average stocking rates	Possibly from stock returns, ABARE data (difficult to quantify by landtype)	In combination with water point indicators can indicate grazing pressure on ecosystems	Med	Low
Density of artificial water-points	Mapping by State agencies (may be inaccurate)	Surrogate for grazing pressure and land-use intensity; also directly correlated with changes in water-dependent species	Med	Med
Percentage of land area that is remote from water points (by landtype)	GIS analysis	Indicates the extent to which grazing sensitive, and water-affected species have refuges from these pressures.	Med	Med
Management action type				
Progress toward a CAR (comprehensive, adequate and representative) conservation network	State tenure mapping; GIS analysis	Shows proportion of land area explicitly managed for biodiversity outcomes and potential reduction in some landuse pressures.	High	High
Infrastructure to protect special areas	eg. Length of fencing, area protected	Direct investment in protecting areas outside the conservation estate	Med	Med
Regional conservation plans	Coverage and adequacy of explicit plans	Planning is an important initial step in management; suggest appropriate data is available	High	Med

5. Retention of Biodiversity in Australia's Northern Rangelands

Although developing a robust system for monitoring savanna biodiversity is an important goal, it will not in itself ensure that biodiversity values are maintained and improved. Rather, monitoring should be seen as a key component of an adaptive management system that is able to adjust land management regimes in response to trends in biodiversity or indicators for biodiversity status.

Unfortunately, we do not have the luxury of developing such a monitoring system before any substantial efforts and investment are directed toward implementing biodiversity-friendly management regimes throughout the savanna rangelands. Rather it is vital to advocate 'best-bet' options that should form the initial step of adaptive management, and ensure that monitoring is developed and implemented that will allow these options to be refined over time.

This project, which concentrated on issues related to biodiversity monitoring, did not seek to proscribe management regimes that would be most favourable to biodiversity in tropical savanna rangelands. The results of the project suggest that maintenance of pastoral lands in good condition, and improvements in land condition across rangeland landscapes, are likely to have positive biodiversity consequences. It also emphasised that 'ideal' habitat conditions vary widely between species, taxonomic groups and across habitat, and therefore that maintenance of habitat complexity at a variety of scales is likely to be a key component of biodiversity-friendly management.

In addition to insights form this study and the accumulated knowledge of the broader project team, we have drawn on a variety of sources to develop broad guidelines for biodiversity-friendly management. These include published and unpublished ecological studies of the habitat relations of savanna biota and the effects of landuse regimes on biodiversity, primarily within the tropical savannas, but also from other Australian rangelands where relevant (eg. Chilcott 2005, Landsberg *et al*. 1999, Fisher 2001, Woinarski *et al.* 2002, Woinarski & Ash 2002, Andersen *et al.* 2003, Kutt 2004, Crowley *et al.* 2004, Tassicker *et al.* 2006, Woinarski *et al.* 2006, Kutt & Woinarski 2007); some attempts to describe similar management guidelines at a regional scale (notably Williams 2004), or for some management aspects at broader scales (eg. Biograze 2000, Hunt 2003, Fisher *et al.* 2004, Myers *et al.* 2004); collated material on the Tropical Savannas CRC "North Australia Land Manager" website[19], which includes management guidelines for some habitats and sensitive species; and prescriptions for biodiversity-friendly management in some other Australian landscapes (eg. McIntyre *et al.* 2002, Lindenmayer *et al.* 2003).

Here, we concentrate on management guidelines that are relevant at an enterprise or property scale. Mechanisms and targets for conserving biodiversity at broader scales (such as establishment of a CAR reserve system) have generally been elucidated within State/territory government plans and strategies (eg. NT Parks and Conservation Masterplan[20]) and the Natural Resource Management Plans for relevant NHT/NAP regions [21].

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[19] http://www.landmanager.org.au/
[20] http://www.nt.gov.au/nreta/parks/management/masterplan/index.html
[21] QLD: http://www.regionalnrm.qld.gov.au/my_region/nrm_plans.html; NT: http://www.nt.gov.au/nreta/naturalresources/nht/inrm/finalplan.html; WA: http://strategy.rangelandswa.info/

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 (Hunt *et al.* 2006, Crowley 2006).

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

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8. Tables

Table 3. Number of species in each major taxon recorded from sites in each land type, and mean (with range) site richness. The distribution of individual species amongst landtypes is detailed in Appendix 3.

		NT loam	NT clay	QLD bas	QLD sed	QLD alv
	sites	*48*	*56*	*48*	*34*	*24*
Plants	Total	264	175	167	152	179
	Site	52.3 (32-74)	40.0 (21-71)	43.9 (25-61)	36.1 (25-50)	47.1 (31-59)
Ants	Total	123	54	106	95	73
	Site	18.7 (9-25)	13.2 (6-21)	17.9 (9-32)	18.3 (9-29)	17.8 (9-25)
Birds	Total	72	62	86	70	58
	Site	12.8 (6-27)	10.8 (2-23)	17.9 (8-28)	18.3 (8-30)	18.1 (11-25)
Reptiles	Total	20	17	29	26	16
	Site	3.0 (0-7)	2.3 (0-6)	5.2 (1-10)	5.5 (2-11)	5.8 (4-9)
Mammals	Total	9	8	11	8	6
	Site	0.6 (0-2)	0.9 (0-3)	1.0 (0-3)	1.4 (0-3)	0.9 (0-3)

Table 4. Proportion of the species complement of each landtype that occurred in a single site, in less than 5 sites, or less than 10 sites, within that landtype.

		VRD loam	VRD clay	QLD bas	QLD sed	QLD alv
	sites	*48*	*56*	*48*	*34*	*24*
Plants	1 site	22%	25%	17%	29%	27%
	<5 sites	47%	45%	38%	47%	54%
	<10 sites	64%	58%	56%	68%	78%
Ants	1 site	29%	13%	30%	26%	29%
	<5 sites	55%	37%	60%	55%	62%
	<10 sites	73%	52%	76%	76%	74%
Birds	1 site	25%	32%	16%	21%	22%
	<5 sites	56%	55%	47%	46%	47%
	<10 sites	76%	71%	65%	67%	72%
Reptiles	1 site	20%	18%	21%	27%	38%
	<5 sites	50%	53%	52%	46%	56%
	<10 sites	70%	71%	69%	65%	63%
Mammals	1 site	33%	29%	36%	38%	17%
	<5 sites	67%	57%	82%	63%	50%
	<10 sites	89%	86%	82%	88%	100%

Table 5. General comparison of habitat variables between landtypes. Values are mean (across all condition classes) and range.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
Canopy height	8.2 (3.5-11)	-	11.6 (8-24)	10.9 (6-21)	8.5 (7-11)
Live basal area	2.7 (0.1-7)	-	8.1 (0.5-57)	12.0 (4-23)	8.5 (2-15)
Dead basal area	0.2 (0-0.8)	-	5.8 (0-18)	3.9 (0-13)	4.4 (0.5-13)
Foliage projective cover >10m	0	0	5.0 (0-37)	5.5 (0-16)	1.8 (0.5-4)
Foliage projective cover 5-10m	7.1 (0-15)	0.03 (0-0.3)	4.4 (0-10)	8.8 (0.3-22)	8.3 (4-13)
Foliage projective cover 3-5m	9.0 (0-18)	0.05 (0-0.6)	0.9 (0-4)	3 (0-14)	4 (0.3-8)
Foliage projective cover 1-3m	6.2 (1-21)	0.01 (0-0.1)	0.03 (0-0.5)	2.1 (0-10)	7.1 (0.3-15)
Rock cover	1.1 (0-12)	15.6 (1-39)	1.6 (0-33)	6.1 (0-44)	0.7 (0-6.5)
Litter cover	26.1 (9-44)	20.5 (1-75)	33.5 (11-70)	37.2 (12-74)	46.0 (28-64)
No. of logs	1-4 (0-5)	0	2.0 (0-8)	3.5 (0-14)	1.9 (0-7)
Termite mounds no.	30.1 (0-100)	0	2.0 (0-9)	20.7 (0-60)	35.6 (8-60)
Termite mound ht	-	0	0.3 (0-1.0)	0.5 (0-1.2)	0.8 (0.3-1.5)

Table 6. Comparison of **habitat variables** between condition classes within each landtype (or sub-landtype). A significant difference between condition classes is reported if either the Kruskal Wallis test or GLZ modelling returned a significant result. Where the GLZ returned a significant (condition*location) or (condition*vegetation) interaction for NT loam or QLD sed/alv sites, respectively, the results are reported for individual locations (H,K) or vegetation types (Box, Ironbark) within that landtype. The form of the response (decreaser, increaser, etc; as per Fig. 4) is indicated with the significance level of the test (*, p<0.1; **p<0.01; ***, p<0.001).

	NT loam	**NT loam H**	**NT loam K**	**NT clay**	**QLD bas**	**QLD sed**	**QLD sed B**	**QLD sed I**	**QLD alv**
sites	*48*	*(24)*	*(24)*	*56*	*48*	*34*	*(17)*	*(17)*	*24*
Canopy height	Int**			-	D*	-			-
Live basal area	D*			-	D*	-			I*
Dead basal area	-			-	I*	I*			-
Foliage projective cover >10m	-			-	D***	-			-
Foliage projective cover 5-10m	D*			-	Int**	Int***			I
Foliage projective cover 3-5m	D**			-	-		Int*	-	I*
Foliage projective cover 1-3m		D*	-	-	-	-			-
Rock cover		-	I*	-	-	-			-
Litter cover	D**	-	-	-	I***	Ext/I*			-
No. of logs	-			-	I**	-			-
Termite mounds no		-	D*	-	D**	-			-
Termite mound ht				-	Int\D**	-			-

Table 7. Comparison of **grazing variables** between condition classes within each landtype. There were no important (condition*location) or (condition*vegetation) interaction, so no results are reported at the sub-landtype level. DPW is distance to permanent water, either the minimum distance (direct) or taking into account obstacles such as fences (cow), whereas 'drainage' may be a non-perennial, natural water source. Response type and significance as per Table 13.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
Dung	I****	-	I***	-	I*
Tracks	I****	-	I***	-	I*
Defoliation	I****	EXT***	I***	I**	EXT\I**
Grazing Index	I****	-	I****	I*	I**
DPW (direct)	-	-	D**	-	-
DPW (cow)	-	-	D**	-	-
Dist. drainage	-	-	D*	-	-

Table 8. Comparison of **pasture condition variables** between condition classes within each landtype (or sub-landtype). There were no important (condition*location) or (condition*vegetation) interactions for NT loam or QLD sed sites. 'nm' indicates where a variable was not measured for that landtype. Response type and significance as per Table 13.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv	QLD alv B	QLD alv I
sites	*48*	*56*	*48*	*34*	*24*	*(16)*	*(8)*
Bare ground cover	I**	-	D*	Int*		I*	-
Total understorey cover	D***	D*	D***	Int\D*	-		
Perennial grass cover	D***	D***	D*	Int\D*		D*	-
Perennial grass frequency	D***	D***	I**	-	Int\I*		
Perennial grass basal area	nm	D***	nm	nm	nm		

Table 9. Results of ANOSIM analyses testing differences in **species (or functional group) composition** between condition classes, for each landtype and major taxonomic group. For NT loam and QLD sedimentary/alluvial landtypes the results are for 2-way ANOSIM, with location or vegetation types as the second factor. Values for the ANOSIM R-statistic are given with significance level (ns, p>0.1; *, p<0.1; **p<0.01; ***, p<0.001). Letters in bracket indicate significant results from pairwise comparisons (eg. GI means good and intermediate sites had significantly different composition)

Group	NT loam		NT clay	QLD basalt	QLD sedimentary		QLD alluvial	
	Cond	Locn	Cond	Cond	Cond	Veg	Cond	Veg
all plants	0.21*** (GI** GP***)	0.65***	0.12** (IP* GP**)	0.36*** (GI** IP*** GP***)	0.29*** (GI** IP** GP**)	0.69***	0.40*** (GI** IP** GP*)	1.00***
ground layer plants	0.22*** (GI** GP***)	0.64***	0.12** (IP* GP**)	0.36*** (GI*** IP*** GP***)	0.27*** (GI** IP** GP**)	0.19**	0.25* (GI* IP*)	0.96***
ants	0.20*** (GI* IP* GP***)	0.89***	0.05* (GP*)	0.29*** (GI*** IP* GP*)	0.32*** (GI*** IP* GP***)	0.23**	0.10ns	0.74***
ant functional group	0.15** (IP* PG***)	0.15**	0.05ns (GP*)	0.15** (GI** GP**)	0.22** (IP*** GP*)	0.18*	-0.01ns	0.35**
birds	0.11** (GI* GP**)	0.61***	0.04ns (GP*)	0.24*** (GI** IP* GP**)	0.60*** (GI*** IP*** GP*)	0.22**	0.15* (ns)	0.39**
bird guilds	0.02ns (GP*)	0.09*	0.05ns (GP*)	0.14* (GI** IP* GP**)	0.27** (GI*** IP***)	0.57***	0.05ns	0.27*
mammal/reptiles	0.10* (GP**)	0.34***	0.00ns	0.08* (GI*)	0.34*** (GI*** IP** GP**)	0.06ns	0.00ns	0.40**
all vertebrates	0.15** (GI* GP***)	0.66***	0.03ns (GP*)	0.23*** (IP** GP**)	0.61*** (GI*** IP*** GP*)	0.26**	0.03ns	0.48***

Table 10. Comparison of **plant summary variables** between condition classes for each landtype (or sub-landtype). There were no important (condition*vegetation) interactions for QLD sedimentary sites. Response type and significance as per Table 13.

	NT loam	**NT loam H**	**NT loam K**	**NT clay**	**QLD bas**	**QLD sed**	**QLD alv**	**QLD alv B**	**QLD alv I**
Sites	*48*	*(24)*	*(24)*	*56*	*48*	*34*	*24*	*(18)*	*(6)*
Species richness									
All plants	INT\I*			-	Int\D***	I**		Int*	-
Perennial grass	D*			-	D***	-	Int\D*		
Fac. perennial grass	-		I*	-	D**	Ext*	-		
Annual grass	-		I*	-	Int*	Int\I***	-		
Sedges	I*			INT\D*	D**	Ext*	-		
Perennial forbs	Int\I*			-	Int\D***	I**			
Annual forbs	I*			-	Int\D*	I*	D*		
Shrubs & trees	Int\D*			I*	I*	-	-		
3P plants	I**				Int\D***	-		Int*	-
Species diversity									
All plants	I***			-	Int\D***	I*	-		
Cover									
Total understorey	D***			D*	D***	Int\D*	-		
Perennial grass	D***			D***	D*	Int\D*		D*	
Fac. perennial grass	I**			-	D**	-	-		
Annual grass	I**			-	Int\D*	Int\I**	Int*		
Sedges	-			-	D**	Ext*	Int*		
Perennial forbs	I*			Int\I*	-	I*	-		
Annual forbs	I**			I*	D*	I*	-		
Shrubs & trees	D*			INT\I**	nc	nc	nc		
3P plants	nc			nc	-	D*	I*		
Frequency									
All plants	I***				nc	nc	nc		
Perennial grass	D***			D***	I**	-	Int\I*		
Fac. perennial grass	I**				Int\D**	-	-		
Annual grass	I***				-	I**	-		
Sedges		I*	-	D*	D*	Ext*	-		
Perennial forbs	Int\I**				-	Ext**	-		
Annual forbs	I***				-	-	-		
Shrubs & trees		D*	I*						
3P plants					I**	-	-		

Table 11. Comparison of **ant summary variables** between condition classes for each landtype (or sub-landtype). There were no important (condition*vegetation) interactions for QLD sedimentary or alluvial sites. Membership of each functional group is shown in App.3. Response type and significance as per Table 13.

	NT loam	NT loam H	NT loam K	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*(24)*	*(24)*	*56*	*48*	*34*	*24*
Species richness	I**			D**	D***	Ext\I*	-
Species diversity	I*			D**	D***	Ext\I*	-
Functional group diversity	-			-	D***	-	-
Total abundance	I**				-	Ext\I*	-
Functional group (richness)							
Cold Climate Specialist					-	-	-
Cryptic	-			-	-	Ext*	-
Dominant Dolichoderinae	-			D*	-	-	-
Generalised Myrmicinae		-	I*	-	D**	Ext\I*	-
Hot Climate Specialist	I***			D**	D**	Ext*	-
Opportunist	-			-	-	-	-
Subordinate Camponotini	-			D*	D***	-	-
Specialist Predator	-			-	-	-	-
Tropical climate specialist	-			-	-	-	-
Functional group (abund.)							
Cold Climate Specialist				-	-	-	-
Cryptic	-			-	-	Ext\I*	-
Dominant Dolichoderinae	I*			-	I*	-	-
Generalised Myrmicinae	-	-	I*	-	D**	I*	I*
Hot Climate Specialist	I***			-	D*	Int*	-
Opportunist	-			-	-	-	-
Subordinate Camponotini	-			-	D***	-	-
Specialist Predator	-			-	-	-	-
Tropical climate specialist	-			-	-	-	-

Table 12. Comparison of **vertebrate summary variables** between condition classes for each landtype (or sub-landtype). Membership of each functional group is shown in Appendix 1. Response type and significance as per Table 13.

	NT loam	NT loam H	NT loam K	NT clay	QLD bas	QLD sed	QLD sed B	QLD sed I	QLD alv	QLD alv B	QLD alv I
Sites	*48*			*56*	*48*	*34*			*24*		
Vertebrates											
Richness	-			-	D***	INT***			-		
Diversity	-			-	-	INT*			-		
Birds											
Richness	-			I*	D**	INT***			-		
Total abundance		INT*	I*	-	D**	INT***			-		
Diversity	-			-	D**	INT*			-		
Bird guilds											
aerial insectivore richness	-			-	-	INT***			-		
abundance		I*	INT*	-	-	INT***			-		
foliage insectivore/nectarivore richness		D*	INT*	I*	-	-				-	EXT\I*
abundance		D*	-	I*	-		INT\I*	INT*	I*		
foliage/trunk insectivore richness	-			-	-	-			-		
abundance	INT*			EXT\I*	Int/D*		INT\I*	INT**	-		
granivore richness	I**			I*	-	INT***			-		
abundance	I*			I*	I*	INT***			-		
ground insectivore richness	-			-	D***	INT*			-		
abundance		D*	INT*	D*	D**		INT\I*	INT*	EXT*		
ground insectivore/omnivore richness	-			-	-	INT**	I*	INT*	-		
abundance	-			-	-	INT\I*			-		
raptor richness	-			-	-	-			-		
abundance	-			I*	-	INT***			-		
nectarivore richness					D**	-			-		

	NT loam	NT loam H	NT loam K	NT clay	QLD bas	QLD sed	QLD sed B	QLD sed I	QLD alv	QLD alv B	QLD alv I
abundance					INT\D*		I*	-	-		
Mammals											
Richness	-			-	D**		EXT*	-	-		
Total abundance	-			-	D*	-			-		
Diversity	-			-	D**		EXT\D*	-	-		
Mammals groups											
dasyurid richness	-			D*	-	-			-		
abundance	?			D*	-	-			-		
murid richness	D**			D*	-	-			-		
abundance	?			D*	-	-			-		
macropod richness	-			-	-		EXT*		INT*		
abundance	?			-	D*	-			INT*		
Reptiles											
Richness	D**			-	-	-				I*	-
Total abundance	D***			-	-		-	INT*		-	INT*
Diversity	D**			-	D*	-				I*	-
Reptile groups											
varanid/agamid richness	-			-	D*	D*			-		
abundance	D*			-	D*	D*			-		
gekkonid richness	-			-	-	INT\I**			-		
abundance	-			EXT\D*	I**	INT\I***			-		
scincid richness	D**			-	-	-			-		
abundance	D*			-	INT\D*		EXT\D*	-		-	INT*
serpent richness	-			-	-		-	D*	-		
abundance	-			-	-		-	D*	-		

Table 13. Response (to condition class) of **individual plant species** in each landtype. Only species that occurred in at least 5 sites within a landtype were analysed. Asterisks indicate significance of test for difference between condition classes Species in brackets had a significant interaction between condition class and location/vegetation type (ie. they showed a different response in each sub-landtypes) and therefore appear in two cells within a column.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*123*	*97*	*96*	*85*	*75*
Increaser	*Alysicarpus muelleri** *Aristida holathera** *Blumea tenella** *(Bonamia media)* *(Bonamia pannosa)* *Brachyachne convergens*** *Buchnera asperata** *(Bulbostylis barbata)* *(Cleome viscosa)* *Corchorus aestuans** *(Dichanthium sericeum)* *Enneapogon purpurascens** *Euphorbia sp. JR1** *(Evolvulus alsinoides)* *(Hakea arborescens)* *(Heteropogon contortus)* *Heliotropium foveolatum** *Heliotropium plumosum** *Indigofera linifolia** *(Indigofera linnaei)* *(Iseilema macratherum)* *Leptopus decaisnei** *(Mnesithea formosa)* *(Panicum laevinode)* *Perotis rara** *Polycarpaea corymbosa** *Pterocaulon serrulatum** *(Ptilotus fusiformis)* *Senna notabilis** *Sida brachypoda** *Solanum chippendalei** *Spermacoce auriculata** *Sporobolus australasicus** *(Sida fibulifera)* *Tribulopis bicolor**	*Chionachne hubbardiana** *Commelina ensifolia** *Corchorus macropetalus*** *Corchorus tridens** *Corchorus trilocularis** *Euphorbia stevenii** *Flemingia pauciflora** *Iseilema ciliatum** *Jacquemontia browniana** *Rhynchosia minima** *Sida spinosa** *Spermacoce pogostoma** *Terminalia volucris**	*Bothriochloa pertusa**** *Chloris virgata** *Indigofera linnaei** *Sida spinosa** *Tephrosia juncea** *Urochloa panicoides****	*Acmella grandiflora** *Aristida calycina var. calycina*** *Bothriochloa decipiens** *Chamaesyce mitchelliana** *(Chrysopogon fallax)* *(Crotalaria medicaginea)* *Dichanthium sericeum***** *Digitaria brownii** *Emilia sonchifolia** *Glycine tabacina*** *Hybanthus enneaspermus** *Indigofera hirsuta** *(Indigofera pratensis)* *Malvastrum americanum** *(Mnesithea formosa)* *(Panicum effusum)* *(Scleria brownii)Sida spinosa** *Sporobolus australasicus** *Tephrosia juncea** *Tripogon loliiformis** *Urochloa mosambicensis** *(Wedelia spilanthoides)* *Zornia muriculata**	*(Melhania oblongifolia)* *(Panicum effusum)* *(Sida spinosa)*
Intermediate / Increaser	*(Aristida hygrometrica)* *Crotalaria medicaginea** *Crotalaria montana** *Enneapogon pallidus** *Euphorbia schultzii /*	*Pentalepis ecliptoides** *Astrebla elymoides**	*Malvastrum americanum** *Stylosanthes scabra** *Vigna lanceolata** *Waltheria indica**	*Eriochloa crebra** *(Brunoniella australis)*	-

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
	*drummondii** *Gomphrena canescens** *Heliotropium dichotomum** *Indigofera colutea** *Ipomoea eriocarpa** *Neptunia dimorphantha**				
Extreme / Increaser	*Boerhavia dominii** *(Dichanthium fecundum)* *Enneapogon polyphyllus** *(Gossypium australe)* *Ipomoea diversifolia**	*Boerhavia paludosa** *Dichanthium sericeum**	*Sida cordifolia**	*(Brunoniella australis)*	-
Intermediate	*(Indigofera linnaei)* *(Bonamia pannosa)* *(Cleome viscosa)* *Corymbia terminalis** *(Dichanthium sericeum)* *(Iseilema macratherum)* *Polymeria longifolia** *Tinospora smilacina** *Vigna lanceolata**	*Alysicarpus muelleri** *Cucumis melo** *Heliotropium plumosum** *Neptunia gracilis**	*Acmella grandiflora*** *Centipeda racemosa** *Chamaecrista nomame** *Digitaria ciliaris** *Ipomoea polymorpha** *Rostellularia adscendens**	*(Alternanthera nana)* *Aristida jerichoensis** *Brunoniella acaulis** *(Crotalaria medicaginea)* *Fimbristylis dichotoma*** *(Heteropogon contortus)* *Indigofera colutea*** *(Panicum effusum)* *Sida cordifolia*** *Xenostegia tridentata**	*Alloteropsis cimicina** *Aristida calycina var. calycina** *(Aristida pruinosa)* *Digitaria brownii** *Fimbristylis dichotoma** *Mnesithea formosa** *(Panicum effusum)* *(Paspalidium rarum)* *unidentified Tephrosia** *Vigna lanceolata**
Decreaser	*Aristida inaequiglumis** *(Aristida pruinosa)* *(Bonamia media)* *Chrysopogon fallax** *(Dichanthium fecundum)* *Eragrostis tenellula** *Eriachne obtusa** *Eulalia aurea** *(Gossypium australe)* *(Hakea arborescens)* *(Heteropogon contortus)* *Sehima nervosum** *Sorghum annual** *Sorghum perennial** *Themeda triandra** *Trichodesma zeylanicum** *Zornia muriculata**	*Bergia pedicellaris** *Bulbostylis barbata** *Chrysopogon fallax*** *Commelina ciliata** *Crotalaria montana** *Desmodium muelleri** *Dichanthium fecundum*** *Eriachne obtusa*** *Eulalia aurea** *Fimbristylis schultzii** *Gomphrena breviflora** *Goodenia byrnesii** *Ipomoea diversifolia** *Neptunia sp.** *Oldenlandia argillacea** *Panicum decompositum** *Ptilotus spicatus** *Rostellularia adscendens** *Sauropus trachyspermus** *Sehima nervosum** *Sida fibulifera*** *Stemodia glabella** *Streptoglossa bubakii**	*Aristida longicollis** *Brunoniella australis*** *Camptacra barbata*** *Chamaesyce mitchelliana** *Crotalaria medicaginea** *Crotalaria montana** *Cyanthillium cinereum** *Dichanthium annulatum** *Enneapogon polyphyllus** *Heteropogon contortus** *Melinis repens** *Mnesithea granularis** *Scleria brownii*** *Sehima nervosum** *Themeda triandra*** *Wedelia spilanthoides*** *Zornia muriculata**	*(Alternanthera nana)* *(Aristida queenslandica)* *Boerhavia paludosa** *Dichanthium fecundum** *Enneapogon polyphyllus** *(Heteropogon contortus)* *Themeda triandra** *unidentified Phyllanthus**	*(Aristida ingrata)* *Carissa ovata** *(Paspalidium rarum)* *(Stylosanthes viscosa)*
Intermediate / Decreaser	*(Evolvulus alsinoides)* *Hakea lorea**	*Aristida latifolia** *Iseilema macratherum** *Neptunia dimorphantha** *Indigofera trita**	*Aristida leptopoda**** *Bothriochloa ewartiana*** *Cenchrus ciliaris** *Cyperus gracilis**	*(Indigofera linnaei)*	*Bothriochloa ewartiana**

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
			Dichanthium fecundum** Dichanthium sericeum** Indigofera linifolia* Indigofera pratensis* Marsdenia australis* Polygala wightiana* Pterocaulon redolens* Sporobolus australasicus**		
Extreme / Decreaser	(Aristida hygrometrica)	Indigofera linifolia*	-	Grewia retusifolia*	-
Extreme	-	Iseilema vaginiflorum* Sesbania simpliciuscula*	-	Cyanthillium cinereum* Cyperus gracilis* Enneapogon lindleyanus* Evolvulus alsinoides* Jacquemontia paniculata* Melhania oblongifolia* (Scleria brownii) (Wedelia spilanthoides)	Bothriochloa pertusa* (Eriachne obtusa) Glycine tomentella*
Neutral	Abutilon andrewsianum Abutilon otocarpum Acacia colei Acacia farnesiana Acacia hemignosta Achyranthes aspera Alternanthera nana (Aristida pruinosa) Atalaya hemiglauca Bauhinia cunninghamii Brachychiton diversifolius Brachychiton megaphyllus (Bulbostylis barbata) Carissa lanceolata Cayratia trifolia Cenchrus ciliaris Clerodendrum floribundum Corchorus sidoides Corymbia confertiflora Cullen plumosum Dichrostachys spicata Dolichandrone heterophylla Ehretia saligna Eragrostis sp. Eucalyptus pruinosa Euphorbia biconvexa Flueggea virosa Galactia tenuiflora Gomphrena lanata Goodenia byrnesii	Abelmoschus ficulneus Abutilon andrewsianum Achyranthes aspera Alternanthera nana Ammannia multiflora Astrebla pectinata Atalaya hemiglauca Bauhinia cunninghamii Blumea tenella Brachyachne convergens Calotropis procera Cardiospermum halicacabum Carissa lanceolata Cleome viscosa Corchorus aestuans Corchorus fascicularis Corchorus olitorius Corymbia terminalis Crotalaria medicaginea Cyperus bifax Desmodium flagellare Echinochloa colona Eragrostis tenellula Euphorbia alsiniflora Euphorbia maconochieana Euphorbia schizolepis Evolvulus alsinoides Glycine falcata Heliotropium sp. Hybanthus enneaspermus	Acanthospermum hispidum Alternanthera nana Aristida calycina var. calycina Aristida ingrata Aristida jerichoensis Aristida latifolia Boerhavia paludosa Bothriochloa decipiens Brunoniella acaulis Chamaecrista absus var. absus Chamaesyce drummondii Chrysopogon fallax Crotalaria juncea Cyperus fulvus Dactyloctenium radulans Dianella caerulea Digitaria divaricatissima Enneapogon lindleyanus Eragrostis cilianensis Evolvulus alsinoides Fimbristylis dichotoma Glycine tabacina Glycine tomentella unidentified Goodenia Grewia retusifolia Heteropogon triticeus Hibiscus meraukensis Hybanthus enneaspermus Indigofera colutea Indigofera hirsuta	(Aristida queenslandica) (Chrysopogon fallax) Crotalaria montana Dichanthium annulatum Melinis repens Camptacra barbata Chloris virgata Bothriochloa pertusa Ipomoea polymorpha Rostellularia adscendens Indigofera linifolia Polygala wightiana Pterocaulon redolens Bothriochloa ewartiana Stylosanthes scabra Acanthospermum hispidum Chamaecrista absus var. absus Chamaesyce drummondii Cyperus fulvus Dianella caerulea Digitaria divaricatissima Eragrostis cilianensis Glycine tomentella unidentified Goodenia Hibiscus meraukensis (Indigofera linnaei) (Indigofera pratensis) Ipomoea plebeia (Mnesithea formosa) Phyllanthus fuernrohrii	(Aristida ingrata) (Aristida pruinosa) Alternanthera nodiflora Aristida jerichoensis Aristida latifolia Brunoniella acaulis Brunoniella australis Cenchrus ciliaris Chamaecrista absus var. absus Chamaesyce drummondii Chamaesyce mitchelliana Chloris virgata Chrysopogon fallax Crotalaria montana Cyanthillium cinereum Dactyloctenium radulans Dichanthium fecundum Dichanthium sericeum Digitaria divaricatissima Enneapogon lindleyanus Enneapogon polyphyllus (Eriachne obtusa) Eriochloa crebra Evolvulus alsinoides Grewia retusifolia Heteropogon contortus Hibiscus meraukensis Hybanthus enneaspermus Indigofera colutea Indigofera linifolia

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
	Goodenia hispida *Goodenia odonnellii* *Grewia retusifolia* *Gyrocarpus americanus* *Indigofera trita* *Ipomoea polymorpha* *Marsdenia sp.* *(Mnesithea formosa)* *(Panicum laevinode)* *Phyllanthus maderaspatensis* *Polygala rhinanthoides* *Polymeria ambigua* *Portulaca digyna* *Portulaca filifolia* *(Ptilotus fusiformis)* *Rhynchosia minima* *Sauropus trachyspermus* *Schizachyrium fragile* *Sida cordifolia* *(Sida fibulifera)* *Sida spinosa* *Solanum quadriloculatum* *Spermacoce D139759 dolichosperma* *Streptoglossa sp.* *Stylosanthes hamata* *Tephrosia supina* *Terminalia arostrata* *Terminalia volucris* *Ventilago viminalis* *Waltheria indica* *Wedelia affin. Verbesinoides* *Xenostegia tridentata*	*Ipomoea lonchophylla* *Iseilema fragile* *Malvastrum americanum* *Paspalidium retiglume* *Phyllanthus maderaspatensis* *Polygala rhinanthoides* *Polymeria ambigua* *Polymeria longifolia* *Portulaca filifolia* *Sorghum timorense* *Sporobolus australasicus* *Stemodia tephropelina* *Tephrosia rosea* *Terminalia arostrata* *Trichodesma zeylanicum* *Wedelia asperrima*	*Ipomoea plebeia* *Melhania oblongifolia* *Panicum decompositum* *Panicum effusum* *Phyllanthus fuernrohrii* *Phyllanthus virgatus* *Portulaca oleracea* *Rhynchosia minima* *Sarga plumosum* *Sauropus trachyspermus* *Sida subspicata* *Sida trichopoda* *Spermacoce brachystema* *Stylosanthes humilis* *Tephrosia leptoclada* *Tragus australianus* *Tridax procumbens* *Tripogon loliiformis* *Urochloa mosambicensis* *Urochloa subquadripara*	*Phyllanthus virgatus* *Portulaca oleracea* *Rhynchosia minima* *Sida subspicata* *Spermacoce brachystema* *Stylosanthes humilis* *Tephrosia leptoclada* *Urochloa subquadripara* *Carissa lanceolata* *Eragrostis schultzii* *Eriachne obtusa* *Schizachyrium fragile*	*Indigofera linnaei* *Ipomoea plebeia* *Jacquemontia paniculata* *Malvastrum americanum* *Marsdenia australis* *(Melhania oblongifolia)* *Phyllanthus fuernrohrii* *Phyllanthus virgatus* *Portulaca oleracea* *Rhynchosia minima* *Rostellularia adscendens* *Sauropus elachophyllus* *Sauropus trachyspermus* *Schizachyrium fragile* *Sida cordifolia* *(Sida spinosa)* *Sida trichopoda* *Spermacoce brachystema* *Sporobolus australasicus* *Stylosanthes hamata* *Stylosanthes humilis* *Stylosanthes scabra* *(Stylosanthes viscosa)* *Tephrosia leptoclada* *Themeda triandra* *Tragus australianus* *Tripogon loliiformis* *Urochloa mosambicensis* *Urochloa subquadripara* *Waltheria indica* *Xenostegia tridentata* *Zornia muriculata*

Table 14. Summary of responses of **individual plant species** to condition class. Values are the number of species within each response type for each landtype, and as a proportion of the total number of responses analysed in that landtype (the number of responses analysed can be slightly larger than the number of species, as some species had to be analysed separately in each sub-landtype).

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*123*	*97*	*96*	*85*	*75*
responses analysed	*141*	*97*	*96*	*97*	*83*
Increaser	35 24.8%	13 13.4%	6 6.3%	23 23.7%	3 3.6%
Intermediate / Increaser	10 7.1%	2 2.1%	4 4.2%	2 2.1%	0 -
Extreme / Increaser	5 3.5%	2 2.1%	1 1.0%	1 1.0%	0 -
Intermediate	9 6.4%	4 4.1%	6 6.3%	10 10.3%	10 12.0%
Decreaser	17 12.1%	23 23.7%	17 17.7%	8 8.2%	4 4.8%
Intermediate / Decreaser	2 1.4%	4 4.1%	12 12.5%	1 1.0%	1 1.2%
Extreme / Decreaser	1 0.7%	1 1.0%	0 -	1 1.0%	0 -
Extreme	0 -	2 2.1%	0 -	8 8.2%	3 3.6%
Neutral	61 43.3%	46 47.4%	49 51.0%	42 43.3%	62 74.7%

Table 15. Condensed summary of responses of **individual plant species** to condition class. As per Table 21, with simplified condition classes (eg. “increaser” includes “intermediate/increaser” and “extreme/increaser”). Only the proportion of responses analysed is shown.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*123*	*97*	*96*	*85*	*75*
responses analysed	*141*	*97*	*96*	*97*	*83*
Increaser	35.5%	17.6%	11.5%	26.8%	3.6%
Intermediate	6.4%	4.1%	6.3%	10.3%	12.0%
Decreaser	14.2%	28.8%	30.2%	10.3%	6.0%
Extreme		2.1%		8.2%	3.6%
Neutral	43.3%	47.4%	51.0%	43.3%	74.7%

Table 16. Response (to condition class) of **individual ant species** in each landtype. Table structure as per Table 13.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*56*	*37*	*63*	*64*	*33*
Increaser	*(Camponotus sp. E (denticulatus gp.))* *Camponotus sp. J (novaehollandiae gp.)*** *(Iridomyrmex hartmeyeri)* *Iridomyrmex pallidus** *(Iridomyrmex sanguineus)* *(Iridomyrmex sp. A (anceps gp.))* *Iridomyrmex sp. B (gracilis gp.)** *(Iridomyrmex sp. C (mattiroloi gp.))* *Melophorus sp. B (fieldi gp.)** *Melophorus sp. C (wheeleri gp.)** *Melophorus sp. L (Group F)** *Melophorus sp. O (Group C)*** *Melophorus sp. S (mjobergi gp.)*** *Monomorium disetigerum** *Monomorium sp. A (rothsteini gp.)** *(Monomorium sp. E (sordidum gp.))* *Monomorium sp. K (rothsteini gp.)** *(Rhytidoponera sp. C (aurata gp.))* *Tetramorium sp. B (striolatum gp.)**	*Iridomyrmex spC (anceps gp.)** *Rhytidoponera spB (Group A)**	*Iridomyrmex sp. E (rufoniger gp.)** *Iridomyrmex sp. K (pallidus gp.)**	*Iridomyrmex pallidus** *(Iridomyrmex sanguineus)Melophorus sp. K (Group D)** *(Iridomyrmex sp. H (mattirolia gp.))* *(Leptogenys cornigera)* *(Melophorus sp. H (mjobergi gp.))* *(Monomorium fieldi)* *(Monomorium sp. F (laeve gp.))* *Monomorium sp. G (nigrium gp.)** *Polyrhachis sp. E (gab gp.)** *(Rhytidoponera lamellinodis)* *(Rhytidoponera sp. C (convexa gp.))*	*(Iridomyrmex sp. A (rufoniger gp.))* *(Iridomyrmex sp. F (mattiroloi gp.))* *(Odontomachus sp. A (ruficeps gp.))* *(Pheidole sp. B (Group D))* *Pheidole sp. E (Group D)** *(Rhytidoponera sp. F (metallica gp.))*
Intermediate / Increaser	*(Monomorium sp. E (sordidum gp.))* *(Monomorium fieldi)* *Pheidole sp. A (mjobergi gp.)**	-	*Iridomyrmex sp. A (anceps gp.)**** *Paratrechina sp. A (obscura gp.)*** *Rhytidoponera ?convexa**	-	*Pheidole sp. A (Group C)** *(Rhytidoponera sp. F (metallica sp.))*
Extreme / Increaser		-	*Iridomyrmex sp. H (mattirolia gp.) *** *Melophorus sp. E (wheeleri gp.)** *Rhytidoponera sp. C (convexa gp.)**	*Iridomyrmex sp. D (pallidus gp.)** *Monomorium sp. C (laeve gp.)** *Monomoruim sp. E (sordidum gp.)** *Solenopsis sp. A**	*(Odontomachus sp. A (ruficeps gp.))*

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
Intermediate	*(Iridomyrmex hartmeyeri)* *Melophorus sp. F (Group E)** *Polyrhachis sp. B (obtusa gp.)**	*Iridomyrmex Kak1 (anceps gp.)**	-	*Iridomyrmex sp. E (rufoniger gp.)** *Meranoplus sp. C (diversus gp.)** *Odontomachus sp. B (ruficeps gp.)** *Pheidole sp. A (Group E)** *(Polyrhachis sp. E (gab gp.))*	*Melophorus sp. A (aeneovirens gp.)*** *(Pheidole sp. B (Group D))*
Decreaser	*(Camponotus sp. F (rubiginosus gp.))* *Melophorus sp. Y (aeneovirens gp.)** *Monomorium anderseni** *Monomorium sp. F (nigrium gp.)** *Odontomachus sp. nr. turneri** *(Iridomyrmex sanguineus)* *(Iridomyrmex sp. A (anceps gp.))* *(Iridomyrmex sp. C (mattiroloi gp.))* *(Rhytidoponera sp. C (aurata gp.))* *(Rhytidoponera sp. D (convexa gp.))*	*Iridomyrmex spD (mattiroloi gp.)** *Melophorus spB (aeneovirens gp.)** *Meranoplus spB (mjobergi gp.)** *Monomorium sp.C (laeve gp.)** *Opisthopsis rufoniger*** *Polyrhachis (chariomyrma gp.)** *Rhytidoponera spA (convexa gp.)**	*Camponotus sp. B (denticulatus gp.)** *Iridomyrmex sp. I (suchieri gp.)** *Melophorus sp. D (pillipes gp.)** *Melophorus sp. H (mjobergi gp.)**** *Melophorus sp. P (froggatti gp.)** *Monomorium fieldi** *Monomorium sp. C (laeve gp.)*** *Paratrechina sp. B (vaga gp.)** *Pheidole impressiceps*** *Tapinoma sp. A** *Tapinoma sp. B****	*Rhytidoponera sp. B (metallica gp.)** *Tapinoma sp. A****	*(Iridomyrmex sp. A (rufoniger gp.))* *Monomorium sp. G (laeve gp.)**
Intermediate / Decreaser	*Rhytidoponera sp. E (tenuis gp.)**	*Iridomyrmex sanguineus** *Leptogenys adlerzi** *Meranoplus ?pubescens** *Odontomachus spA (ruficeps gp.)**	*Camponotus sp. A (novaehollandiae gp.)** *Cardiocondyla sp. A (nuda gp.)** *Iridomyrmex sp. D (pallidus gp.)** *Pheidole sp. A (Group E)**	-	*Rhytidoponera ?convexa**
Extreme / Decreaser	-	-	-	*Iridomyrmex sp. A (anceps gp.)** *Melophorus sp. A (aeneovirens gp.)** *Melophorus sp. J (Group F)**	-
Extreme	*Melophorus sp. AA (pillipes gp.)* *	-	*Rhytidoponera sp. B (metallica gp.)**	*(Monomorium sp. B (laeve gp.))* *(Monomorium sp. F (laeve gp.))* *Paratrechina sp. A (obscura gp.)** *Pheidole impressiceps**	*Pheidole sp. C (Group D)**
Neutral	*(Camponotus sp. E (denticulatus gp.))* *(Camponotus sp. F (rubiginosus gp.))* *Calomyrmex ?splendidus* *Camponotus fieldae*	*Camponotus Kak9 (novaehollandiae gp.)* *Camponotus spA (nigroaeneus gp.)* *Camponotus spC (discors gp.)* *Cardiocondyla spA (nuda gp.)*	*Bothroponera sp. A (sublaevis gp.)* *Camponotus dromas* *Camponotus fieldae* *Camponotus sp. E (novaehollandiae gp.)*	*Camponotus fieldae* *Camponotus sp. A (novaehollandiae gp.)* *Camponotus sp. B (denticulatus gp.)* *Camponotus sp. E*	*Camponotus dromas* *Camponotus fieldae* *Camponotus sp. A (novaehollandiae gp.)* *Iridomyrmex ?septentrionalis* *Iridomyrmex sanguineus*

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
	Camponotus sp. A (novaehollandiae gp.) Camponotus sp. C (discors gp.) Cardiocondyla sp. A (nuda gp.) Iridomyrmex sp. F Iridomyrmex sp. H (cyaneus gp.) Melophorus sp. D (Group F) Melophorus sp. E (aeneovirens gp.) Melophorus sp. FF Melophorus sp. G (Group A) Melophorus sp. P (mjobergi gp.) Melophorus sp. V (froggatti gp.) Meranoplus ?pubescens Monomorium sp. B (laeve gp.) (Monomorium fieldi) Monomorium sp. G (carinatum gp.) Monomorium sp. J (laeve gp.) Odontomachus sp. B (ruficeps gp.) Opisthopsis haddoni Polyrhachis prometheus Polyrhachis senilis Polyrhachis sp. F (appendiculata gp.) Rhytidoponera borealis (Rhytidoponera sp. D (convexa gp.)) Rhytidoponera reticulata Tapinoma sp. A (minutum gp.)	*Cerapachys clarki Crematogaster queenslandica Doleromyrma spA Iridomyrmex spE (gracilis gp.) Melophorus spA (Group F) Melophorus spC (Group A) Melophorus spD (mjobergi gp.) Melophorus spE (mjobergi gp.) Meranoplus spA (diversus gp.) Meranoplus spD Monomorium ?fieldi Monomorium anderseni Monomorium Ka24 (laeve gp.) Monomorium spE (rothsteini gp.) Monomorium spF (rothsteini gp.) Pheidole impressiceps Pheidole spC (Group D) Tapinoma spA Tetramorium spB (striolatum gp.)*	*Camponotus sp. H (discors gp.) Crematogaster sp. A (laeviceps gp.) Iridomyrmex pallidus Iridomyrmex sanguineus Iridomyrmex septentrionalis Iridomyrmex spadius Leptogenys adlerzi Leptogenys cornigera Melophorus sp. A (aeneovirens gp.) Melophorus sp. B (froggatti gp.) Melophorus sp. C (mjobergi gp.) Melophorus sp. F Melophorus sp. G Melophorus sp. J (Group F) Melophorus sp. K (Group D) Melophorus sp. M Melophorus sp. N (bruneus gp.) Meranoplus ?pubescens Meranoplus sp. C (diversus gp.) Monomorium sp. B (laeve gp.) Monomorium sp. D (rothsteini gp.) Monomorium sp. G (nigrium gp.) Monomoruim sp. E (sordidum gp.) Notoncus sp. A (enormis gp.) Odontomachus sp. B (ruficeps gp.) Odontomachus turneri Opisthopsis haddoni Paratrechina prometheus Paratrechina sParatrechina nr. Inconspicua Pheidole sp. B (Group E) Pheidole sp. G (Group A) Polyrhachis sp. E (gab gp.) Rhytidoponera lamellinodis Rhytidoponera sp. D (spoliata gp.) Tetramorium sp. A (striolatum gp.)*	*(novaehollandiae gp.) Camponotus sp. H (discors gp.) Cardiocondyla sp. A (nuda gp.) Crematogaster sp. A (laeviceps gp.) Iridomyrmex septentrionalis (Iridomyrmex sp. H (mattirolia Iridomyrmex sp. I (suchieri gp.) Iridomyrmex sp. K (pallidus gp.) Iridomyrmex spadius Leptogenys adlerzi (Leptogenys cornigera) Leptogenys exigua Melophorus sp. B (froggatti gp.) Melophorus sp. C (mjobergi gp.) Melophorus sp. E (wheeleri gp.) Melophorus sp. F Melophorus sp. G (Melophorus sp. H (mjobergi gp.))Melophorus sp. M Melophorus sp. N (bruneus gp.) Melophorus sp. P (froggatti gp.) Meranoplus ?pubescens (Monomorium fieldi (Monomorium sp. B (laeve gp.) Monomorium sp. D (rothsteini gp.) Notoncus sp. A (enormis gp.) Odontomachus turneri Opisthopsis haddoni Paratrechina prometheus Paratrechina sp. B (vaga gp.) Paratrechina sParatrechina nr. Inconspicua Pheidole sp. B (Group E) Pheidole sp. F (longiceps gp.) Pheidole sp. G (Group A) Rhytidoponera ?convexa (Rhytidoponera sp. C (convexa gp.)) Rhytidoponera sp. D (spoliata gp.) (Rhytidoponera lamellinodis Tapinoma sp. B Tetramorium sp. A (striolatum gp.)*	*Iridomyrmex sp. B (rufoniger gp.) Iridomyrmex sp. D (anceps gp.) (Iridomyrmex sp. F (mattiroloi gp.)) Iridomyrmex spadius Leptogenys cornigera Melophorus sp. I (Group A) Melophorus sp. K (wheeleri gp.) Melophorus sp. N (bruneus gp.) Meranoplus sp. F (diversus gp.) Monomorium ?fieldi Paratrechina sp. B (obscura gp.) Pheidole sp. F (variabilis gp.) Pheidole sp. G (Group C) Polyrhachis senilis Rhytidoponera ?hilli Rhytidoponera lamellinodis Solenopsis sp. A Tetramorium sp. H (striolatum gp.)*

Table 17. Summary of responses of **individual ant species** to condition class. Table structure as per Table 14.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*56*	*37*	*63*	*64*	*33*
responses analysed	*66*	*37*	*63*	*73*	*38*
Increaser	19 28.8%	2 5.4%	2 3.2%	10 13.7%	6 15.8%
Intermediate / Increaser	3 4.5%	0 -	3 4.8%	0 -	2 5.3%
Extreme / Increaser	0 -	0 -	3 4.8%	4 5.5%	1 2.6%
Intermediate	3 4.5%	1 2.7%	0 -	5 6.8%	2 5.3%
Decreaser	10 15.2%	7 18.9%	11 17.5%	2 2.7%	2 5.3%
Intermediate / Decreaser	1 1.5%	4 10.8%	4 6.3%	0 -	1 2.6%
Extreme / Decreaser	0 -	0 -	0 -	3 4.1%	0 -
Extreme	1 1.5%	0 -	1 1.6%	4 5.5%	1 2.6%
Neutral	28 42.4%	23 62.2%	39 61.9%	41 56.2%	23 60.5%

Table 18. Condensed summary of responses of **individual ant species** to condition class. Table structure as per Table 15.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*56*	*37*	*63*	*64*	*33*
responses analysed	*66*	*37*	*63*	*73*	*38*
Increaser	33.3%	5.4%	12.8%	19.2%	23.7%
Intermediate	4.5%	2.7%	-	6.8%	5.3%
Decreaser	16.7%	29.7%	23.8%	6.8%	7.9%
Extreme	1.5%	-	1.6%	5.5%	2.6%
Neutral	42.4%	62.2%	61.9%	56.2%	60.5%

Table 19. Distribution of response types amongst **ant functional groups**. Only coarse response types are used. Some species may have more than one response type across all (sub-)landtypes.

Guild	species	No. of responses			
		Decreaser	Increaser	Intermediate	Extreme
Cold Climate Specialist	*1*	0	0	0	0
Cryptic	*1*	0	1	0	0
Dominant Dolichoderinae	*27*	10	10	4	1
Generalised Myrmicinae	*35*	6	7	1	1
Hot Climate Specialist	*46*	8	14	1	1
Opportunist	*29*	5	5	2	2
Subordinate Camponotini	*26*	8	8	2	2
Specialist Predator	*9*	4	4	1	0

Table 20. Response (to condition class) of **individual bird species** in each landtype. Table structure as per Table 13.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*32*	*34*	*64*	*59*	*43*
Increaser	black-faced woodswallow* galah* crested pigeon*** (mistletoebird) (white-bellied cuckoo-shrike) (yellow-throated miner)	australian hobby* budgerigar* crested pigeon* galah* magpie-lark* peaceful dove* pied butcherbird* singing honeyeater* yellow-throated miner*	australian magpie* cockatiel** yellow-throated miner***	(apostlebird) (grey-crowned babbler) (little friarbird) (magpie-lark) mistletoebird* (noisy friarbird) (olive-backed oriole) pallid cuckoo* rainbow lorikeet* white-winged triller*	(apostlebird) (double-barred finch) magpie-lark* (striated pardalote) yellow-throated miner* (weebill)
Intermediate / Increaser	-	brown quail* masked woodswallow*	black-faced cuckoo-shrike*	australian magpie*** black-faced cuckoo-shrike** (grey-crowned babbler)	-
Extreme / Increaser	-	black-faced woodswallow*	-	(forest kingfisher)	(apostlebird)
Intermediate	black-faced cuckoo-shrike* (red-backed fairy-wren) (rufous whistler) (willie wagtail) (yellow-throated miner)	-	blue-winged kookaburra**	(apostlebird) Australian owlet-nightjar** Australian raven*** blue-faced honeyeater* crested pigeon* emu* galah** grey butcherbird*** grey fantail*** (magpie-lark) peaceful dove*** pied butcherbird*** (rufous whistler) striated pardalote*** Torresian crow*** wedge-tailed eagle* weebill*** white-throated gerygone* yellow-throated miner**	-

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*32*	*34*	*64*	*59*	*43*
Decreaser	banded honeyeater* black-tailed treecreeper* grey-fronted honeyeater* (little friarbird) (red-backed fairy-wren) singing honeyeater* (white-bellied cuckoo-shrike)	brown songlark* brown falcon* singing bushlark**	grey butcherbird** horsfield's bronze-cuckoo* noisy miner*** pale-headed rosella* pheasant coucal* red-winged parrot* rufous whistler* white-winged triller* willie wagtail (northern)*	(forest kingfisher) (rufous whistler) (white-bellied cuckoo-shrike)	brown falcon* (double-barred finch) (grey-crowned babbler) variegated fairy-wren*
Intermediate / Decreaser	rufous-throated honeyeater*	-	rainbow lorikeet* red-backed fairy-wren* rufous songlark*	pale-headed rosella* red-backed fairy-wren**	-
Extreme / Decreaser	brown honeyeater*	-	pied currawong*	-	(grey-crowned babbler)
Extreme	-	pictorella mannikin*	-	channel-billed cuckoo* (little friarbird)	(striated pardalote)
Neutral	australian owlet-nightjar diamond dove great bowerbird grey shrike-thrush grey-crowned babbler (little friarbird) (mistletoebird) peaceful dove pied butcherbird rainbow bee-eater red-backed kingfisher restless flycatcher (rufous whistler) singing bushlark torresian crow varied sittella (willie wagtail) white-winged triller yellow-tinted honeyeater	australian bustard black-faced cuckoo-shrike brown honeyeater diamond dove golden-headed cisticola masked lapwing red-backed fairy-wren red-backed kingfisher red-chested button-quail restless flycatcher rufous songlark rufous-throated honeyeater torresian crow tree martin weebill white-winged triller willie wagtail zebra finch	apostlebird australian bustard australian owlet-nightjar australian raven barn owl blue-faced honeyeater black-faced woodswallow brown falcon brown songlark brown treecreeper channel-billed cuckoo common bronzewing crested pigeon emu forest kingfisher galah golden-headed cisticola grey-crowned babbler great bowerbird jacky winter laughing kookaburra	australian bustard blue-winged kookaburra brown falcon brown songlark brown treecreeper common bronzewing double-barred finch great bowerbird Horsfield's bronze-cuckoo jacky winter laughing kookaburra little bronze-cuckoo nankeen kestrel (noisy friarbird) noisy miner (olive-backed oriole) pheasant coucal pied currawong red-backed kingfisher red-tailed black-cockatoo red-winged parrot	australian magpie australian owlet-nightjar barn owl black-faced cuckoo-shrike blue-faced honeyeater black-faced woodswallow blue-winged kookaburra brown treecreeper cockatiel common bronzewing crow spp crested pigeon emu galah great bowerbird grey butcherbird jacky winter little friarbird nankeen kestrel pale-headed rosella pallid cuckoo

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*32*	*34*	*64*	*59*	*43*
			little bronze-cuckoo little friarbird magpie-lark mistletoebird nankeen kestrel noisy friarbird olive-backed oriole pallid cuckoo peaceful dove pied butcherbird red-backed kingfisher red-tailed black-cockatoo singing bushlark southern boobook striated pardalote tawny frogmouth Torresian crow varied sittella weebill western gerygone wedge-tailed eagle white-bellied cuckoo-shrike white-throated gerygone white-throated honeyeater zebra finch	rufous songlark southern boobook tawny frogmouth varied sittella (white-bellied cuckoo-shrike) white-throated honeyeater willie wagtail (northern)	peaceful dove pied butcherbird rainbow lorikeet red-backed fairy-wren red-backed kingfisher rufous songlark rufous whistler singing honeyeater tawny frogmouth (weebill) wedge-tailed eagle white-throated gerygone willie wagtail (northern) zebra finch

Table 21. Summary of responses of **individual bird species** to condition class. Table structure as per Table 21.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*32*	*34*	*64*	*59*	*43*
responses analysed	*39*	*34*	*64*	*68*	*48*
Increaser	6 15.4%	9 *26.5%*	3 *4.7%*	10 *14.7%*	6 *12.5%*
Intermediate / Increaser	-	2 *5.9%*	1 *1.6%*	3 *4.4%*	-
Extreme / Increaser	-	1 *2.9%*	-	1 *1.5%*	1 *2.1%*
Intermediate	5 12.8%		1 *1.6%*	19 *27.9%*	
Decreaser	7 17.9%	3 *8.8%*	9 *14.1%*	3 *4.4%*	4 *8.3%*
Intermediate / Decreaser	1 2.6%	-	3 *4.7%*	2 *2.9%*	
Extreme / Decreaser	1 2.6%	-	1 *1.6%*	-	1 *2.1%*
Extreme	-	1 *2.9%*	-	2 *2.9%*	1 *2.1%*
Neutral	18 46.2%	18 *5.3%*	46 71.9%	28 *41.2%*	35 *72.9%*

Table 22. Condensed summary of responses of **individual bird species** to condition class. Table structure as per Table 22.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*32*	*34*	*64*	*59*	*43*
responses analysed	*39*	*34*	*64*	*68*	*48*
Increaser	15.4%	35.3%	6.3%	20.6%	14.6%
Intermediate	12.8%		1.6%	27.9%	-
Decreaser	23.1%	8.8%	20.4%	7.3%	10.4%
Extreme	-	2.9%	-	2.9%	2.1%
Neutral	46.2%	52.9%	71.9%	41.2%	72.9%

Table 23. Distribution of response types amongst **bird guilds**. Only coarse response types are used. Some species may have shown more than one response type across all (sub-)landtypes.

Guild	**species**	**No. of responses**			
		Decreaser	**Increaser**	**Intermediate**	**Extreme**
aerial insectivore	*9*	1	2	3	-
foliage insectivore / nectarivore	*12*	7	4	2	1
Frugivore	*2*	-	1	-	-
foliage/trunk insectivore	*17*	5	7	5	2
ground insectivore / omnivore	*5*	1	2	2	-
granivore	*15*	3	7	3	1
ground insectivore	*9*	6	2	2	-
nectarivore	*1*	1	1	-	-
raptor	*17*	4	3	6	-

Table 24. Response (to condition class) of **individual reptile species** in each landtype. Table structure as per Table 13.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*10*	*12*	*19*	*20*	*12*
Increaser	-	*Demansia torquata** *Proablepharus kinghorni**	*Gehyra dubia** *Heteronotia binoei**	*Carlia foliorum** *(Morethia taeniopleura)* *(Oedura rhombifer)*	*(Cryptoblepharus sp)*
Intermediate / Increaser	-	-	-	*(Gehyra dubia)* *Heteronotia binoei**	-
Extreme / Increaser	-	*Tympanocryptis lineata**	-	*(Ctenotus spaldingi)* *(Morethia taeniopleura)*	-
Intermediate	*Menetia greyii**	*Proablepharus tenuis**	-	*(Gehyra dubia)* *Carlia schmeltzii** *Oedura castelnaui**	*(Menetia greyii)*
Decreaser	*Carlia munda** *Ctenotus spaldingi*** *Diporiphora bilineata**	*Rattus villosissimus**	*Oedura castelnaui**	*Carlia munda** *Cryptoblepharus virgatus** *(Ctenotus spaldingi)* *Diporiphora australis***	*(Cryptoblepharus sp)*
Intermediate / Decreaser	*Proablepharus tenuis**	-	*Cryptoblepharus virgatus**	-	*Carlia munda**
Extreme / Decreaser	-	-	-	-	-
Extreme	-	-	-	-	-
Neutral	*Cryptoblepharus plagiocephalus* *Diporiphora magna* *Heteronotia binoei* *Lophognathus gilberti* *Menetia maini*	*Cryptoblepharus plagiocephalus* *Ctenotus rimacola* *Delma tincta* *Diplodactylus stenodactylus* *Heteronotia binoei* *Menetia maini* *Ramphotyphlops sp.* *Varanus storri*	*Carlia foliorum* *Carlia munda* *Carlia schmeltzii* *Carlia vivax* *Cryptoblepharus plagiocephalus* *Ctenotus robustus* *Ctenotus taeniolatus* *Diplodactylus steindachneri* *Diporiphora australis* *Egernia striolata*	*Carlia vivax* *Cryptoblepharus plagiocephalus* *Ctenotus robustus* *Ctenotus strauchii* *Diplodactylus steindachneri* *Egernia striolata* *Menetia greyii* *(Oedura rhombifer)* *Proablepharus tenuis* *Varanus tristis*	*Amphibolurus nobbi nobbi* *Ctenotus robustus* *Ctenotus strauchii* *Gehyra dubia* *Heteronotia binoei* *(Menetia greyii)* *Morethia taeniopleura* *Oedura castelnaui* *Proablepharus tenuis* *Varanus tristis*

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
			Menetia greyii *Morethia taeniopleura* *Oedura rhombifer* *Proablepharus tenuis* *Varanus tristis*		

Table 25. Summary of responses of **individual reptile species** to condition class. Table structure as per Table 14.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*10*	*12*	*19*	*20*	*12*
responses analysed	*10*	*12*	*19*	*24*	*14*
Increaser	-	2 *16.7%*	2 *10.5%*	3 *12.5%*	1 *7.1%*
Intermediate / Increaser	-	-	-	2 *8.3%*	-
Extreme / Increaser	-	1 *8.3%*	-	2 *8.3%*	-
Intermediate	1 *10%*	1 *8.3%*	-	3 *12.5%*	1 *7.1%*
Decreaser	3 *30%*	-	1 *5.3%*	4 *16.7%*	1 *7.1%*
Intermediate / Decreaser	1 *10%*	-	1 *5.3%*	-	1 *7.1%*
Extreme / Decreaser	-	-	-	-	-
Extreme	-	-	-	-	-
Neutral	5 *50%*	8 *66.7%*	15 *78.9%*	10 *41.7%*	10 *71.4%*

Table 26. Condensed summary of responses of **individual reptile species** to condition class. Table structure as per Table 15.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*10*	*12*	*19*	*20*	*12*
responses analysed	*10*	*12*	*19*	*24*	*14*
Increaser	-	25.0%	10.5%	29.1%	7.1%
Intermediate	10%	8.3%	-	12.5%	7.1%
Decreaser	40%	-	10.6%	16.7%	14.2%
Extreme	-	-	-	-	-
Neutral	50%	66.7%	78.9%	41.7%	71.4%

Table 27. Response (to condition class) of **individual mammal species** in each landtype. Table structure as per Table 13.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*3*	*5*	*5*	*4*	*4*
Increaser	-	-	-	-	-
Intermediate / Increaser	-	-	-	-	-
Extreme / Increaser	-	-	-	-	-
Intermediate	-	-	-	*Aepyprymnus rufescens**	*Aepyprymnus rufescens**
Decreaser	*Pseudomys nanus***	*Sminthopsis macroura** *Rattus villosissimus**	*Macropus giganteus**	-	-
Intermediate / Decreaser	-	-	-	-	-
Extreme / Decreaser	-	-	-	-	-
Extreme	-	-	-	-	-
Neutral	*Macropus antilopinus* *Onychogalea unguifera*	*Planigale ingrami* *Onychogalea unguifera* *Macropus antilopinus*	*Aepyprymnus rufescens* *Leggadina lakedownensis* *Planigale maculata* *Tachyglossus aculeatus*	*Macropus giganteus* *Macropus robustus* *Planigale maculata*	*Leggadina lakedownensis* *Macropus giganteus* *Planigale maculata* *Tachyglossus aculeatus*

Table 28. Summary of responses of **individual mammal species** to condition class. Table structure as per Table 14. (Response types such as intermediate/increaser are not included as no species fell into these types).

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
species analysed	*3*	*5*	*5*	*4*	*5*
responses analysed	*3*	*5*	*5*	*4*	*5*
Increaser	-	-	-	-	-
Intermediate	-	-	-	1 *25%*	1 *20%*
Decreaser	1 33.3%	2 *20%*	1 *20%*	-	-
Extreme	-	-	-	-	-
Neutral	2 66.6%	3 *60%*	4 *80%*	3 *75%*	4 *50%*

Table 29. Strength of predictive models using continuous condition variables for **plant summary variables**. Values are the % deviance explained by the model for each response variable in each landtype. "-" indicates there was no significant model; "nm" that a variable was not measured in that landtype.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
Sites	*48*	*56*	*48*	*34*	*24*
Species richness					
All plants	16	10	7	-	-
Perennial grasses	36	9	-	19	-
Fac. perennial grasses	16	-	-	9	-
Annual grasses	-	-	9	27	29
Sedges	12	29	-	24	-
Perennial forbs	7	13	-	11	16
Annual forbs	31	17	10	-	21
Shrubs & trees	11	13	nm	nm	nm
3P plants	nm	nm	-	-	-
Species diversity					
All plants	35	19	7	-	-
Cover					
Total understorey	100	100	30	40	36
Perennial grasses	100	96	43	77	65
Fac. perennial grass	30	-	-	10	-
Annual grasses	33	54	6	-	41
Sedges	-	17	-	-	-
Perennial forbs	51	-	-	-	14
Annual forbs	51	23	26	-	39
Shrubs & trees	12	15	nm	nm	nm
3P plants	nm	nm	-	29	100
Frequency					
All plants	53	33	nm	nm	nm
Perennial grasses	78	81	8	12	-
Fac. perennial grass	41	-	-	-	-
Annual grasses	15	17	-	-	13
Sedges	-	48	-	25	-
Perennial forbs	59	-	-	-	36
Annual forbs	50	25	-	-	19
Shrubs & trees	-	7	nm	nm	nm
3P plants	nm	nm	12	30	21

Table 30. Strength of predictive models using continuous condition variables for **ant summary variables**. Values are the % deviance explained by the model for each response variable in each landtype. "-" indicates there was no significant model; "np" that a functional group was not present in that landtype.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
sites	*48*	*56*	*48*	*34*	*24*
Species richness	-	20	32	12	14
Species diversity	-	18	27	11	15
Functional group diversity	14	-	17	-	-
Total abundance	18	11	21	-	19
Functional group (richness)					
Cold Climate Specialist	np	np	-	-	-
Cryptic	12	-	-	10	-
Dominant Dolichoderinae	-	26	11	-	-
Generalised Myrmicinae	-	11	-	29	-
Hot Climate Specialist	39	33	24	-	32
Opportunist	-	5	18	-	-
Subordinate Camponotini	-	10	16	-	-
Specialist Predator	12	-	-	-	-
Tropical climate specialist	-	-	-	-	-
Functional group (abund.)					
Cold Climate Specialist	np	np	-	-	-
Cryptic	12	-	-	-	-
Dominant Dolichoderinae	-	8	7	-	-
Generalised Myrmicinae	-	9	-	21	-
Hot Climate Specialist	51	16	31	-	-
Opportunist	-	-	24	-	13
Subordinate Camponotini	-	11	14	-	-
Specialist Predator	18	-	-	-	-
Tropical climate specialist	np	-	-	-	-

Table 31. Strength of predictive models using continuous condition variables for **vertebrate summary variables**. Values are the % deviance explained by the model for each response variable in each landtype. "-" indicates there was no significant model.

	NT loam	**NT clay**	**QLD bas**	**QLD sed**	**QLD alv**
Sites	*48*	*56*	*48*	*34*	*24*
Vertebrates					
Richness	-	-	-	25	10
Diversity	-	7	-	17	15
Birds					
Richness	-	13	-	29	-
Total abundance	-	-	8	39	-
Diversity	-	12	-	9	13
Bird guilds					
aerial insectivore richness	-	9	-	-	-
abundance	-	-	-	12	-
foliage insectivore/nectarivore richness	11	8	-	-	-
abundance	13	12	-	-	-
foliage/trunk insectivore richness	-	-	11	-	-
abundance	-	16	-	29	-
granivore richness	21	11	7	26	-
abundance	15	7	8	43	-
ground insectivore richness	-	7	-	21	-
abundance	28	-	-	-	42
ground insectivore/omnivore richness	-	-	-	32	-
abundance	-	-	-	34	-
raptor richness	-	-	-	-	24
abundance	-	-	-	33	-
nectarivore richness	-	-	-	-	-
abundance	-	-	-	-	-
frugivore richness	-	-	-	-	-
abundance	-	-	-	-	-
Mammals					
Richness	-	8	7	10	-
Total abundance	-	-	9	-	-
Diversity	-	-	16	-	-
Mammals groups					
dasyurid richness	22	19	-	-	-
abundance	22	24	-	-	-
murid richness	19	18	-	-	-
abundance	20	18	-	-	-

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
macropod richness	10	-	11	-	-
abundance	11	-	10	-	-
arboreal mammal richness	-	-	7	-	-
abundance	-	-	10	-	-
Reptiles					
Richness	13	6	-	-	14
Total abundance	17	-	-	10	-
Diversity	13	6	-	-	14
Reptile groups					
varanid/agamid richness	-	-	-	-	-
abundance	39	-	-	-	-
gekkonid richness	-	-	-	-	27
abundance	-	-	11	22	18
scincid richness	23	-	-	-	26
abundance	17	8	-	-	-
serpent richness	-	-	-	16	-
abundance	-	-	-	16	-

Table 32. Summary of predictive models testing the relationship between continuous condition variables and the abundance of **individual species**. Table shows: the number of species in each major group that occurred in sufficient sites to be analysed; the proportion of analysed species for which there was a significant model (at least 5% deviance explained); the range and mean for % deviance explained (significant models only).

		NT loam	NT clay	QLD bas	QLD sed	QLD alv	total / %
Sites		*48*	*56*	*48*	*34*	*24*	*210*
Species analysed	*Plants*	*123*	*97*	*72*	*48*	*39*	*380*
	Ants	*56*	*33*	*42*	*43*	*28*	*202*
	Birds	*32*	*34*	*46*	*38*	*31*	*181*
	Reptiles	*10*	*12*	*14*	*14*	*7*	*57*
	Mammals	*3*	*5*	*2*	*3*	*3*	*16*
% Species significant	Plants	36	58	22	27	33	37.4%
	Ants	46	42	40	28	32	38.6%
	Birds	38	62	20	32	13	32.0%
	Reptiles	50	42	21	29	43	35.1%
	Mammals	67	40	50	0	0	31.3%
% deviance explained range (mean)	Plants	7-52 (18.5)	5-53 (12.5)	8-26 (13.8)	10-44 (21.0)	13-46 (29.8)	
	Ants	9-44 (20.1)	6-28 (12.7)	7-23 (12.0)	10-33 (18.2)	13-53 (24.6)	
	Birds	9-35 (15.6)	7-28 (13.0)	6-16 (10.1)	11-54 (26.4)	13-41 (26.8)	
	Reptiles	9-47 (22.5)	8-25 (17.6)	9-20 (13.0)	10-21 (13.8)	13-22 (16.7)	
	Mammals	14-24 (19.0)	18-24 (21.4)	- (11.0)	-	-	

Table 34. Summary of significant terms in predictive models testing the relationship between continuous condition variables and **biodiversity summary variables**. Table shows the number of models for each major group that were analysed, and the number of models in which each of the three condition variables was a significant term. Positive and negative parameter estimates are distinguished (eg. bare ground cover was a significant term in 4 models for plant summary variables in NT loam sites and had a positive effect in 3 of these and a negative effect in 1).

		NT loam	**NT clay**	**QLD bas**	**QLD sed**	**QLD alv**	**total**	**%**
Sites		*48*	*56*	*48*	*34*	*24*	*210*	
Models tested	*Plants*	*52*	*41*	*39*	*39*	*39*	*210*	
	Ants	*25*	*28*	*24*	*24*	*24*	*125*	
	Birds	*27*	*26*	*27*	*27*	*27*	*134*	
	Reptiles	*9*	*11*	*12*	*12*	*12*	*56*	
	Mammals	*9*	*9*	*14*	*14*	*14*	*60*	
bare ground cover	Plants	1/3	14/1	4/0	4/4	8/0	31/8	19.5
	Ants	0/2	9/0	11/1	0/5	0/0	20/8	22.4
	Birds	0/0	0/0	1/0	13/0	0/0	14/0	10.4
	Reptiles	0/5	0/0	0/0	2/0	0/1	2/6	14.3
	Mammals	2/2	1/0	5/0	0/1	0/0	8/3	18.3
total understorey cover	Plants	14/8	4/5	1/1	3/5	6/0	28/19	22.4
	Ants	4/2	6/0	1/1	0/0	0/0	11/3	11.2
	Birds	4/1	0/0	0/1	7/0	1/0	12/2	10.4
	Reptiles	1/0	3/0	1/0	0/0	0/4	5/4	16.1
	Mammals	0/2	0/0	0/1	0/0	0/0	0/3	5.0
perennial grass cover (NT) 3P plant cover (QLD)	Plants	10/22	7/5	3/2	3/2	5/6	28/37	31.0
	Ants	0/7	4/2	3/1	0/0	0/5	7/15	17.6
	Birds	1/1	0/9	1/1	0/1	2/0	4/12	11.9
	Reptiles	0/1	0/0	0/0	2/0	1/1	3/2	8.9
	Mammals	2/0	4/0	5/0	0/0	0/0	11/0	18.3

Table 35. As per Table 34 above, but testing the relative value as a predictor of three variables for perennial grass: cover, perennial and basal area. Frequency data was only tested in NT sites, and basal area was only recorded for NT clay sites.

		NT loam	NT clay	total / %
Sites		*48*	*56*	
Models tested	*Plants*	*52*	*41*	*93*
	Ants	*25*	*28*	*53*
	Birds	*27*	*26*	*53*
	Reptiles	*9*	*11*	*20*
	Mammals	*9*	*9*	*18*
perennial grass cover	Plants	7/22	4/3	38.7%
	Ants	0/3	1/2	11.3%
	Birds	1/0	0/4	9.4%
	Reptiles	0/3	1/0	20.0%
	Mammals	4/0	2/0	33.3%
perennial grass frequency	Plants	5/3	0/2	10.8%
	Ants	0/4	2/0	11.3%
	Birds	0/2	0/12	26.4%
	Reptiles	2/0	0/1	15.0%
	Mammals	0/2	3/2	38.9%
perennial grass basal area	Plants		8/2	24.3%
	Ants		3/0	10.7%
	Birds		8/0	30.8%
	Reptiles		0/0	0%
	Mammals		0/0	0%

Table 36. Summary of significant terms in predictive models testing the relationship between continuous condition variables and **abundance of individual species**. Table shows the number of models for each major group that were analysed, and the number of models in which each of the three condition variables was a significant term. Positive and negative parameter estimates are distinguished (eg. bare ground cover was a significant term in models for 10 plant species in NT loam sites and had a positive effect in 7 of these and a negative effect in 3).

		NT loam	**NT clay**	**QLD bas**	**QLD sed**	**QLD alv**	**total**	**%**
Sites		*48*	*56*	*48*	*34*	*24*	*210*	
Models tested	*Plants*	*123*	*98*	*72*	*48*	*39*	*380*	
	Ants	*56*	*33*	*42*	*43*	*28*	*202*	
	Birds	*32*	*34*	*46*	*38*	*31*	*181*	
	Reptiles	*10*	*12*	*14*	*14*	*7*	*57*	
	Mammals	*3*	*5*	*2*	*3*	*3*	*16*	
bare ground cover	Plants	7/3	21/3	5/2	4/3	7/2	44/13	15.0
	Ants	1/8	3/3	10/2	1/7	0/2	15/22	18.3
	Birds	2/1	4/1	2/0	9/0	1/1	18/3	8.6
	Reptiles	0/1	2/1	0/0	3/0	1/0	6/2	14.0
	Mammals	0/1	1/0	0/0	0/0	0/0	1/1	12.5
total understorey cover	Plants	14/6	10/9	2/2	2/2	4/1	32/20	13.7
	Ants	5/10	3/2	2/4	1/3	0/3	11/22	16.3
	Birds	4/2	1/1	0/3	8/1	2/0	15/7	12.2
	Reptiles	1/2	1/0	2/1	1/0	1/1	6/4	17.5
	Mammals	0/1	0/0	0/0	0/0	0/0	0/1	6.3
perennial grass cover (NT) 3P plant cover (QLD)	Plants	15/20	15/8	3/6	3/2	4/2	40/38	20.5
	Ants	3/8	4/3	3/3	2/3	2/5	17/22	19.3
	Birds	5/3	2/2	2/3	0/1	1/1	10/10	11.0
	Reptiles	1/2	0/0	1/0	0/0	0/1	2/3	8.8
	Mammals	1/0	2/0	1/0	0/0	0/0	4/0	25.0

Table 37. As per Table 36 above, but testing the relative value as a predictor of three variables for perennial grass: cover, perennial and basal area. Frequency data was only tested in NT sites, and basal area was only recorded for NT clay sites.

		NT loam	NT clay	total / %
	Sites	*48*	*56*	
Models tested	*Plants*	*123*	*98*	*221*
	Ants	*56*	*33*	*89*
	Birds	*32*	*34*	*66*
	Reptiles	*10*	*12*	*22*
	Mammals	*3*	*5*	*8*
perennial grass cover (NT)	Plants	5/15	5/9	15.4%
	Ants	5/5	2/1	14.6%
	Birds	5/3	0/8	24.2%
	Reptiles	0/2	1/0	13.6%
	Mammals	1/0	1/0	25%
perennial grass frequency	Plants	4/15	13/7	17.6%
	Ants	3/9	2/1	16.9%
	Birds	0/1	2/6	13.6%
	Reptiles	3/1	1/2	31.8%
	Mammals	0/0	1/1	25%
perennial grass basal area	Plants		11/5	16.0%
	Ants		2/0	6.1%
	Birds		11/0	32.4%
	Reptiles		1/0	8.3%
	Mammals		0/0	0%

Table 38 (next page). Correlation of condition and habitat variables with ordination of sites by species composition (vector-fitting), for each major group in each landtype (NL = NT loam; NC = NT clay, QB = QLD basalt, QS = QLD sedimentary, QA = QLD alluvial). Correlation coefficients in bold are significant ($p<0.05$). Some variables were either not measured in every landscape, not tested in this analysis, or are not meaningful for that landtype (eg. there were no termite mounds in NT clay sites, or no trees >10m in NT sites).

	Plants					Ants					Birds					Reptiles & Mammals				
	NL	**NC**	**QB**	**QS**	**QA**	**NL**	**NC**	**QB**	**QS**	**QA**	**NL**	**NC**	**QB**	**QS**	**QA**	**NL**	**NC**	**QB**	**QS**	**QA**
"Condition variables"																				
Soil cover	**0.28**	**0.45**	0.09	**0.27**	**0.51**	**0.21**	0.10	0.08	**0.38**	**0.30**	**0.19**	0.04	0.07	**0.30**	0.05	0.14	**0.31**	0.09	0.09	**0.17**
Ground cover	**0.27**	0.13	0.05	0.05	0.04	**0.31**	0.00	0.09	0.15	0.05	**0.25**	0.08	0.04	0.08	**0.29**	0.07	0.13	0.05	0.10	0.07
Perennial grass cover	**0.30**	**0.20**	0.08	**0.21**	**0.33**	**0.30**	0.14	0.04	**0.26**	**0.41**	0.06	**0.19**	0.12	0.08	**0.17**	0.01	0.08	0.08	**0.17**	0.08
Per. grass frequency	**0.33**	**0.40**				**0.43**	**0.26**				0.03	**0.29**				0.07	0.07			
Per. grass basal area		**0.24**					0.15					0.11					0.01			
"Habitat variables"																				
Rock cover	**0.24**	0.04	0.02	**0.29**	**0.37**	0.14	0.03	**0.15**	**0.15**	0.12	0.09	0.09	0.03	**0.34**	0.11	0.12	0.09	0.02	0.12	0.14
Litter cover	**0.15**	**0.37**	0.08	**0.40**	**0.39**	**0.24**	**0.18**	**0.27**	**0.39**	**0.42**	**0.18**	0.04	0.15	**0.21**	**0.26**	0.06	**0.31**	0.08	0.05	**0.70**
Canopy height	0.12		**0.43**	**0.34**	0.10	0.10		**0.59**	**0.21**	0.06	**0.11**		**0.60**	0.04	**0.40**	**0.17**		**0.43**	**0.27**	0.13
Foliage cover >10m			**0.49**	**0.23**	**0.15**			**0.54**	**0.23**	0.01			**0.56**	0.11	**0.18**			**0.49**	0.11	0.05
Foliage cover 5-10m	**0.54**	**0.15**	0.04	0.10	**0.27**	**0.38**	0.05	0.20	0.05	**0.37**	0.11	0.08	**0.18**	0.14	0.15	**0.23**	0.01	0.04	**0.17**	0.15
Foliage cover 3-5m	**0.18**	**0.15**	0.01	**0.38**	0.13	**0.46**	0.05	0.03	**0.19**	**0.26**	0.02	0.08	0.16	**0.27**	0.15	0.05	0.01	0.01	**0.21**	0.05
Foliage cover 1-3m	0.11	0.05	0.10	**0.31**	**0.68**	**0.31**	0.06	0.09	**0.21**	**0.51**	**0.15**	0.08	0.13	**0.26**	**0.41**	0.02	0.06	0.10	**0.27**	**0.41**
Shrub cover	**0.31**	0.01	0.00	**0.37**	**0.37**	**0.26**	0.02	0.00	**0.18**	**0.37**	**0.22**	0.01	0.00	0.08	**0.35**	0.16	0.06	0.00	0.03	**0.37**
Dead basal area	**0.22**		0.12	0.07	0.08	0.03		0.05	0.05	0.07	0.04		**0.44**	0.15	0.02	0.15		0.12	0.07	**0.20**
Live basal area	**0.52**		**0.47**	0.08	0.04	**0.48**		**0.48**	**0.15**	**0.20**	**0.23**		**0.53**	0.08	0.10	**0.21**		**0.47**	**0.30**	0.17
Total basal area	**0.51**		**0.39**	**0.20**	0.01	**0.45**		**0.45**	**0.20**	**0.18**	**0.19**		**0.40**	**0.18**	0.05	**0.22**		**0.39**	**0.24**	0.17
No. of fallen logs	**0.17**		0.05	**0.32**	0.05	0.13		**0.17**	0.13	**0.19**	0.03		**0.35**	0.12	0.04	0.13		0.05	**0.18**	0.01
Termite mound - no.	**0.25**		0.06	0.13	**0.65**	0.10		0.10	0.04	**0.37**	**0.16**		**0.31**	0.15	0.08	**0.29**		0.06	0.05	**0.51**
Termite mnd - height			0.08	**0.22**	0.04			**0.28**	0.05	**0.30**			**0.51**	0.03	0.01			0.08	0.04	0.11
Dung score	0.14		0.08	0.05	0.12	**0.20**		**0.36**	**0.16**	**0.19**	0.05		**0.41**	0.10	**0.22**	0.12		0.08	0.10	0.15
Track score	0.14		0.03	0.08	0.07	0.11		0.10	0.07	0.04	0.04		0.16	0.07	**0.32**	0.02		0.03	0.08	0.06
Grazing score	**0.18**		0.01	0.06	**0.25**	**0.13**		0.11	0.03	0.06	0.13		**0.20**	0.03	**0.50**	0.12		0.01	0.06	**0.22**
Cattle use index	0.15	**0.42**				**0.20**	0.04				0.07	**0.21**				0.06	0.09			
Distance to waterpoint	**0.73**	0.04				**0.61**	**0.24**				**0.48**	0.05				0.15	0.12			
Distance to creek	**0.28**					**0.22**					**0.16**					**0.44**				

Table 39. Habitat variables selected for use in predictive models for biodiversity summary variables and individual species abundance, for each major group in each landtype (NL = NT loam; NC = NT clay, QB = QLD basalt, QS = QLD sedimentary, QA = QLD alluvial).

	Plants					Ants					Birds					Reptiles & Mammals				
	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA
Rock cover					✓									✓			✓			
Litter cover		✓	✓	✓	✓		✓	✓	✓	✓		✓			✓			✓		✓
Canopy height				✓											✓				✓	
Foliage cover >10m			✓					✓	✓				✓					✓		
Foliage cover 5-10m		✓			✓		✓			✓		✓				✓	✓			
Foliage cover 3-5m	✓			✓		✓								✓					✓	
Foliage cover 1-3m					✓					✓				✓	✓			✓	✓	
Shrub cover				✓					✓		✓									
Dead basal area			✓										✓	✓				✓		✓
Live basal area	✓					✓					✓								✓	
Total basal area																				
No. of fallen logs																				
Termite mound - no.																✓				✓
Termite mnd - height								✓		✓			✓							
Dung score			✓					✓	✓				✓							
Track score																				
Grazing score															✓					✓
Cattle use index		✓										✓					✓			
Distance to waterpoint	✓					✓	✓				✓									
Distance to creek																✓				

Table 40. Strength of predictive models using continuous condition variables AND other habitat variables for **plant summary variables**. Values are the % deviance explained by the model for each response variable in each landtype; the first value is for a model using only condition variables (as Table 40-42); the second value is for a model that also includes other habitat variables. If there was no improvement to the model from including habitat variables, then only the first result is shown. "-" indicates there was no significant model; "nm" that a variable was not measured in that landtype.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
Sites	*48*	*56*	*48*	*34*	*24*
Species richness					
All plants	16	10 / 27	7 / 57	- / 12	-
Perennial grasses	36 / 53	9	- / 48	19	- / 20
Fac. perennial grasses	16	-	-	9	-
Annual grasses	-	-	9 / 48	27	29
Sedges	12 / 16	29	- / 49	24	-
Perennial forbs	7	13 / 31	- / 37	11 / 27	16 / 17
Annual forbs	31	17 / 31	10 / 41	- / 27	21
Shrubs & trees	11 / 32	13 / 31	nm	nm	nm
3P plants	nm	nm	- / 38	-	- / 21
Species diversity					
All plants	35	19 / 28	7 / 30	-	-
Cover					
Total understorey	100	100	30 / 61	40	36 / 65
Perennial grasses	100	96	43 / 61	77	65 / 77
Fac. perennial grass	30	- / 52	-	10	-
Annual grasses	33	54	6	-	41 / 67
Sedges	-	17	- / 33	-	-
Perennial forbs	51	-	-	- / 15	14 / 32
Annual forbs	51	23 / 30	26 / 38	- / 12	39
Shrubs & trees	12	15 / 39	nm	nm	nm
3P plants	nm	nm	-	29	100
Frequency					
All plants	53	33 / 34	nm	nm	nm
Perennial grasses	78 / 86	81	8 / 16	12 / 22	-
Fac. perennial grass	41	-	-	- / 13	-
Annual grasses	15	17	- / 25	-	13 / 24
Sedges	-	48	- / 38	25	-
Perennial forbs	59	-	- / 9	- / 15	36 / 52
Annual forbs	50	25 / 30	- / 9	- / 12	19
Shrubs & trees	- / 14	7 / 28	nm	nm	nm
3P plants	nm	nm	12 / 27	30 / 39	21

Table 41. Strength of predictive models using continuous condition variables AND other habitat variables for **ant summary variables**. Values are the % deviance explained by the model for each response variable in each landtype; the first value is for a model using only condition variables (as Table 40-42); the second value is for a model that also includes other habitat variables. If there was no improvement to the model from including habitat variables, then only the first result is shown. "-" indicates there was no significant model; "np" that a functional group was not present in that landtype.

	NT loam	**NT clay**	**QLD bas**	**QLD sed**	**QLD alv**
sites	*48*	*56*	*48*	*34*	*24*
Species richness	- / 19	20 / 32	32 / 52	12 / 44	14
Species diversity	- / 16	18 / 39	27 / 41	11 / 29	15
Functional group diversity	14 / 23	- / 11	17 / 23	-	-
Total abundance	18 / 30	11 / 23	21	- / 40	19
Functional group (richness)					
Cold Climate Specialist	np	np	- / 29	-	-
Cryptic	12	- / 51	-	10 / 20	-
Dominant Dolichoderinae	- / 17	26	11	-	-
Generalised Myrmicinae	- / 27	11 / 25	- / 14	29 / 57	-
Hot Climate Specialist	39	33 / 55	24 / 48	- / 16	32
Opportunist	-	5	18	- / 26	-
Subordinate Camponotini	- / 15	10	16 / 30	-	-
Specialist Predator	12	-	- / 7	-	-
Tropical climate specialist	np	-	-	-	-
Functional group (abund.)					
Cold Climate Specialist	np	np	- / 21	-	-
Cryptic	12	- / 51	-	- / 10	-
Dominant Dolichoderinae	- / 28	8 / 36	7 / 19	- / 19	- / 32
Generalised Myrmicinae	-	9 / 35	- / 11	21 / 48	- / 20
Hot Climate Specialist	51	16 / 45	31	- / 32	-
Opportunist	-	-	24	-	13
Subordinate Camponotini	- / 14	11 / 19	14	-	-
Specialist Predator	18	- / 14	-	- / 11	-
Tropical climate specialist	np	-	-	-	-

Table 42. Strength of predictive models using continuous condition variables AND other habitat variables for **vertebrate summary variables**. Values are the % deviance explained by the model for each response variable in each landtype; the first value is for a model using only condition variables (as Table 40-42); the second value is for a model that also includes other habitat variables. If there was no improvement to the model from including habitat variables, then only the first result is shown. "-" indicates there was no significant model.

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
Sites	*48*	*56*	*48*	*34*	*24*
Vertebrates					
Richness	- / 8	-	-	25	10
Diversity	-	7	-	17	15
Birds					
Richness	- / 8	13	- / 37	29	-
Total abundance	- / 9	-	8 / 42	39 / 46	-
Diversity	- / 10	12	- / 40	9 / 17	13
Bird guilds					
aerial insectivore richness	-	9	- / 10	- / 43	-
abundance	-	-	-	12 / 44	-
Foliage insectivore/nectarivore richness	11 / 25	8	- / 9	-	-
abundance	13 / 26	12	- / 22	- / 11	-
foliage/trunk insectivore richness	-	-	11 / 27	-	-
abundance	- / 9	16	- / 35	29	-
granivore richness	21 / 30	11	7	26 / 42	- / 13
abundance	15	7	-	43 / 62	- / 24
ground insectivore richness	-	7 / 14	- / 46	21	-
abundance	28	-	- / 50	- / 17	42
ground insectivore/omnivore richness	- / 19	-	-	32	-
abundance	- / 19	- / 7	- / 10	34	- / 24
raptor richness	-	- / 22	- / 29	- / 13	24
abundance	-	- / 13	- / 37	33	-
nectarivore richness	-	-	- / 16	-	-
abundance	-	-	8 / 14	- / 9	-
frugivore richness	-	-	- / 16	-	-
abundance	-	-	- / 21	-	-
Mammals					
Richness	- / 16	8	7 / 9	10 / 21	-
Total abundance	- / 19	-	9	-	-
Diversity	-	-	16 / 27	-	-
Mammals groups					
dasyurid richness	22	19	-	-	-
abundance	22	24	-	-	-

	NT loam	NT clay	QLD bas	QLD sed	QLD alv
murid richness	19 / 40	18	-	-	-
abundance	20 / 45	18	-	-	-
macropod richness	10	- / 7	11	- / 9	-
abundance	11 / 13	- / 18	10	-	-
arboreal mammal richness	-	-	7 / 37	-	-
abundance	-	-	10 / 39	-	-
Reptiles					
Richness	13 / 20	6	-	-	14 / 15
Total abundance	17 / 29	- / 9	- / 8	10	-
Diversity	13	6	-	-	14
Reptile groups					
varanid/agamid richness	-	- / 14	-	- / 10	-
abundance	39	-	-	-	- / 17
gekkonid richness	-	- / 13	-	-	27 / 57
abundance	-	- / 15	11 / 27	22 / 35	18 / 71
scincid richness	23 / 34	-	- / 7	-	26
abundance	17 / 27	8	- / 18	-	- / 18
serpent richness	-	-	- / 20	16	-
abundance	-	-	- / 37	16	-

Table 43. Summary of predictive models testing the relationship between continuous condition variables PLUS other habitat variables and the abundance of **individual species**. Table shows: the number of species in each major group that occurred in sufficient sites to be analysed; the proportion of analysed species for which there was a significant model (at least 5% deviance explained); the range and mean for % deviance explained (significant models only).

		NT loam	NT clay	QLD bas	QLD sed	QLD alv	total
Sites		*48*	*56*	*48*	*34*	*24*	
Species analysed	*Plants*	*123*	*97*	*72*	*48*	*39*	*380*
	Ants	*56*	*33*	*42*	*43*	*28*	*202*
	Birds	*32*	*34*	*46*	*38*	*31*	*181*
	Reptiles	*10*	*12*	*14*	*14*	*7*	*57*
	Mammals	*3*	*5*	*2*	*3*	*3*	*16*
% Species significant	Plants	71	73	57	52	54	64.5%
	Ants	73	61	71	42	61	62.4%
	Birds	66	71	72	53	35	63.5%
	Reptiles	70	58	57	43	86	39.5%
	Mammals	67	60	50	0	33	43.8%
% deviance explained range (mean)	Plants	6-52 (18.9)	6-61 (21.1)	6-59 (17.6)	9-44 (22.0)	13-77 (33.9)	
	Ants	8-58 (21.5)	7-38 (16.9)	7-80 (19.1)	10-40 (23.1)	14-64 (30.5)	
	Birds	9-40 (18.5)	8-37 (15.5)	6-91 (22.2)	9-24 (25.2)	16-41 (27.3)	
	Reptiles	8-47 (26.0)	6-37 (18.4)	7-36 (16.0)	12-33 (19.5)	13-61 (31.7)	
	Mammals	16-46 (30.8)	18-24 (20.8)	(11.0)	-	(15.0)	

Table 44. Example (using NT loam landtype) of the improvement in predictive models for biodiversity summary variables and individual species abundance. Calculations were limited to those variables for which there was a significant model using only condition variables.

models	***no. of models improved***	**mean % increase in deviance explained**	**mean increase in number of terms**
Plant – summary variables	*12*	70	0.7
Plant – individual species	*19*	79	0.9
Ant – summary variables	*3*	26	1.3
Ant – individual species	*9*	101	0.9
Bird – summary variables	*4*	82	1
Bird – individual species	*5*	125	-0.2
Reptile – summary variables	*4*	61	0.5
Reptile – individual species	*1*	159	-1.0
Mammal – summary variables	*3*	86	0.7
Mammal – individual species	*2*	52	0.5

Table 45. Summary of habitat variables in models for biodiversity summary variables, for each major group in each landtype (NL = NT loam; NC = NT clay, QB = QLD basalt, QS = QLD sedimentary, QA = QLD alluvial).

			Plants					Ants					Birds					Reptiles & Mammals				
	tot	%	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA
Rock cover	7	10.6					1									5			1			
Litter cover	43	11.8		13	6	6	1		7	1	1	1		3			2			0		2
Canopy height	5	5.4				3											1				1	
Foliage cover >10m	62	44.3			21					10	7				13					11		
Foliage cover 5-10m	29	10.6		11			5		6			0		0				1	3			
Foliage cover 3-5m	21	3.9	5			3		7								5					1	
Foliage cover 1-3m	18	10.7					10					1				5	2			0	0	
Shrub cover	13	14.4				3					8		2									
Dead basal area	12	8.3			3										6	0				2		1
Live basal area	12	6.8	9					0					0								3	
Termite mound - no.	8	18.1																7				1
Termite mnd - height	4	5.3								1		0			3							
Dung score	29	25.4			18					0	0				11							
Grazing score	4	7.5															0					4
Cattle use index	12	13.8		5										5					2			
Distance to waterpoint	32	24.2	7					6	9				10									
Distance to creek	2	11.1																2				

Table 46. Summary of habitat variables in models for individual species abundance, for each major group in each landtype (NL = NT loam; NC = NT clay, QB = QLD basalt, QS = QLD sedimentary, QA = QLD alluvial).

			Plants					Ants					Birds					Reptiles & Mammals				
	tot	%	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA	NL	NC	QB	QS	QA
Rock cover	6	7.8					2									2			2			
Litter cover	57	11.6		18	4	7	4		6	3	4	6		2			2			0		1
Canopy height	6	6.3				2											2				2	
Foliage cover >10m	59	26.9			25					12	6				12					4		
Foliage cover 5-10m	23	5.2		14			0		1			2		3				2	1			
Foliage cover 3-5m	43	41.7	26			3		6								8					0	
Foliage cover 1-3m	28	16.6					9					6				6	5			2	0	
Shrub cover	15	7.0				8					4		3									
Dead basal area	20	11.0			6										9	3				2		0
Live basal area	23	8.2	13					6					4								0	
Termite mound - no.	4	17.4																1				3
Termite mnd - height	21	18.1								6		2			13							
Dung score	21	10.3			11					5	1				4							
Grazing score	3	7.3															2					1
Cattle use index	19	12.8		15										2					2			
Distance to waterpoint	72	29.5	38					19	6				9									
Distance to creek	2	15.4																2				

Table 47. Spearman rank correlation matrix for biodiversity richness and diversity variables across all sites, and for sites in each landtype. Only significant correlations are shown, and values of R >0.5 are bolded for clarity. Abbreviations for columns correspond to labels for rows.

	G_Pl	P_Gr	Ant	A_FG	Vert	Bird	Bird_G	Mamm	Rept	Pl_D	Ant_D	AFG_D	Vert_D	Bird_D
All landtypes (n=210)														
Total plant richness	**0.92** ***	0.43 ***	0.2 **			0.12 *				**0.56** ***	0.22 **			
Groundlayer plant richness		0.43 ***	0.12 *							**0.51** ***	0.14 *			
Perennial grass richness			0.19 **		0.45 ***	0.39 ***	0.47 ***		0.41 ***	-0.14 *	0.24 ***		0.45 ***	0.49 ***
Ant richness				**0.5** ***	0.2 **	0.17 *	0.15 *		0.13 *		**0.96** ***	**0.51** ***	0.18 **	0.29 ***
Ant functional group richness								0.12 *			0.44 ***	**0.65** ***		
Vertebrate richness						**0.95** ***	**0.77** ***	0.27 ***	**0.62** ***	-0.34 ***	0.22 **		**0.94** ***	**0.86** ***
Bird richness							**0.79** ***	0.16 *	0.39 ***	-0.24 ***	0.19 **		**0.86** ***	**0.83** ***
Bird guild richness								0.09	0.42 ***	-0.41 ***	0.18 **	-0.14 *	**0.78** ***	**0.79** ***
Mammal richness													0.26 ***	0.14 *
Reptile richness										-0.4 ***	0.19 **		**0.69** ***	**0.57** ***
Plant diversity													-0.44 ***	-0.39 ***
Ant diversity												0.49 ***	0.2 **	0.32 ***
Ant functional group diversity														-0.12 *
Vertebrate														**0.9** ***
NT loam (n=48)														
Total plant richness	**0.95** ***									**0.83** ***				
Groundlayer plant richness					-0.25 *					**0.81** ***				
Perennial grass richness						-0.27 *			0.28 *					
Ant richness				0.39 **							**0.92** ***	0.44 **		
Ant functional group richness											0.34 *	**0.57** ***		
Vertebrate richness						**0.89** ***	0.47 **						**0.78** ***	**0.74** ***
Bird richness							**0.67** ***		-0.3 *		0.29 *		**0.57** ***	**0.82** ***
Bird guild richness									-0.33 *				0.26 *	**0.62** ***
Mammal richness													0.3 *	
Reptile richness														-0.32 *
Plant diversity														
Ant diversity												0.42 **		
Ant functional group diversity														
Vertebrate diversity														**0.76** ***

	G_Pl	P_Gr	Ant	A_FG	Vert	Bird	Bird_G	Mamm	Rept	Pl_D	Ant_D	AFG_D	Vert_D	Bird_D
NT clay (n=56)														
Total plant richness	**0.98 *****		0.25 *	0.26 *	0.26 *	0.25 *		0.29 *		**0.63 *****				
Groundlayer plant richness		0.24 *	0.29 *	0.24 *				0.37 **		**0.61 *****				
Perennial grass richness			0.29 *	0.38 **				0.39 **			0.25 *			-0.28 *
Ant richness				0.48 **					0.23 *	0.3 *	**0.94 *****	**0.68 *****		-0.23 *
Ant functional group richness											0.37 **	**0.59 *****		
Vertebrate richness						**0.94 *****	**0.68 *****	0.25 *	0.38 **				**0.91 *****	**0.51 *****
Bird richness							**0.81 *****						**0.85 *****	**0.63 *****
Bird guild richness													**0.65 *****	**0.58 *****
Mammal richness														
Reptile richness											0.33 *	0.3 *	0.37 **	
Plant diversity											0.25 *			0.27 *
Ant diversity												**0.68 *****		-0.26 *
Ant functional group diversity														
Vertebrate diversity														**0.66 *****
QLD basalt (n=48)														
Total plant richness	**0.99 *****	**0.74 *****			**0.5 ****	0.48 **	0.55 ***			**0.72 *****			0.47 **	0.46 **
Groundlayer plant richness		0.74 ***			**0.5 ****	0.49 **	**0.55 *****			**0.71 *****			0.48 **	0.47 **
Perennial grass richness					**0.59 *****	**0.54 *****	0.45 **		0.27 *	**0.64 *****			**0.57 *****	**0.52 ****
Ant richness				**0.66 *****			0.32 *	0.33 *			**0.97 *****	**0.76 *****		
Ant functional group richness								0.3 *			**0.62 *****	**0.74 *****		
Vertebrate richness						**0.94 *****	**0.7 *****		**0.54 *****	0.31 *		0.34 *	**0.98 *****	**0.91 *****
Bird richness							**0.73 *****		0.27 *	0.33 *		0.28 *	**0.94 *****	**0.98 *****
Bird guild richness								0.27 *		0.29 *	0.34 *	0.28 *	**0.74 *****	**0.71 *****
Mammal richness										0.25 *	0.37 **	0.35 *		
Reptile richness													**0.51 ****	0.27 *
Plant diversity													0.28 *	0.33 *
Ant diversity												**0.77 *****		
Ant functional group diversity													0.31 *	
Vertebrate diversity														**0.93 *****

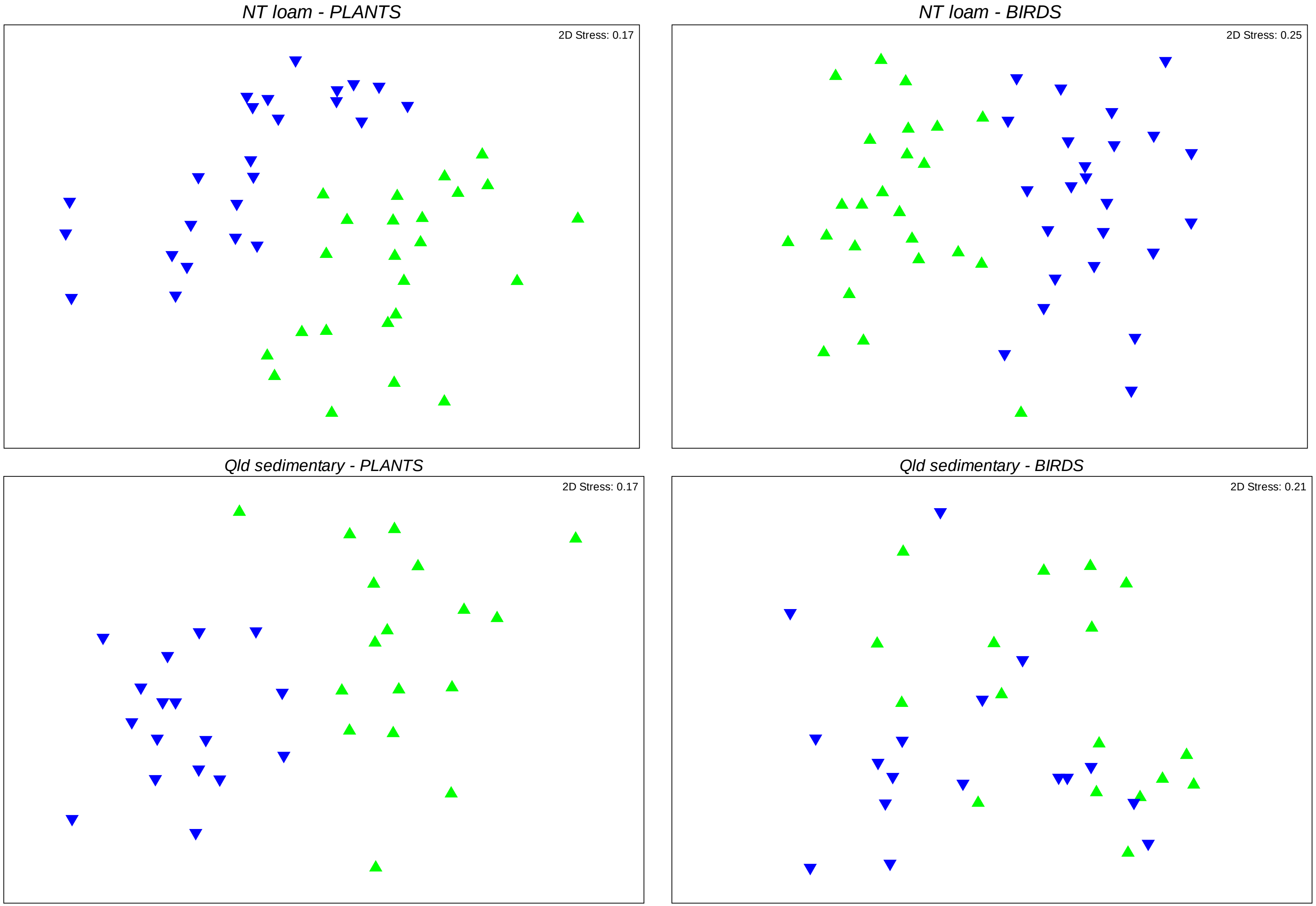
	G_Pl	P_Gr	Ant	A_FG	Vert	Bird	Bird_G	Mamm	Rept	Pl_D	Ant_D	AFG_D	Vert_D	Bird_D
QLD sedimentary (n=34)														
Total plant richness	**0.96 *** **	0.37 *								**0.61 ** **				
Groundlayer plant richness		0.45 **								**0.61 ** **		-0.31 *		
Perennial grass richness			-0.35 *	-0.46 **		0.3 *				**0.57 ** **		-0.49 **		
Ant richness				**0.53 ** **	-0.38 *	-0.38 *	-0.38 *			-0.38 *	**0.95 *** **	**0.5 ** **		-0.32 *
Ant functional group richness											**0.5 ** **	**0.72 *** **		
Vertebrate richness						**0.93 *** **	**0.71 *** **		0.33 *		-0.42 *		**0.96 *** **	**0.93 *** **
Bird richness							**0.82 *** **				-0.41 *	-0.33 *	**0.85 *** **	**0.97 *** **
Bird guild richness											-0.39 *		**0.6 ** **	**0.74 *** **
Mammal richness														
Reptile richness													0.42 *	
Plant diversity											-0.3 *	-0.36 *		
Ant diversity												**0.51 ** **	-0.33 *	-0.34 *
Ant functional group diversity														
Vertebrate diversity														**0.89 *** **
QLD alluvial (n=24)														
Total plant richness	**0.95 *** **	0.44 *								0.47 *				
Groundlayer plant richness		0.42 *								0.42 *				
Perennial grass richness			-0.41 *				**0.52 ** **				-0.41 *			
Ant richness				**0.56 ** **							**0.96 *** **	**0.54 ** **		
Ant functional group richness											**0.51 * **	**0.71 ** **		
Vertebrate richness						**0.91 *** **	0.38 *	0.61 **					**0.86 *** **	**0.77 *** **
Bird richness							0.44 *	0.47 *					**0.82 *** **	**0.87 *** **
Bird guild richness														
Mammal richness													0.35 *	0.48 *
Reptile richness														
Plant diversity														
Ant diversity												0.4 *		
Ant functional group diversity														
Vertebrate diversity														**0.73 *** **

Table 48. Mantel tests comparing similarity matrices for the composition of different taxonomic/functional groups in each landtype (*, p<0.1; **p<0.01; ***, p<0.001).

	Birds	BirdFG	M&R	Ants	AntFG	Plants	G Plants
NT loam							
All vertebrates	0.91***	0.47***	0.47***	0.48***	0.12*	0.37***	0.35***
Birds		0.58***	0.12*	0.48***	0.13*	0.34***	0.33***
Bird guilds			-0.04	0.17**	0.16**	0.08	0.08
Mammals & reptiles				0.25**	0.10	0.22**	0.20**
Ants					0.33***	0.42***	0.40***
Ant functional groups						0.07	0.06
All plants							0.99***
Ground layer plants							
NT clay							
All vertebrates	0.88***	0.71***	0.52***	-0.26**	0.40***	0.18**	0.17**
Birds		0.81***	0.11	0.00	0.58***	0.11	0.10
Bird guilds			0.08	-0.35***	0.12	0.07	0.06
Mammals & reptiles				-0.34***	-0.11	0.23**	0.23**
Ants					0.51***	0.49***	0.49***
Ant functional groups						0.28***	0.28***
All plants							1.00***
Ground layer plants							
QLD basalt							
All vertebrates	0.95***	0.54***	0.67***	0.39***	0.17**	0.54***	0.58***
Birds			0.43***	0.35***	0.15**	0.50***	0.52***
Bird guilds			0.13*	0.07	-0.04	0.36***	0.30***
Mammals & reptiles				0.32***	0.17**	0.47***	0.47***
Ants					0.45***	0.25***	0.40***
Ant functional groups						0.07	0.15**
All plants							0.72***
Ground layer plants							
QLD sedimentary							
All vertebrates	0.93***	0.67***	0.43***	0.30***	0.17**	0.18**	0.16**
Birds		0.70***	0.14*	0.28***	0.13*	0.14*	0.12*
Bird guilds			0.13*	0.31***	0.11	0.12*	0.19**
Mammals & reptiles				0.09	0.12	0.16**	0.10
Ants					0.54***	0.16**	0.18*
Ant functional groups						0.12*	0.16*
All plants							0.58***
Ground layer plants							
QLD alluvial							
All vertebrates	0.74***	0.48***	0.80***	0.35***	0.23*	0.38***	0.32***
Birds		0.60***	0.26***	0.27**	0.23**	0.32***	0.23**
Bird guilds			0.23**	0.25**	0.22**	0.20**	0.21**
Mammals & reptiles				0.22**	0.15*	0.29***	0.28**
Ants					0.52***	0.63***	0.57***
Ant functional groups						0.33***	0.26**
All plants							0.84***
Ground layer plants							

9. Figures

Figure 5. Example ordinations of sites by species composition (plants and birds) to illustrate the influence of location (NT loam; symbols are two properties) and vegetation type (Qld sedimentary; symbols are Box or Ironbark dominance)



[Figure 6](#) (next pages). Ordination of sites by species composition, for each major taxonomic group in each landtype. Ordinations for functional groups are not shown, as they are generally less informative than those at the species level. Symbols show condition class: green circles=good; blue triangles=intermediate; red squares=poor. For NT loam, the dashed line indicates the separation between sites form two sample locations. For Qld sedimentary and alluvial, dashed line indicates separation between box and ironbark vegetation types (lack of dashed line indicates significant overlap between these categories).

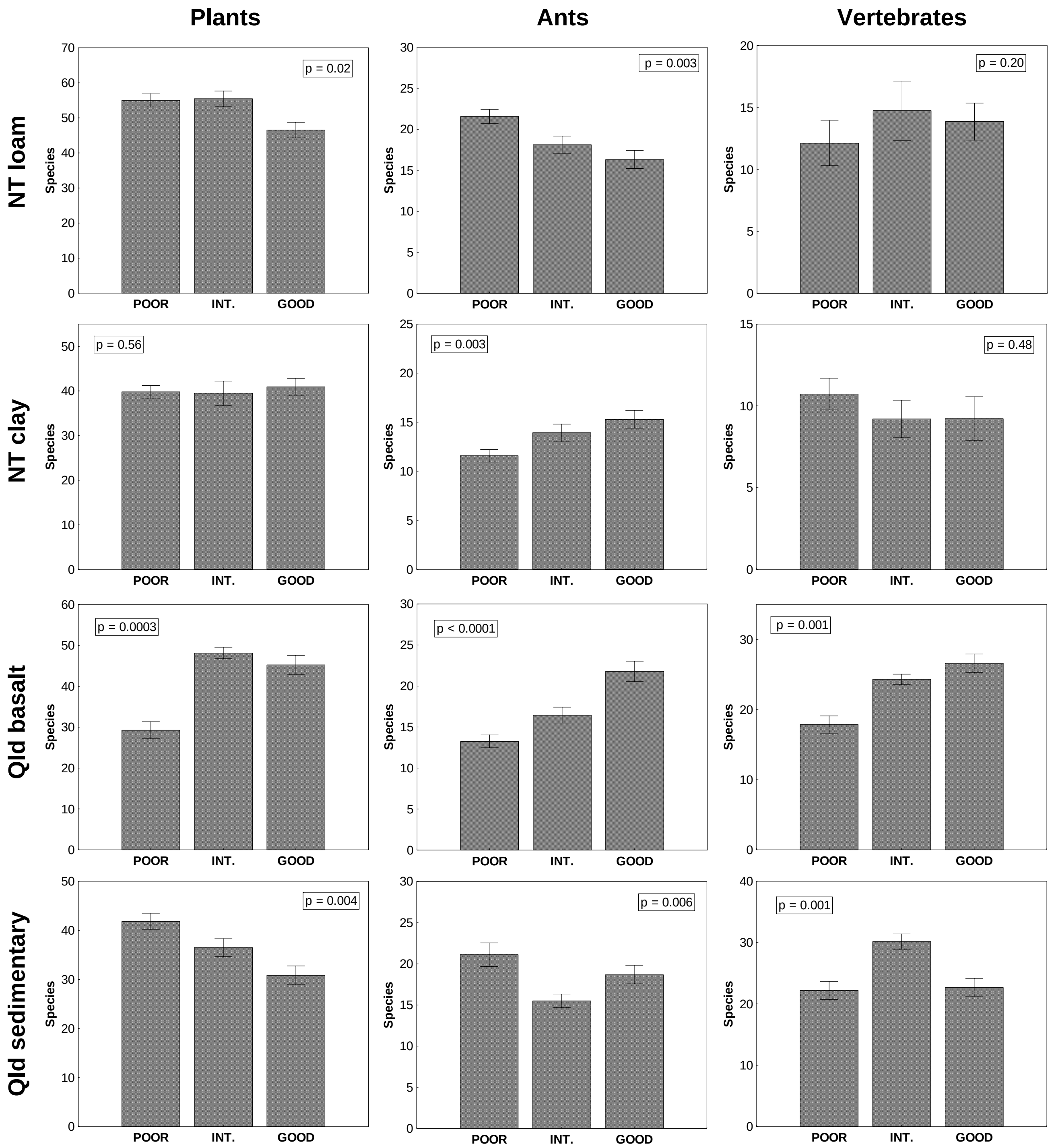
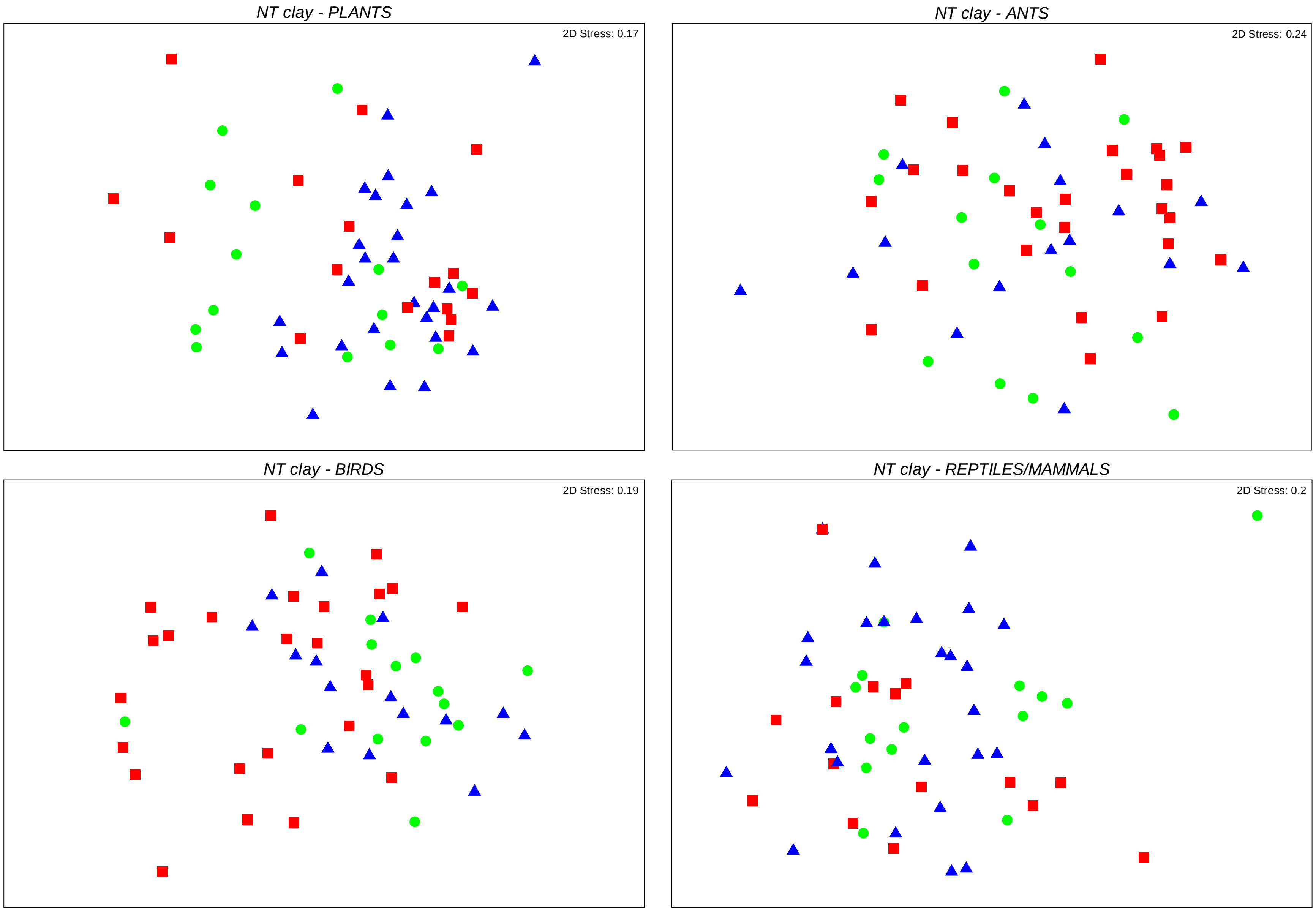
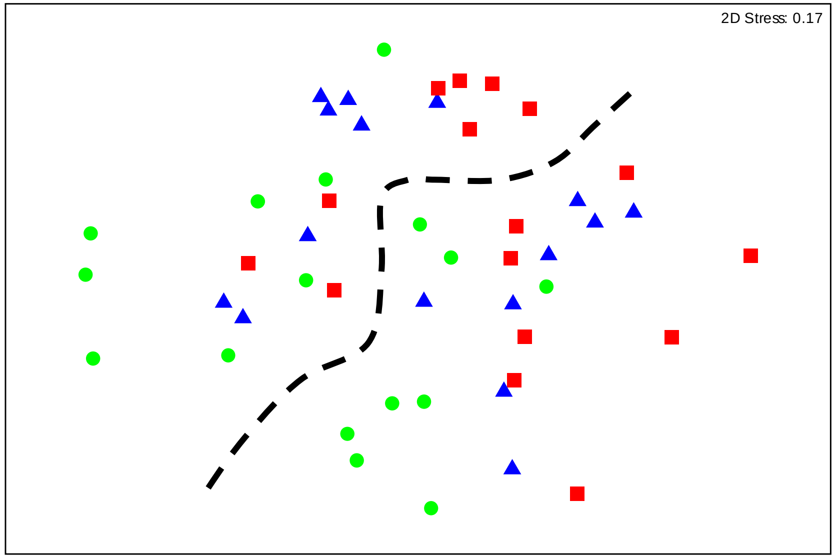


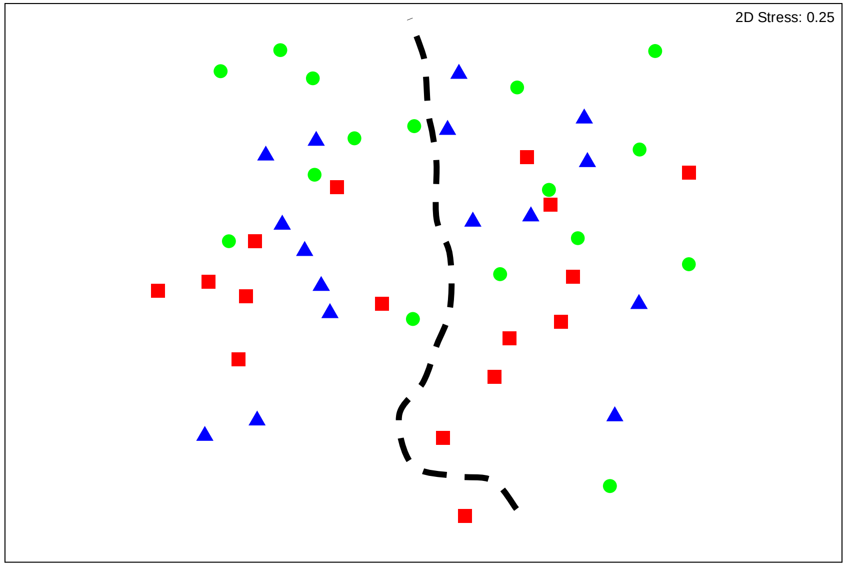
Figure 7. Variation in mean species richness of plants, ants and all vertebrates between condition classes, in four landtypes. P value is the significance of a Kruskal-Wallis test for difference between condition classes.


NT clay - PLANTS
2D Stress: 0.17
NT clay - ANTS
2D Stress: 0.24
NT clay - BIRDS
2D Stress: 0.19
NT clay - REPTILES/MAMMALS
2D Stress: 0.2

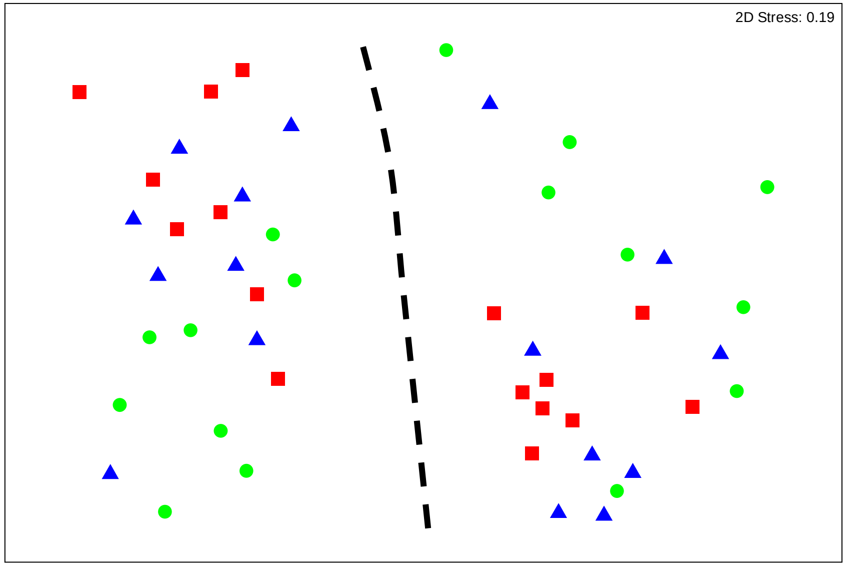
NT loam - PLANTS



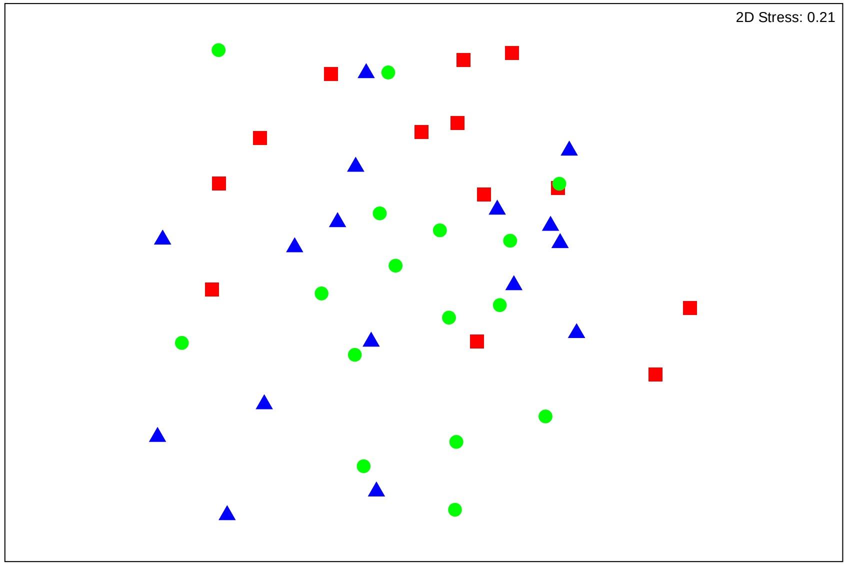
NT loam - BIRDS



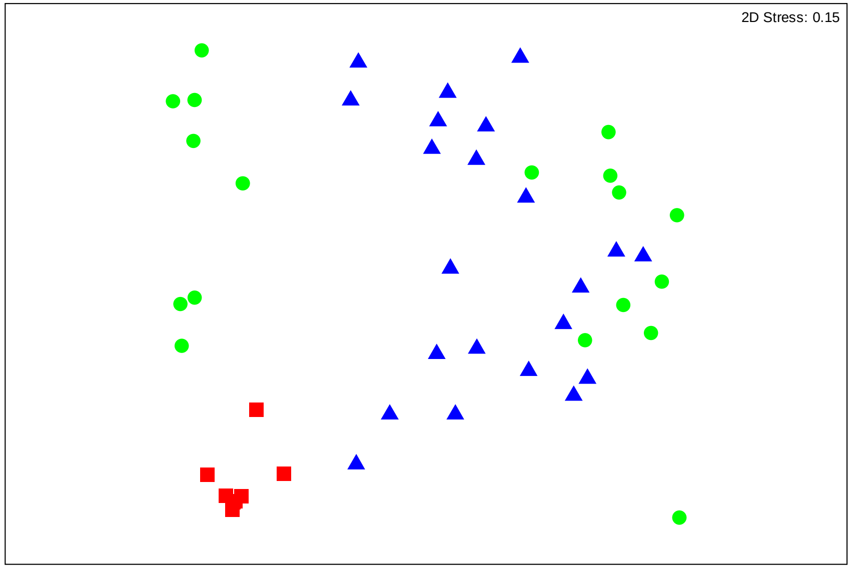
NT loam - ANTS



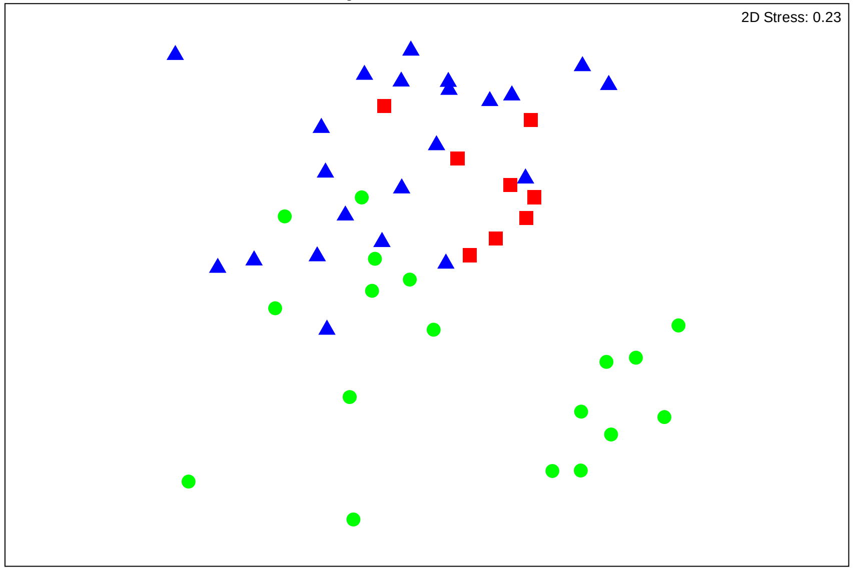
NT loam - REPTILES/MAMMALS



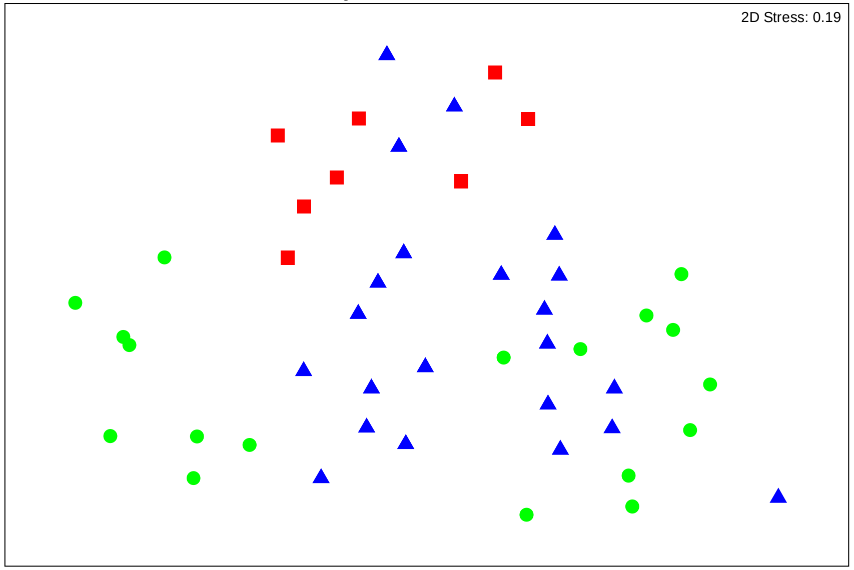
Qld basalt - PLANTS



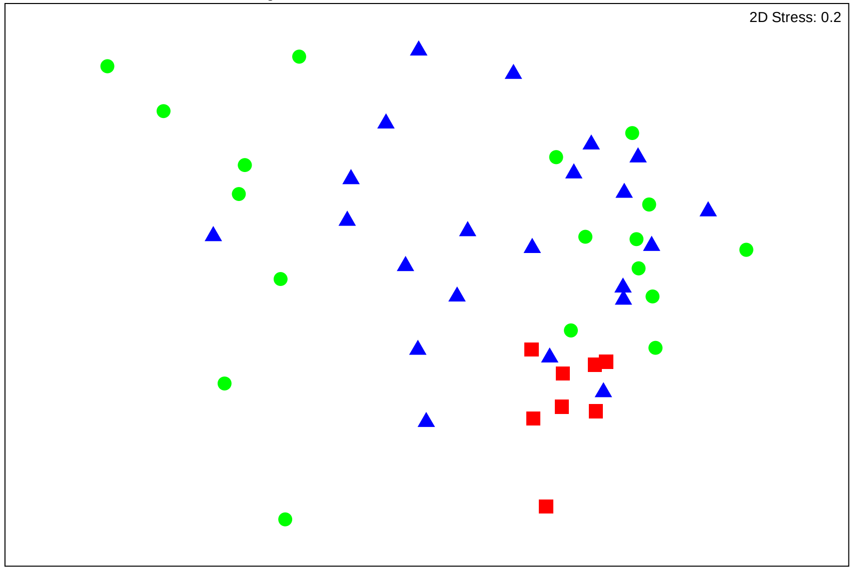
Qld basalt - ANTS

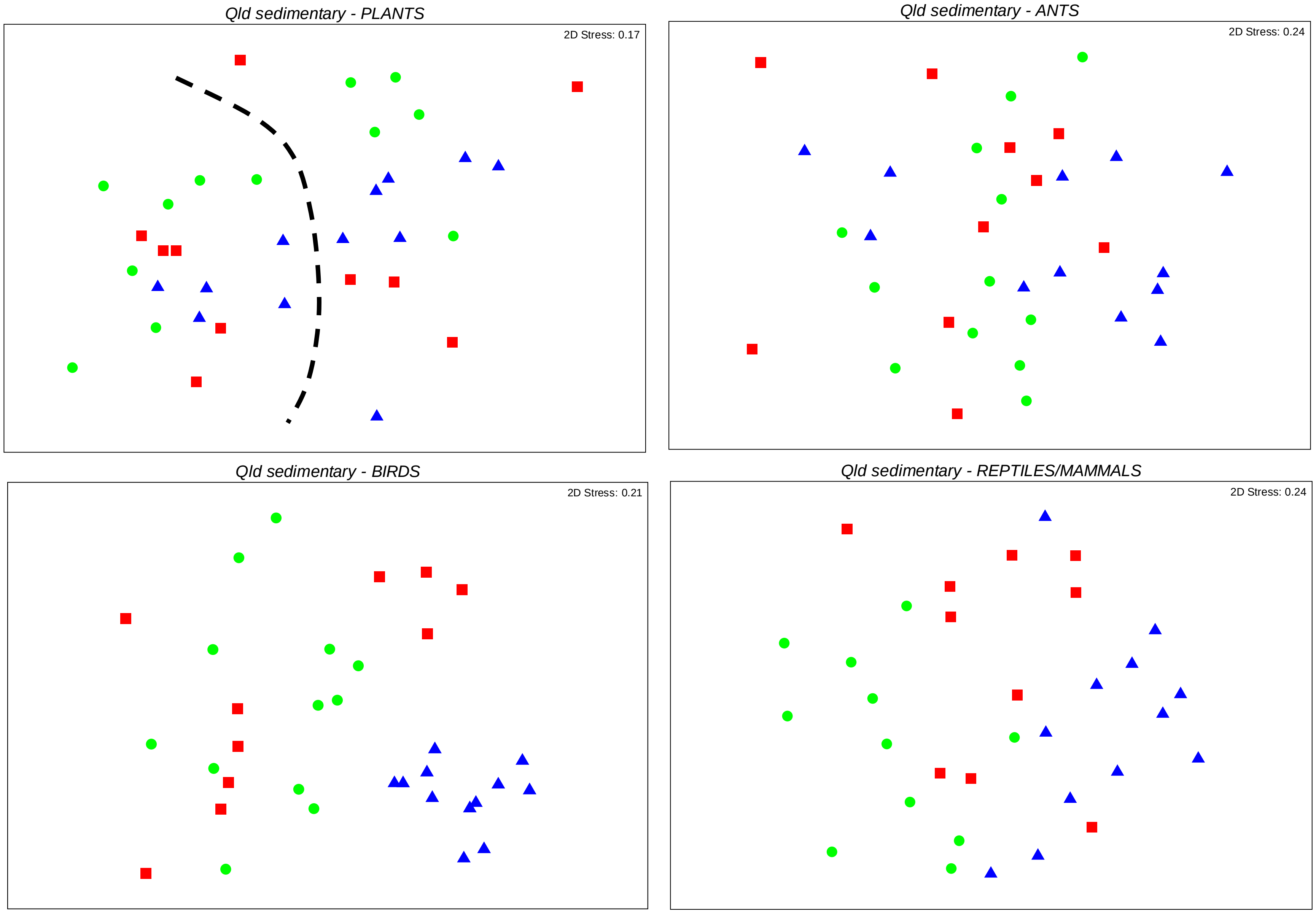


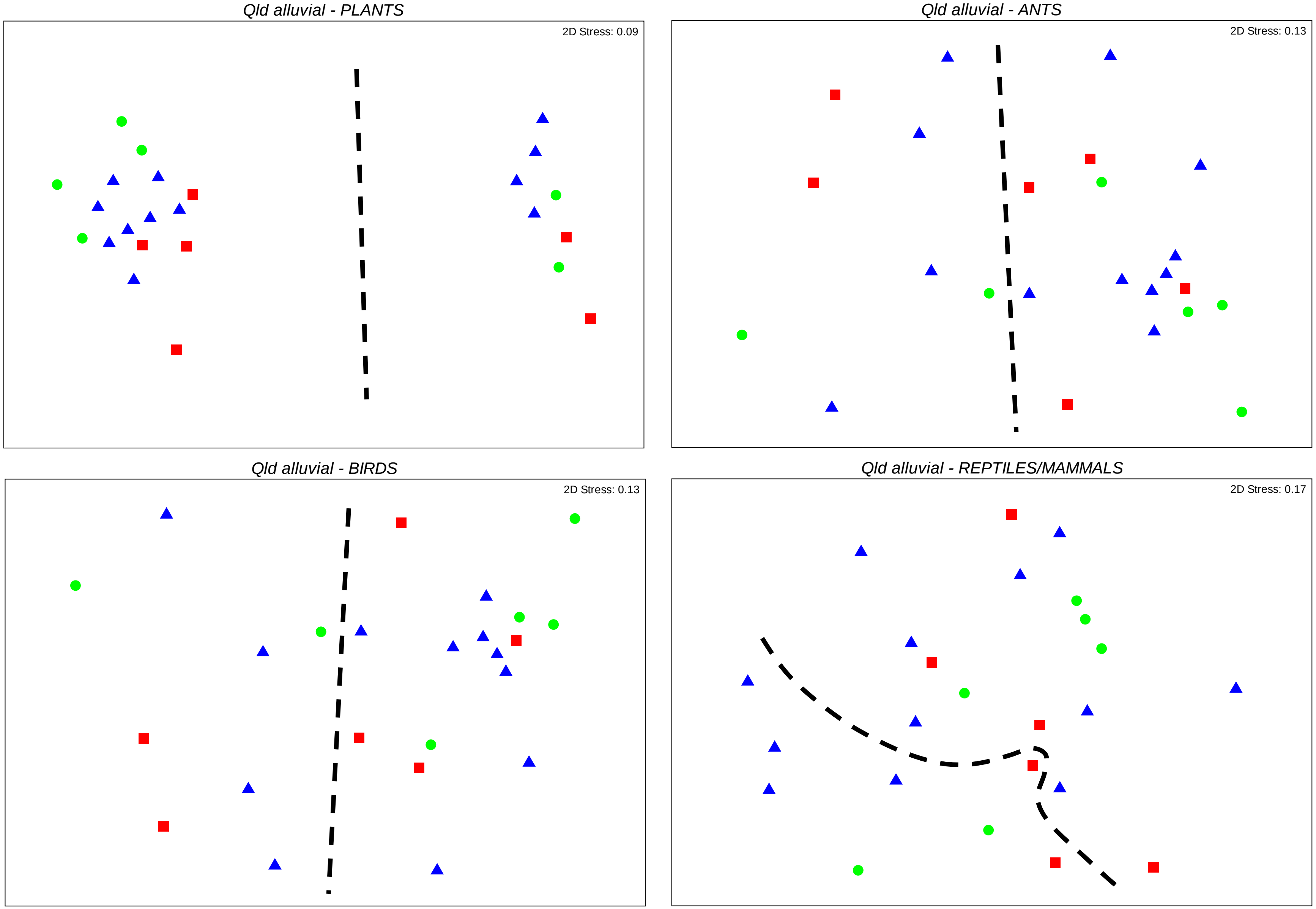
Qld basalt - BIRDS



Qld basalt - REPTILES/MAMMALS




Qld sedimentary - PLANTS
2D Stress: 0.17
Qld sedimentary - ANTS
2D Stress: 0.24
Qld sedimentary - BIRDS
2D Stress: 0.21
Qld sedimentary - REPTILES/MAMMALS
2D Stress: 0.24


Qld alluvial - PLANTS
2D Stress: 0.09
Qld alluvial - ANTS
2D Stress: 0.13
Qld alluvial - BIRDS
2D Stress: 0.13
Qld alluvial - REPTILES/MAMMALS
2D Stress: 0.17

10. Appendices

Appendix 1. Detailed description of biodiversity sampling method and example field proformas.

Appendix 2. Description of VRD pilot study.

Appendix 3. Species recorded from sample sites.

Appendix 4. Effects of an introduced pasture species on biodiversity in a tropical savanna woodland (Kutt & Fisher 2004)

Appendix 5. The influence of different grazing strategies on the patterns of vertebrate fauna in a tropical savanna woodland (Kutt *et al.* 2004)

Appendix 1. Detailed description of biodiversity sampling method and example field proformas

All sampling is based on a 1ha (100X100m) site. Most of the sampling actually occurs in a 0.25ha (50x50m) quadrat placed centrally in the site. Some of the vegetation description (eg. basal area) is centered in the site but theoretically boundless.

Sites are semi-permanently marked by a 1m fence dropper placed in one corner of the 50x50m quadrat. The sides of the quadrat are oriented NESW, so the coordinates of the dropper, and which corner of the quadrat it is at, are sufficient to locate the site. The location of the dropper is established by an averaged GPS reading. [Being able to locate the site reasonable precisely in space is particularly important to any remote-sensing analysis that is subsequently carried out].

During the actual sampling, the boundaries of the 50X50m quadrat are delineated by the trap lines. The corners and sides of the 100x100m site could be marked with flagging tape, but a visual estimate based on the central quadrat is adequate in open woodlands.

Fauna

Birds

Bird censuses are done within the **100x100m** site. Each site is censused for birds eight times (in daylight) and birds may also be recorded during two nocturnal visits (see below). The majority of bird counts should be done in the early to mid morning, with the remainder spread through the day. The sites are not visited in the same order every day, to avoid systematic bias.

Each count is theoretically an instantaneous count of all the birds within the quadrat. In practice this involve walking through the quadrat, for a period of approximately 5 minutes. This also serves to flush ground-dwelling species. The number of individuals of each species is recorded for each count, avoiding counting the same individuals more than once. Only birds actively using the quadrat are counted – birds merely flying past are not included. Raptors etc are included if they are hunting directly overhead.

Two data values are derived from the bird counts for each species – total abundance (sum of all counts) and frequency (number of non-zero counts, out of a total of 10)

Vertebrate traps

The layout of traps within the **50x50m** quadrat is:

- 4 cage traps – one in each corner
- 20 Elliott traps around the perimeter – 5 on each side, c. 8m apart
- 6 single pit traps scattered within the quadrat. Pits are 20l plastic buckets and each pit has 10m of drift-fence. If relevant, the pits should be located in different microhabitats in the quadrat eg. in open ground; in dense grass; close to trees; in rocky areas.
- Traps are opened for 3 nights, checked early each morning and around midday. Elliotts and cages are rebaited each afternoon - the bait used Is a mixture of oats, peanut butter, honey and tinned tuna.
- trapped animals are released after identification in or near the site (except if required as specimens)

Vertebrate searches

Each quadrat is actively searched five times for herps, mammals, scats and signs etc.

- three searches during the day (morning, midday, late afternoon)
- two searches at night using spotlights
- each search should take c. 10min and involves turning rocks and logs, raking through leaf litter, looking under bark, in crevices etc.
- the number of individuals of each species seen while searching is recorded
- scats, bones and other signs should be recorded where these can confidently be attributed to species
- carnivore scats can be collected for hair analysis [this isn't done systematically in this project, so the data wouldn't be included in quantitative analyses]

A total abundance score for each vertebrate species is derived from the sum of all counts from trapping and searches. Scats and signs are scored with a value of 1, regardless of their relative abundance.

Incidental vertebrate records

Species that are seen/heard in the vicinity of the quadrat and in the same habitat should be recorded as incidental records for that site, with an abundance of zero to indicate they were not within the quadrat

Other species seen in the general area that are not attributable to a quadrat should be recorded separately on a list for the general area. For this study, it may be possible to break down these records on the basis of paddock, property etc. [this hasn't been done systematically in the NT]

Ants

Ants are sampled at all sites using small pits (specimen containers with 45mm aperture) with an ethylene glycol preservative.

- 15 pits within the 50x50m quadrat, in 3 rows of 5 with 5m spacing between pits. The 3 rows commence at the three middle Elliott traps on one side of the quadrat, with 5m before the first pit on each row
- pits are dug in flush with the ground surface and left open for 48h [using a narrow-bladed trowel, a narrow diameter hand auger, or a wrecking bar or crowbar for concrete-like soils, might work well]
- each vial is labelled with the site number on the side using permanent marker
- ants are transferred to alcohol, sorted and IDs done at CSIRO Darwin
- ant data is a frequency (out of 15) for each species in each site
- during the project, the value of increasing sample intensity (eg. 25 pits per site) will be tested

Floristic sampling

Floristic sampling will occur at all sites during or immediately after the Wet season. The (minimum) aim will be a complete species list for each 50x50m quadrat, with an abundance measure for at least the more frequent species. It may also be appropriate to sample a set of (smaller) sites additional to those used for fauna. Note that some vegetation description is carried out in the late dry season and is included in the habitat proforma described below.

Trees and tall shrubs

These are sampled within a 1ha (100 x 100 m) site as per the main site proforma (below).

- there are 4 sampling points at the corners of a 50 x 50 m square in the centre of the site: this effectively divides the site into 4 50 x 50 m sectors
- mode canopy height for each sector is measured by clinometer
- total crown cover is measured for each sector using a Bitterlich device, for 4 height classes
- basal area is measured for each sector by Bitterlich sweep. Basal area is recorded for individual species, scored into 3 size classes.
- crown cover is visually estimated for all tree and tall shrub (>1m) species in each of the 4 sectors (ie. including species not captured during Bitterlich sweeps) . Appropriate crown cover scores are <<1%, <1%, 1%, 2%, 5% and then multiples of 5%

[NOTE: if this is excessively time consuming, two diagonal sectors can be scored rather than all 4]

Ground layer and small shrubs

These are sampled within a 50 x 50m plot in the centre of the site. Small sub-plots are used to estimate cover and score frequency.

- 25 x 0.5m^2 subplots are laid out in a regular grid (ie. 8m between plots, and 8m from edges)
- within each subplot, record all species present. Score the projective foliage cover of each species on the 6-point scale (1=<1%, 2=1-5%, 3=5-25%, 4=25-50%, 5=50-75%, 6=75-95%, 7=>95%).
- after scoring the subplots, conduct a timed search of the entire 50x50m plot and record additional species. Estimate the projective foliage cover of the additional species within the entire plot (as <<1%, <1%, 1%, 2%, 5% and then multiples of 5%)
- the length of the timed search may have to be adjusted depending on the complexity of the vegetation. I suggest 20 minutes.

[NOTE: this can be combined with the groundcover structural sampling, if necessary. Score the structural/grazing attributes within the 0.5m^2 plots, missing every third one, plus the last].

Groundlayer and general habitat description

Habitat descriptions are done at all sites at the time of late dry season fauna sampling. These descriptions can be separated into “general” and “ground-layer” sampling and the descriptions should be read with reference to the attached proformas.

It is strongly recommended that the same person does the habitat description for all sites. or that adequate calibration is done if there are two or more recorders.

Ground-layer

Data is visually estimated within 0.5 m^2 (71cm x71cm) plots. 16 plots are arranged in a regular 4x4 grid within the 50x50m site, with 10m spacing between all plots. [The data sheet allows for 25 plots (5x5 grid) – preferred but too consuming in practice].

Apart from dung/tracks/grazing and tree/tall shrubs crown, all data are cover estimates, which are scored on a 8-point scale (see bottom of proforma).

sector: used where 2 or more 50x50m quadrats are sampled within the 1ha site, otherwise record as “C” (central).

dung: presence of cattle dung in plot: 0=none, 1=1 dropping, 2=more than 1

tracks: cattle tracks: 0=none, 1=1 track, 2=several tracks, 3=numerous tracks

grazing: estimate of vegetation removed by grazing: 0=none, 1=small amount form few plants, 2=small amount from all plants or moderate amount from some plants, 3=moderate amount from all plants or some plants eaten to ground, 4=all plants eaten to ground soil / rock / litter / u/s cover: visual estimate of the projective cover of bare soil, rocks, litter and understorey, summing to a total of 100%.

trees/tall shrubs cr: indicate (+) if the crown of trees or tall shrubs are vertically overhead any part of the plot

shrubs<1m / herb / per gr / fpg / ann gr: estimated projective foliage cover of small shrubs, herbs (ie. all plants that are not shrubs or grasses), perennial grasses, facultative perennial grasses and annual grasses. Note that these are independently estimated and can potentially sum to more than 100%.

dominant species: for perennial grasses, fp grasses and annual grasses, estimate the cover of the major species. Particulalry for annual grasses, these may be “unidentifiable” in end-of-dry season samples, but the perennials are of most importance. In some environments, it may be appropriate to identify dominant shrubs or herbs, if these are amongst the most frequent species.

For each variable, data derived will be a measure of the mean/median, a measure of variability, and a frequency.

General habitat

Note: some of these variables are recorded so that the data is comparable to the general PWCNT biodiversity surveys, and this has dictated their format. Variables that are self-evident are not described here. Location description, landscape position, veg description and condition description are entered to the database as memo fields and can be any length – they should be sufficiently detailed to evoke the nature of the site for long-term reference.

corner: corner of 50x50m quadrat where GPS reading occurred

x,y: averaged GPS location in decimal degree or UTM

zone: if UTM

datum: AGD66, WGS84, GDA94

landscape position: described in terms of landform pattern and landform element as per Yellow Book

landunit: from local landunit mapping, if relevant

slope: measured using clinometer (% not ^{o})

aspect: compass bearing

condition description: should mention aspects of evidence of grazing, vegetation composition, fire, soil surface condition, weeds

distance to permanent water: straight line distance and accounting for fencelines (latter may be “not accessible”, entered as 99

distance to nearest creek: nearest ephemeral/intermittent water source that may influence species distbn and grazing patterns

fire impact: an (imperfect) scale from 0 (no visible signs) to 5 (intense fire burning all of site). 3 would indicate a fire sufficiently hot to kill sensitive shrubs (eg. Acacias) affecting most of the site.

last fire: “this year” is during the current dry season (approximately equivalent to calendar year)

rock cover: cover of stones in each of 8 size classes, using a 7-point scale (as per Yellow Book). Note that these can add to more than 100%.

rock type: surface rocks

lithology: underlying lithology from geological map

soil texture: coarse texture class of surface soil (see soil sample below)

logs: number of fallen logs with a diameter >5cm, intersected by the perimeter of the 50X50m quadrat

termite mounds: estimated total number of mounds in 50x50m quadrat

canopy height/cover/basal area:

- measurements are made from the 4 corners of the 50x50m quadrat.
- canopy height: mode height of canopy in the 50x50m square around the measuring point (measured with clinometer)
- crown cover is measured for 4 height classes using a Bitterlich device. Note that this is potentially unbounded, and that individual trees may be counted from more than one corner. A tree or tall shrub may have a cover reading in 1 to 4 height classes, depending on its shape
- [densiometer readings have not been done in the NT, as the canopy is too sparse and clumped]
- basal area sweeps are done at a minimum of 2 of the 4 corners. Counts are broken down by species and size class (including dead trees).
- for each species, also visually estimate crown cover in the 50x50m square centered on the corner. Add any additional tree / tall shrub species not included in the basal area count [I use <1% entered as 0.5% and <<1% entered as 0.1%]
- presence of nectarivorous flows or fleshy fruits is scored on a 3-point scale for each species: 1= few on few plants, 2=few on most plants or many on few plants, 3=many on most plants

Soil sample

Collect a sample of surface soil (0-5cm) and store in a heavy-duty paper soil bag labelled with site name and date. Soil samples are used to assess field texture, colour and potentially pH.

Photographs

Two digital photographs are taken in each site:
- showing typical ground cover conditions near the center of the quadrat. Taken standing on a 20l bucket, looking S, with 20% sky, using standard focal length.
- 'habitat shot' illustrative of the nature of the site including tree layer

Digital photos are filed by site name and date eg. kill02_020902_1.jpg

Data recording & storage

All data is entered onto standard proformas in the field, then transferred to an Access database, using purpose-built data entry forms.

VRD 2002 Biodiversity & land condition survey

SITE:	**survey**: VRD 2002	**quad. size:** 100 X 100 (birds)

station:	**date**:	**observer:**
location description:		
corner: NE SE SW NW	**x**:	**y**:

UTM zone:	**datum:** AGD66 WGS84 GDA94	**photos:**	

dist from fence / track:	**bearing <u>from</u> fence / track:**

landscape position:

land unit:	**slope %:**	**aspect:**

veg description:

condition description:

dist to perm water	**direct:**	cow walk:	dist to nearest creek:

fire impact: 0 1 2 3 4 5	**last fire:** this year last year 2+ years ago long unburnt

rock cover (%)		**rock type**
pebbles (<0.6cm):	0 <2 2-10 10-20 20-50 50-90 >90	sandstone
small stones (0.6-2cm):	0 <2 2-10 10-20 20-50 50-90 >90	laterite
stones (2-6cm):	0 <2 2-10 10-20 20-50 50-90 >90	limestone
small rocks (6-20cm):	0 <2 2-10 10-20 20-50 50-90 >90	basalt
rocks (20-60cm):	0 <2 2-10 10-20 20-50 50-90 >90	other:
big rocks (60cm-2m)	0 <2 2-10 10-20 20-50 50-90 >90	
boulders (>2m):	0 <2 2-10 10-20 20-50 50-90 >90	lithology:
outcrop:	0 <2 2-10 10-20 20-50 50-90 >90	

soil texture: S SL L CL C CC	**soil colour:**	**logs >5cm:**
termite mounds - no:	**max ht (m)**:	**profile**: tower dome magnetic

	can ht	cov > 10 m	cov 5-10 m	cov 3-5 m	cov 1-3 m	dens 1	dens 2	dens 3	dens 4	dens 5
NE										
SE										
SW										
NW										

QUAD:	Basal area sweeps number: 2 4	Multiplier: 0.25 0.5 1.0

species	FL FR (0 - 3)	NE				SE				SW				NW			
		<5	5-20	>20	%cov	<5	5-20	>20	%cov	<5	5-20	>20	%cov	<5	5-20	>20	%cov
dead trees																	

Biodiversity Monitoring survey – VRD 2002

STATION:	**SITE:**	**SECTOR:** C NE SE SW NW
DATE:	**OBSERVER:**	

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
dung (0-2)																									
tracks (0-3)																									
grazing (0-4)																									
soil cov																									
rock cov																									
litter cov																									
u/s (<1m) cov																									
trees cr (+/-)																									
tall shrubs cr (+/-)																									
shrubs<1m cov																									
herb cov																									
per. gr cov																									
chry fall																									
hete cont																									
sehi nerv																									
dich fecu																									
aris inae																									
aris lati																									
erag falc																									
eria obtu																									
unidentifiable pg																									
fpg cov																									
enne purp																									
enne poly																									
aris hola																									
aris cont																									
unidentifiable fpg																									
ann. gr cov																									
brac conv																									
sorg timo																									
mnes form																									
dich seri																									
aris hygr																									
schi frag																									
isei sp.																									
unidentifiable ag																									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**

0=none; 1=0-1%; 2=1-5%; 3=5-25%; 4=25-50%; 5=50-75%; 6=75-95%; 7=>95% (* in brackets if not rooted in quadrat)

Biodiversity Monitoring Survey 2002/3 - Groundlayer Floristic Data

STATION:	SITE:	DATE:	OBSERVER:

species	coll	%cov	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
species	coll	%cov	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

1=0-1%; 2=1-5%; 3=5-25%; 4=25-50%; 5=50-75%; 6=75-95%; 7=>95%

Appendix 2. Description of VRD pilot study.

Modified from a presentation by Robert Karfs & Alaric Fisher: "*Land condition, landscape function and biodiversity 'health' in savanna rangelands*", Landscape Heterogeneity Conference, Darwin, July 2002.

Land condition, landscape function and biodiversity 'health' in savanna rangelands

A pilot study in the Victoria River District, NT

Alaric Fisher & Robert Karfs

NT Dept. of Infrastructure, Planning & Environment
Tropical Savannas CRC
Land and Water Australia

Tropical Savannas CRC

TROPICAL SAVANNAS CRC

Land & Water AUSTRALIA research • development • innovation

Landscape heterogeneity conference 2002

'Landscape health'

Savanna Health:

Maintains basic functions at all spatial scales including nutrient cycling, water capture and provision of food and shelter for fauna

Maintains viable populations of all native species of plants and animals at appropriate space and time scales

Reliably meets the long-term needs (material, aesthetic and spiritual) of people who have an ongoing interest in the savannas

Tropical Savannas CRC

Tropical Savannas CRC

Landscape heterogeneity conference 2002

Biodiversity "health"

Questions:

- What is the strength & form of the relationship between landscape function/condition & biodiversity ?
- Given the increasing desire/requirement to monitor biodiversity 'health" (in rangelands), can remote sensing techniques be used as a tool to infer biodiversity values over the broad landscape?

Issues:

- response is different for different ecosystems
  - " is different for different time scales
  - " is different for different taxonomic groups

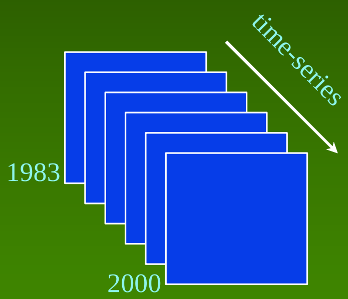
Tropical Savannas CRC

Landscape heterogeneity conference 2002

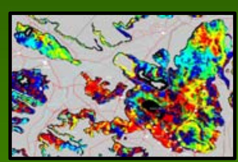
Remote Sensing

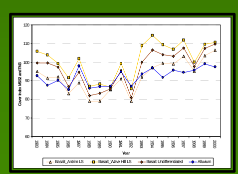
- cover change analysis for summarising sequences of Landsat imagery over many years (Wallace et al. 1994)

Raw Landsat Data | Data Calibration | Product



map





graph

Tropical Savannas CRC

Landscape heterogeneity conference 2002

Sample Design

- 45 sites on 5 stations
- ‘good’ & ‘poor’ sites at each station
  - – selected from satellite trend maps + visual confirmation
- sites selected to be ~comparable for:
  - – soil type
  - – land unit
  - – vegetation structure
  - – dominant plant species
  - – fire history
- sampling conducted in 1999

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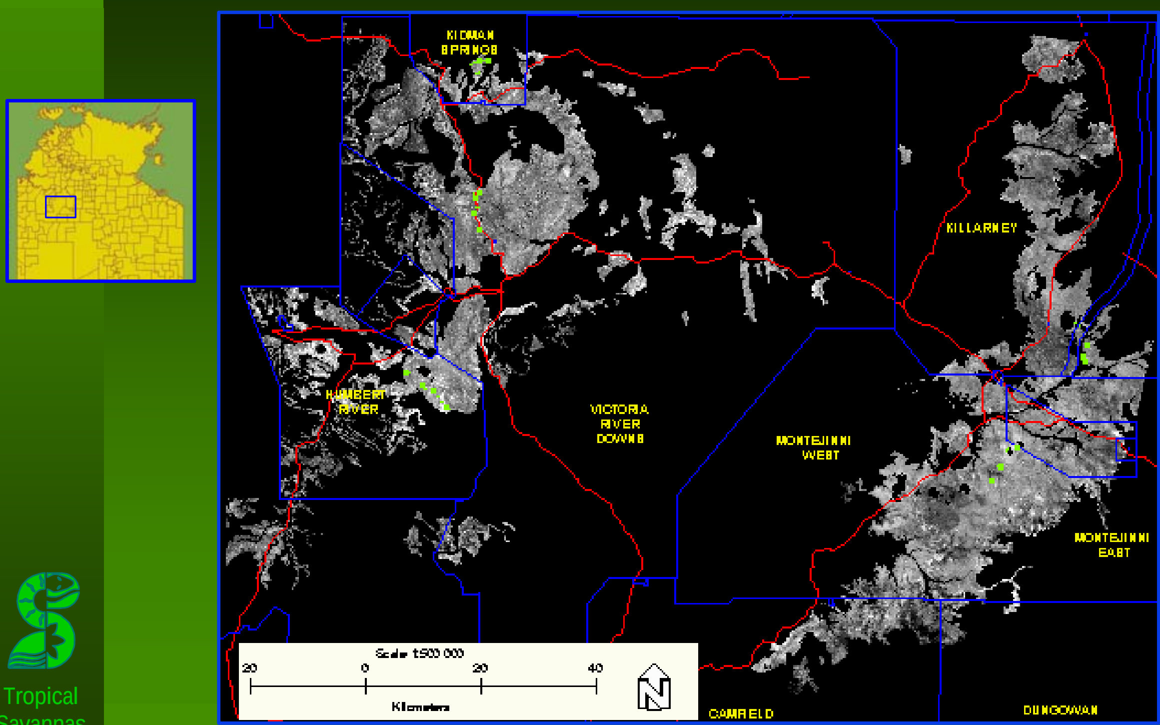
Distribution of Calcareous Landscapes and Site Locations



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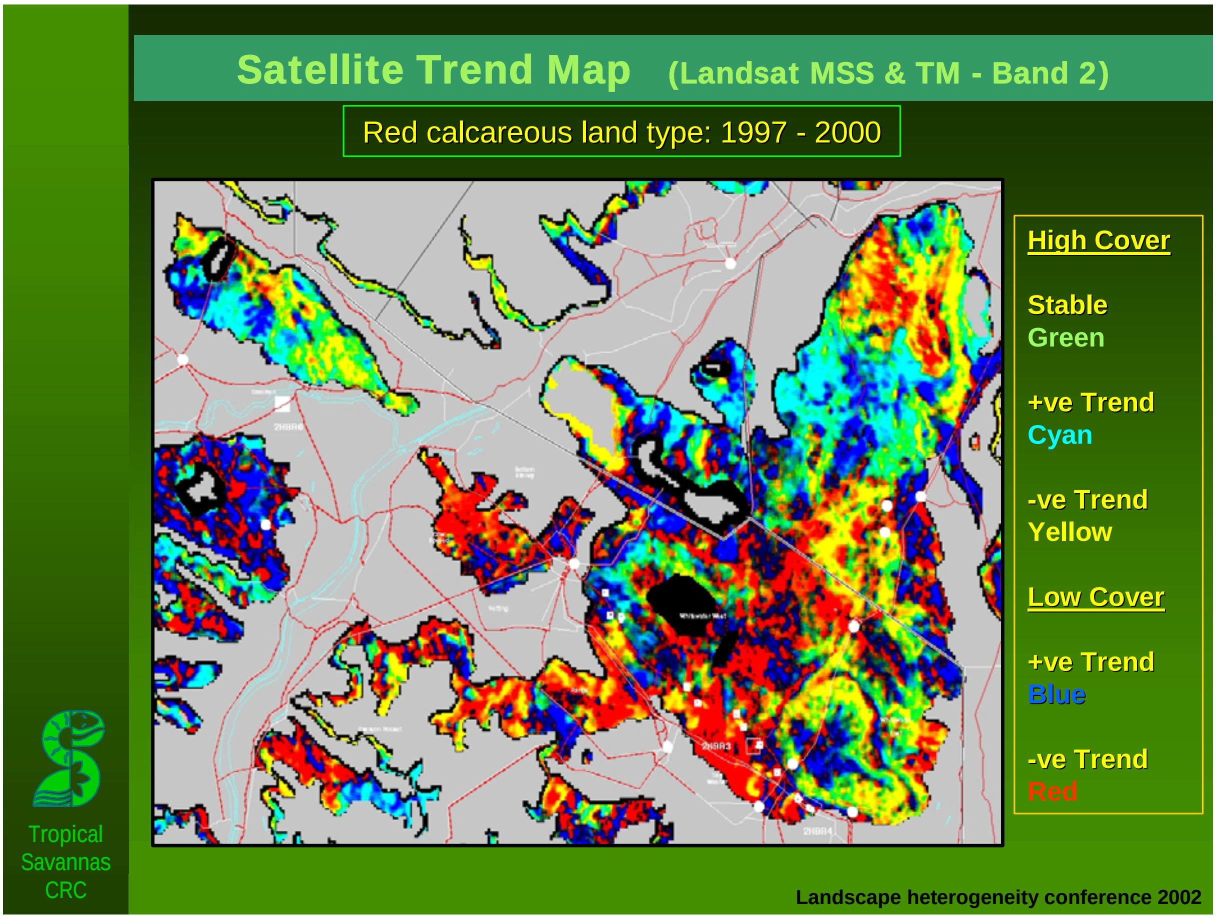
Satellite Trend Map (Landsat MSS & TM - Band 2)
Red calcareous land type: 1997 - 2000
High Cover
Stable
Green
+ve Trend
Cyan
-ve Trend
Yellow
Low Cover
+ve Trend
Blue
-ve Trend
Red
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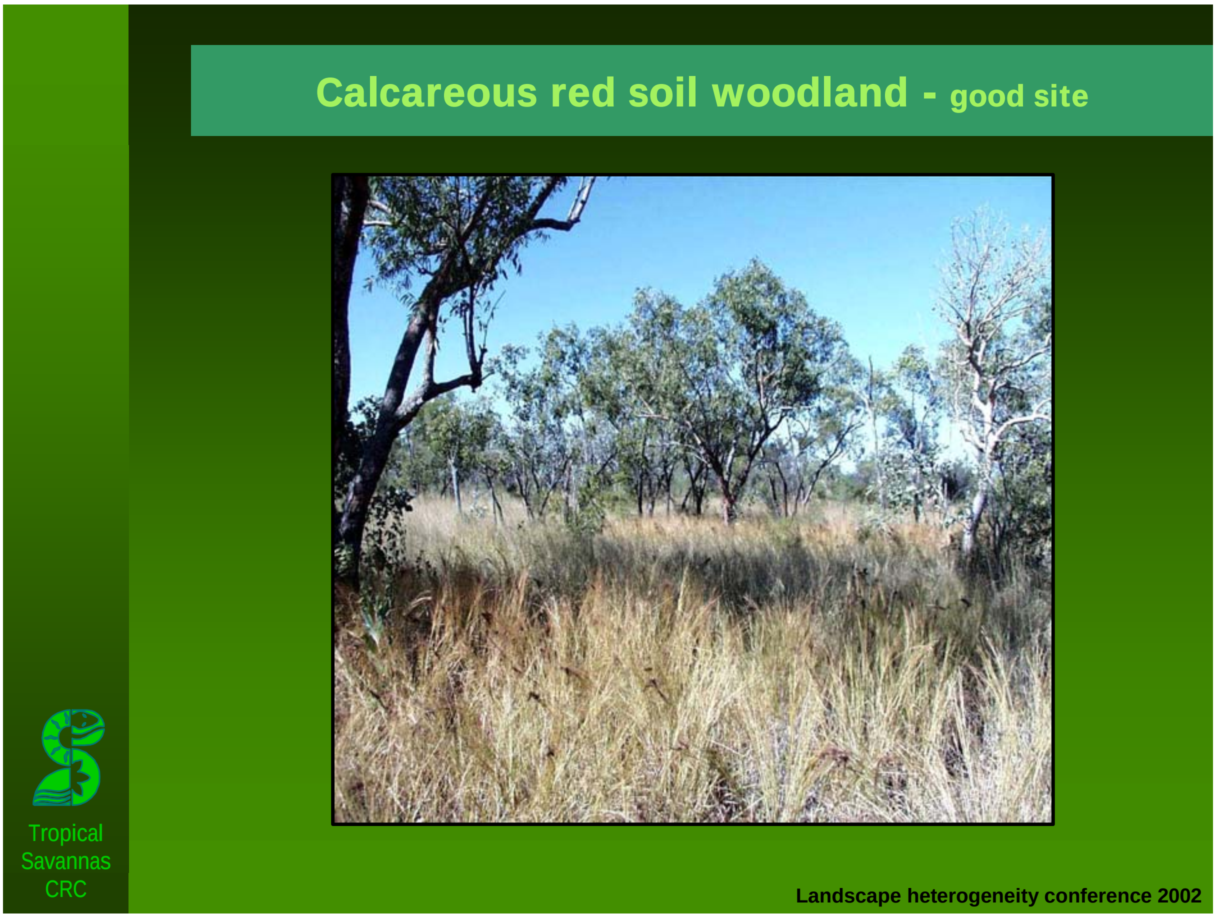
Calcareous red soil woodland - good site
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Calcareous red soil woodland - poor site

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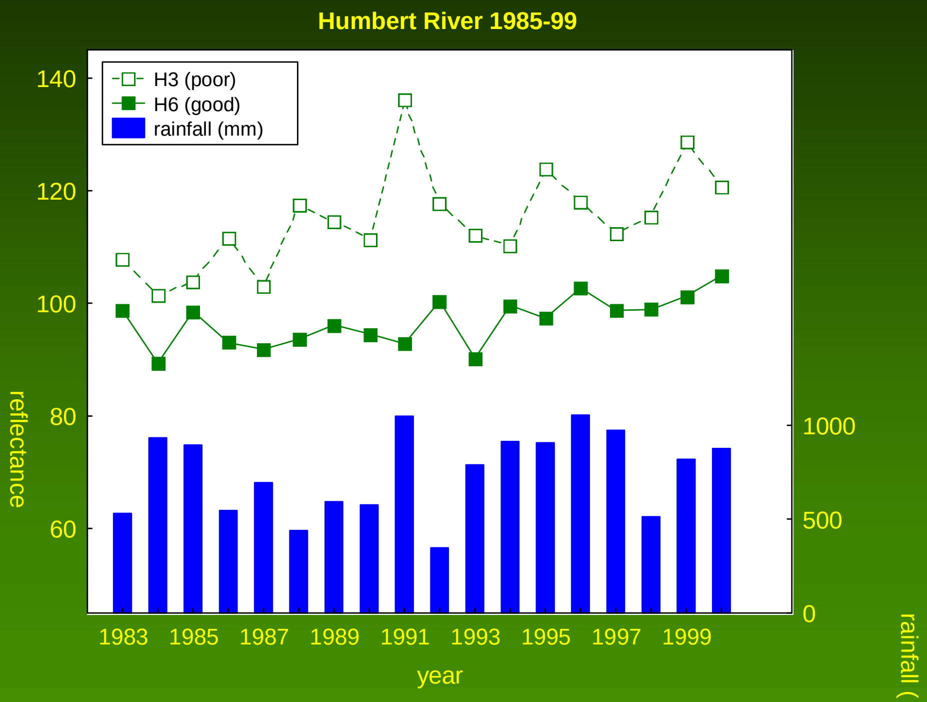
Time-trend analysis (Site scale = 1ha)



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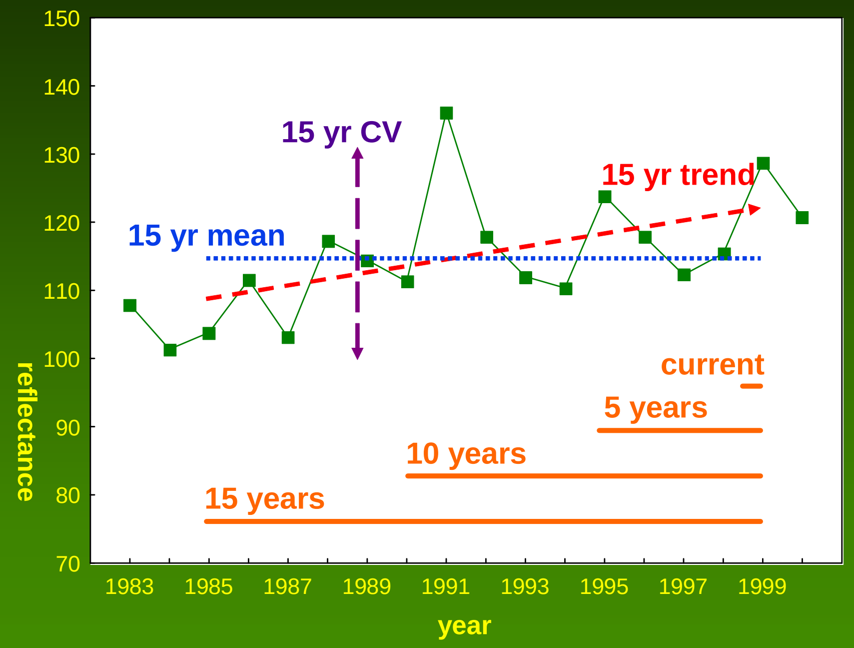
Condition - time scales



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Remotely-sensed variables of sites over different time scales

- reflectance late 99

- mean reflectance 95-99
- mean reflectance 90-99
- mean reflectance 85-99

- CV of reflectance 95-99
- CV of reflectance 90-99
- CV of reflectance 85-99

- significant trend (slope) 95-99
- significant trend (slope) 90-99
- significant trend (slope) 85-99

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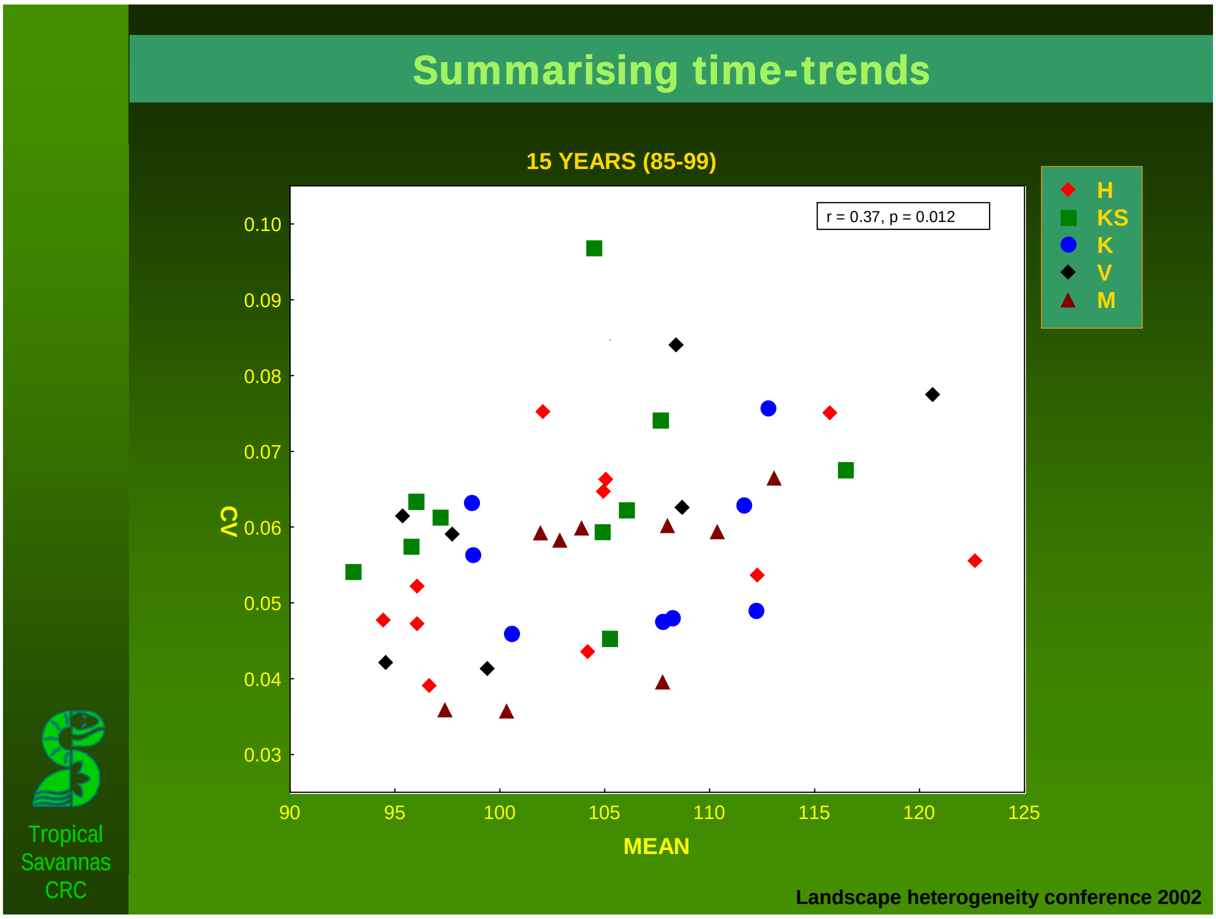
Summarising time-trends
15 YEARS (85-99)
r = 0.37, p = 0.012
H
KS
K
V
M
CV
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
90
95
100
105
110
115
120
125
MEAN
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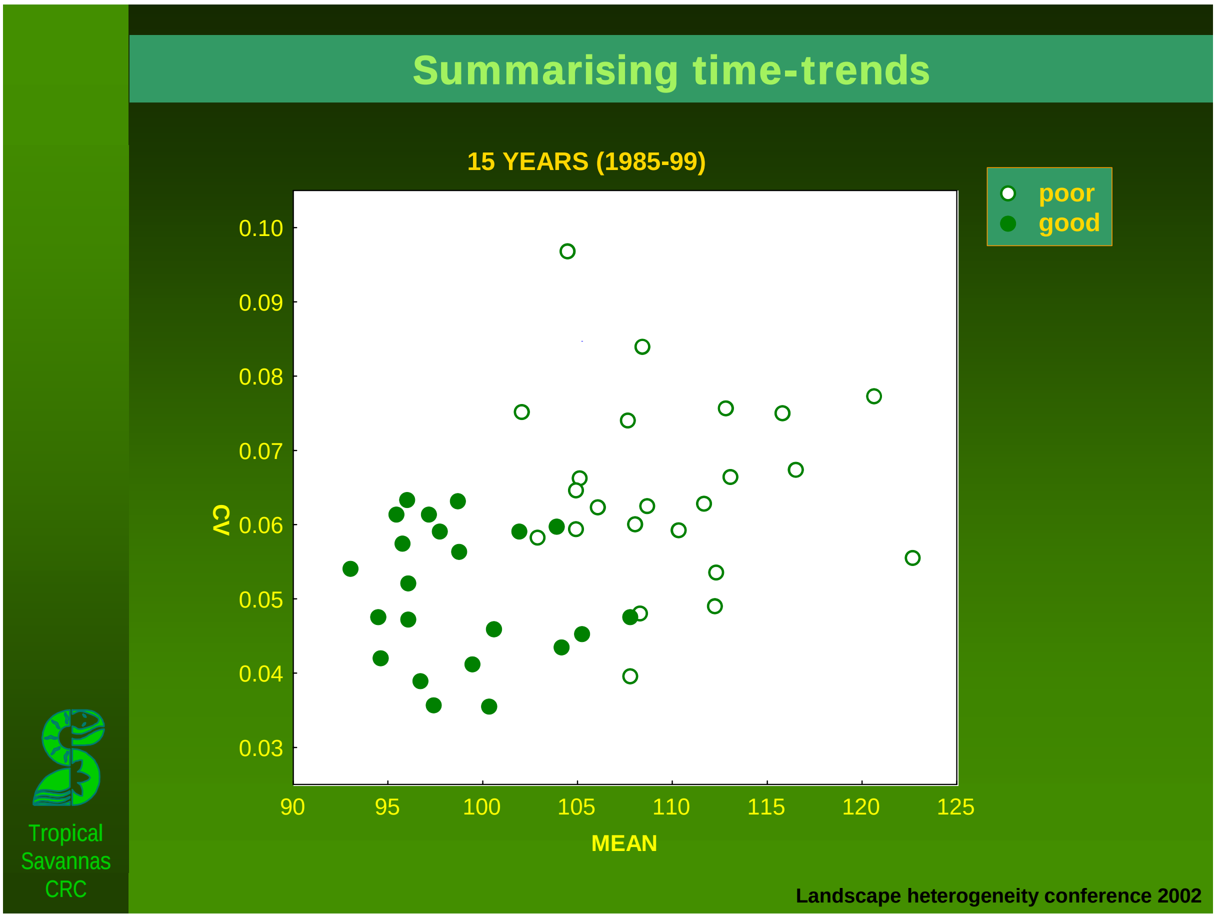
Summarising time-trends
15 YEARS (1985-99)
poor
good
CV
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
90
95
100
105
110
115
120
125
MEAN
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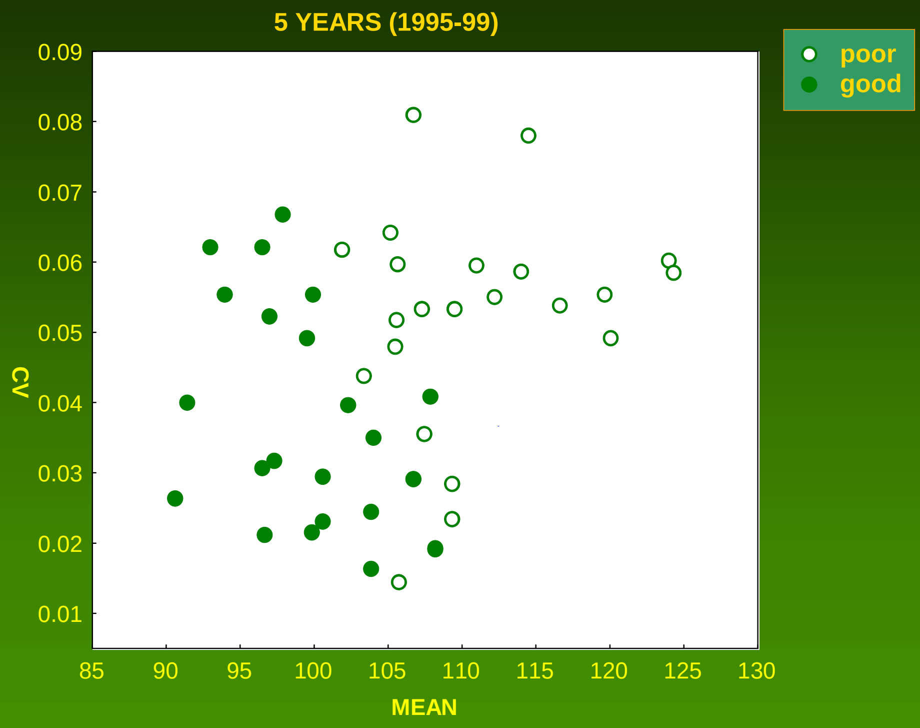
Summarising time-trends



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Biodiversity sampling

1 hectare quadrats

3 day sample period

vertebrates

birds: visual/aural counts (x8)

reptiles: pit traps + day/night searches

mammals: Elliott + pit traps

invertebrates

ants: collected from pit traps

large beetles: " "

scorpions: " "

centipedes: " "

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Biodiversity sampling

vascular plants

floristic composition: all species in quad + visual cover estimate

vegetation structure: canopy cover at 4 heights (Bitterlich) + basal area + ground cover by growth-form (point-transect)

other environmental attributes

- % rock cover
- % bare ground
- cattle use (pats, tracks, grazing)
- fire impact
- etc.

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Species tallies

	total spp.	in 5+ sites	in 1 site
plants	235	124	59
an. grasses	18	9	7
pe. grasses	19	10	5
forbs	118	58	30
shrubs	42	21	9
trees	30	18	6
vertebrates	113	52	33
birds	73	42	15
reptiles	32	10	14
(mammals)	8	0	4
ants	50	16	18
(beetles)	25	3	16
Carabidae	11	2	6
(centipedes)	4	2	2
(scorpions)	4	1	2

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Analysis approach

1. Simple comparison between "good" / "poor" sites interpreted from satellite trend maps
2. Model relationship with remote-sensed condition variables

for

a) overall composition
 - broken down into groups / guilds / life-form

b) total richness & abundance
 - broken down into groups / guilds / life-form

c) relative abundance of individual species

\+ d) vegetation structure & other environmental variables.

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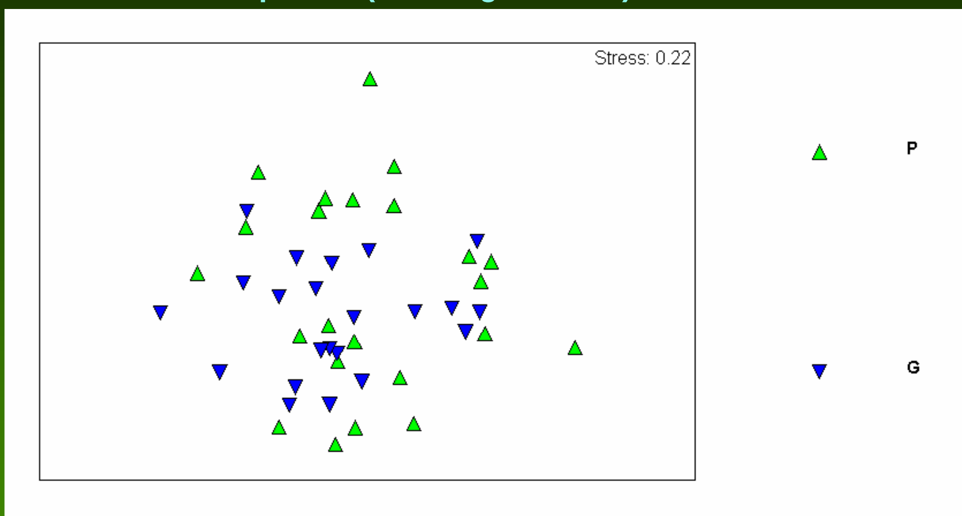
Overall composition

Ordination for all plants (showing location)



- no obvious separation of good and poor condition sites
- obscured in (2D) ordination by location effect

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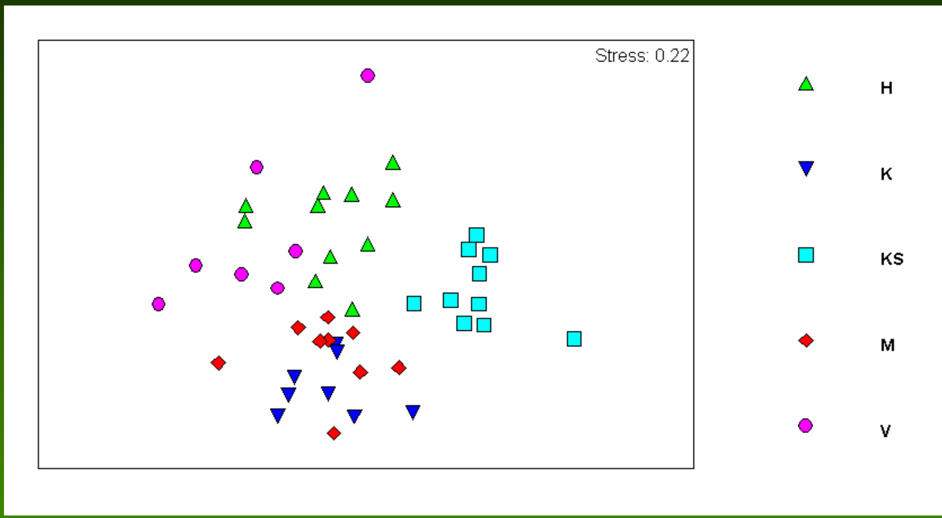
Overall composition

Ordination for all plants (showing location)



- pronounced location effect
- evident for all taxonomic groups / functional groups (except ants)

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Overall composition

2-way ANOSIM (separates location & condition effect)

Group analysed	significance of effect (P)	
	CONDITION	LOCATION
all plants	*0.003*	*0.001*
u/s plants	*0.001*	*0.001*
vertebrates	*0.004*	*0.001*
birds	*0.006*	*0.001*
bird guild richness	*0.015*	*0.001*
ants	*0.55*	*0.08*
ant functional gps	*0.64*	*0.10*

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Overall composition

1-way ANOSIM (for <u>condition</u> effect)
with a separate analysis for each station

location	significance of effect (P)			
	plants	u/s plants	verts	bird guilds
Humbert River	*0.07*	*0.05*	*0.01*	*0.03*
Killarney	*0.17*	*0.23*	*0.63*	*0.83*
Kidman Springs	*0.06*	*0.04*	*0.21*	*0.07*
Montejinni	*0.73*	*0.38*	*0.25*	*0.28*
VRD	*0.06*	*0.06*	*0.06*	*0.03*

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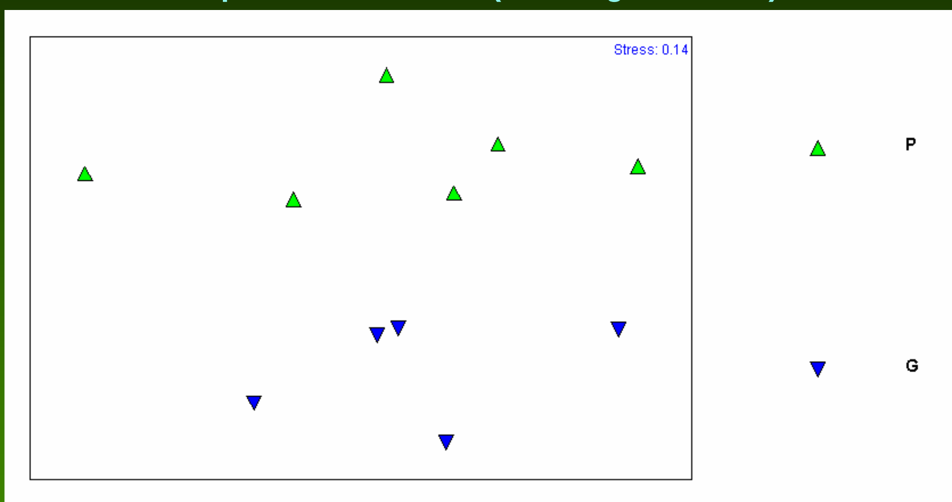
Overall composition

Ordination for plants at HR sites (showing condition)



- Clear "condition" effect on composition of <u>understorey plants</u> and <u>birds</u> at some stations, but not all.

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Total richness / abundance
by taxonomic / functional groups

Plants	Vertebrates	Ants
annual grass	bird	DD
facultative perennial grass	reptile	SC
perennial grass	mammal	GM
annual herb	aerial insectivore	SP
facultative perennial herb	foliage insectivore / nectarivore	OP
perennial herb	frugivore	HC
shrub	foliage & trunk insectivore	
tree	ground insectivore	
	granivore	
	raptor	

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Total richness / abundance
by taxonomic / functional groups

- For simple "good" / "poor" comparison, there was no significant effect for any variable except:
  - perennial grass cover (+ *good sites*)
  - facultative perennial grass cover (+ *poor sites*)
  - tree cover (+ *good sites*)
  - tree richness (+ *good sites*)

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Total richness / abundance
by taxonomic / functional groups

- Improved analysis: General Linear Model (GLM) that includes terms for condition, location and canopy cover
- Showed complex condition x location interactions for:
  - vertebrate richness & abundance
  - bird richness & abundance
  - richness of foliage insectivores/nectarivores
  - richness and abundance of frugivores
  - richness & abundance of granivores
  - tree richness & cover

ie. some significant, but complex, effects for birds but not for plants or ants

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Total richness / abundance
by taxonomic / functional groups

- Model relationship between remote-sensed variables & total richness/abundance (including term for location)
- remote-sensed variables have significant predictive power for many groups:
  - vertebrate richness & abundance
  - bird richness & abundance
  - reptile richness & abundance
  - some bird guilds, reptile families & dasyurid mammals
  - 2 ant functional groups
  - plant richness
  - richness & cover of most plant life-forms

Many of these models are quite weak, and some are complex (greater sample size needed?)

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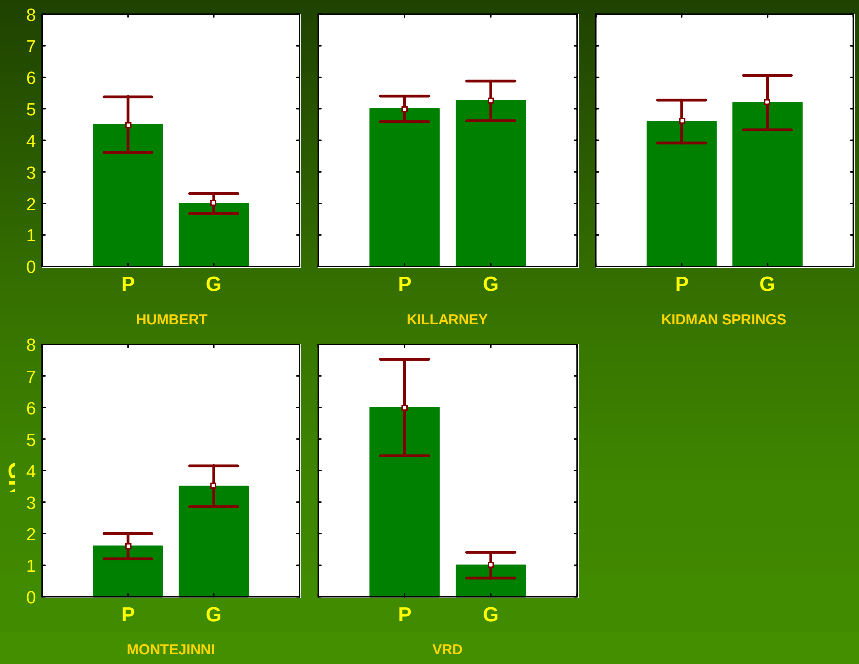
Total richness / abundance
by taxonomic / functional groups

Granivorous bird richness by condition x location



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Species-level responses

- Tested all species occurring in at least 5 sites:
  – 49 vertebrates
  – 123 plants
  – 16 ants
- In a simple comparison between "good / poor" sites, there were significant difference in abundance for:
  – 3 vertebrates (birds)
  – 19 plants
  – no ants

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Species-level responses

- Model relationship between <u>remote-sensed variables</u> & <u>abundance of individual species</u> (including term for location)
- remote-sensed variables have significant predictive power for many species:
  - 20 vertebrates (41%)
  - 56 plants (46%)
  - 7 ants (44%)
- although many of these models are weak, and can have a complex number of terms
- relationships can be summarised by putting species in "condition space"

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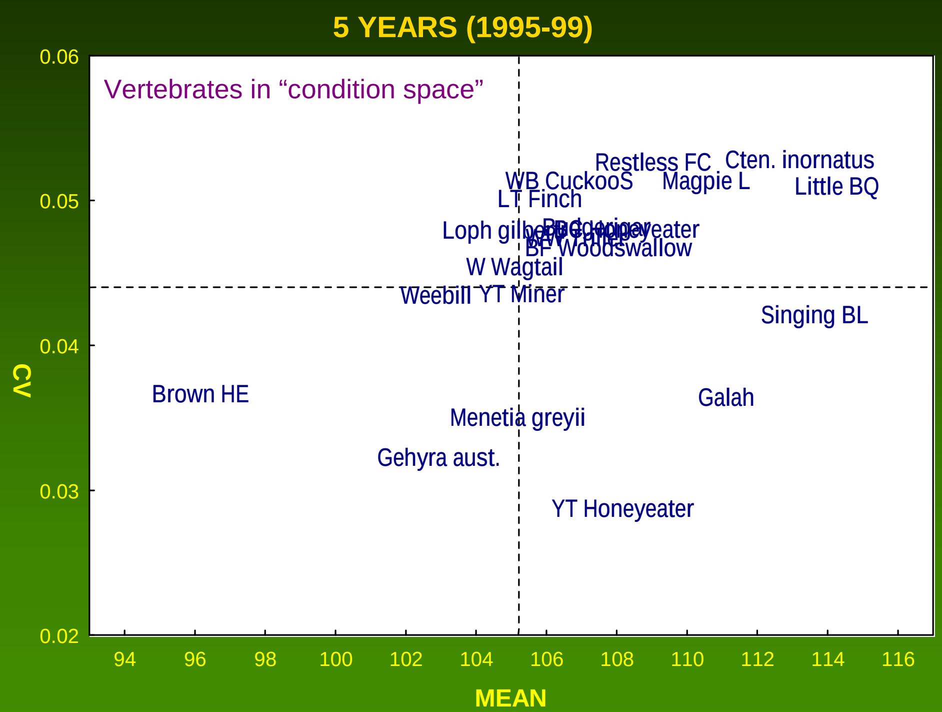
Species-level responses



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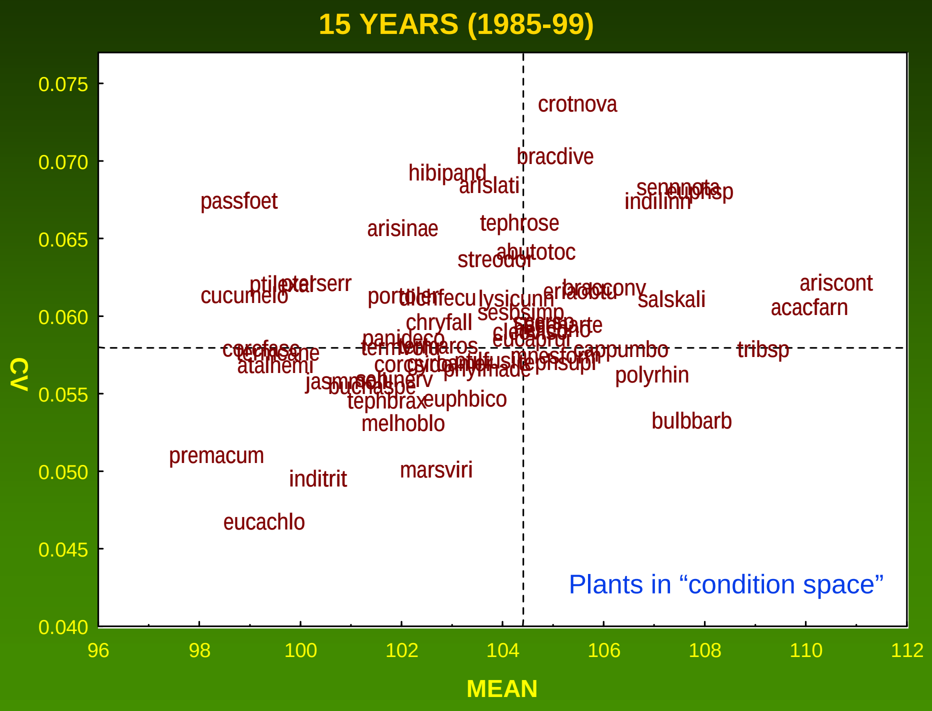
Species-level responses



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Conclusions

- Coarse ‘good and poor’ classes were related to overall composition of birds and understorey plants at some properties only
- Remotely-sensed condition variables had some predictive power for richness/abundance of many groups & many more common species

- Interpretation of condition is complex
  - requires good environmental stratification
  - requires a good understanding of the area, rainfall history, fire history, etc.
  - spatial patterns in red-soil country are more intricate than black-soil
- Linking biodiversity health to land condition is very complex
  - strong interaction between location and condition trends
  - appropriate scale to compare condition - pixel, local, paddock, property?
  - complex spatial patterns of condition in red-soils
- Further investigation is required

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Further research

- Further sampling in VRD in 2002/3
- careful selection of large areas in range of condition
- more intensive sampling of biota, including termites
- include on-ground assessment of landscape function (LFA)

- incorporate consideration of spatial patterning of condition
- paddock- and property-scale difference in mean condition
- what is the importance of improving or worsening trend?

- widen study to other environments / climatic zones / grazing systems

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Appendix 3. Species recorded from sample sites.

Plants

LF is lifeform, used to group species for analysis (af=annual forb, ag=annual grass, fpg=facultative perennial grass, pf=perennial forb, pg=perennial grass, s=sedge, sh=shrub, tr=tree). The number of sites in each landtype from which each species was recorded is given (L=NT loam, C=NT clay, B=QLD basalt, S=QLD sedimentary, A=QLD alluvial).

Family	Species	LF	L	C	B	S	A
ACANTHACEAE	*Brunoniella acaulis*	af				1	21
ACANTHACEAE	*Brunoniella australis*	af			37	19	8
ACANTHACEAE	*Rostellularia adscendens*	pf	2	7	21	6	7
ADIANTACEAE	*Cheilanthes sieberi*	af				1	
AIZOACEAE	*Trianthema patellitecta*	pf	2				
AIZOACEAE	*Trianthema triquetra*	af			15		
AIZOACEAE	*Zaleya galericulata*	pf		1			
AMARANTHACEAE	*Achyranthes aspera*	af	13	16			
AMARANTHACEAE	*Alternanthera dentata*	af *				1	1
AMARANTHACEAE	*Alternanthera nana*	af	9	5			
AMARANTHACEAE	*Alternanthera nodiflora*	af	1		36	16	12
AMARANTHACEAE	*Alternanthera pungens*	af *	2	2			
AMARANTHACEAE	*Alternanthera sp. (Mt Isa R.L.Specht+ 49)*	af					1
AMARANTHACEAE	*Amaranthus sp.*	af	1				
AMARANTHACEAE	*Gomphrena affinis*	af	1				
AMARANTHACEAE	*Gomphrena breviflora*	af		13			
AMARANTHACEAE	*Gomphrena canescens*	af	16	1			
AMARANTHACEAE	*Gomphrena celosioides*	af *			37	8	1
AMARANTHACEAE	*Gomphrena lanata*	af	5				
AMARANTHACEAE	*Ptilotus corymbosus*	af	2				
AMARANTHACEAE	*Ptilotus exaltatus*	pf	1	1			
AMARANTHACEAE	*Ptilotus fusiformis*	af	28				
AMARANTHACEAE	*Ptilotus spicatus*	af	1	31			
ANNONACEAE	*Desmos sp. (Mossman River L.W.Jessup 550)*	pf			2		1
ANNONACEAE	*Polyalthia sp. (Wyvuri B.P.Hyland RFK2632)*	af			3		3
APOCYNACEAE	*Carissa lanceolata*	sh	30	8			
APOCYNACEAE	*Carissa ovata*	sh				24	18
APOCYNACEAE	*Wrightia saligna*	tr	4		7	10	1
ASCLEPIADACEAE	*Calotropis procera*	sh *	4	27			
ASCLEPIADACEAE	*Marsdenia australis*	pf	3		31		1
ASCLEPIADACEAE	*Marsdenia sp.*	pf	9				
ASCLEPIADACEAE	*Marsdenia viridiflora*	pf	1				
ASTERACEAE	*Acanthospermum hispidum*	af *				1	
ASTERACEAE	*Acmella grandiflora*	af			9	2	
ASTERACEAE	*Bidens bipinnata*	af *	7				
ASTERACEAE	*Blumea saxatilis*	af	2		2		
ASTERACEAE	*Blumea tenella*	af	17	32	2		
ASTERACEAE	*Camptacra barbata*	af			3		
ASTERACEAE	*Centipeda racemosa*	af			19		
ASTERACEAE	*Cyanthillium cinereum*	pf			3	2	1
ASTERACEAE	*Epaltes australis*	af					1
ASTERACEAE	*Flaveria australasica*	af		1			
ASTERACEAE	*Pentalepis ecliptoides*	af		36			
ASTERACEAE	*Pterocaulon redolens*	af				1	
ASTERACEAE	*Pterocaulon serrulatum*	af	18		18	1	1
ASTERACEAE	*Pterocaulon sphacelatum*	af	1	3	2		8
ASTERACEAE	*Streptoglossa bubakii*	pf		17			
ASTERACEAE	*Streptoglossa odora*	pf	3				

Family	Species	LF	L	C	B	S	A
ASTERACEAE	*Streptoglossa sp.*	pf	7				
ASTERACEAE	*Tridax procumbens*	pf *			1		
ASTERACEAE	*Wedelia aff. verbesinoides*	pf	15				
ASTERACEAE	*Wedelia asperrima*	pf		51			
ASTERACEAE	*Wedelia spilanthoides*	pf			11		
BIGNONIACEAE	*Dolichandrone heterophylla*	tr	23	2			
BIXACEAE	*Cochlospermum fraseri*	sh	1				
BORAGINACEAE	*Ehretia saligna*	tr	13				
BORAGINACEAE	*Heliotropium brachythrix*	af	3				
BORAGINACEAE	*Heliotropium conocarpum*	af		1			
BORAGINACEAE	*Heliotropium dichotomum*	af	14				
BORAGINACEAE	*Heliotropium foveolatum*	af	12				
BORAGINACEAE	*Heliotropium peninsulare*	af			2		
BORAGINACEAE	*Heliotropium plumosum*	af	13	20			
BORAGINACEAE	*Heliotropium ramulipatens*	af	4				
BORAGINACEAE	*Heliotropium sp.*	af	1	7			
BORAGINACEAE	*Heliotropium tabuliplagae*	af			9		6
BORAGINACEAE	*Heliotropium tachyglossoides*	af	1				
BORAGINACEAE	*Heliotropium tenuifolium*	af		3			6
BORAGINACEAE	*Trichodesma zeylanicum*	af	13	57			
CAESALPINIACEAE	*Bauhinia cunninghamii*	tr	18	18			
CAESALPINIACEAE	*Chamaecrista absus*	af			12		8
CAESALPINIACEAE	*Chamaecrista concinna*	af				3	
CAESALPINIACEAE	*Chamaecrista mimosoides*	af			7	1	
CAESALPINIACEAE	*Chamaecrista nomame*	af			5	8	
CAESALPINIACEAE	*Erythrophleum chlorostachys*	tr	2				
CAESALPINIACEAE	*Lysiphyllum carronii*	tr			4	2	3
CAESALPINIACEAE	*Senna artemisioides*	sh	1				
CAESALPINIACEAE	*Senna glutinosa*	sh	3				
CAESALPINIACEAE	*Senna notabilis*	sh	18	1			
CAESALPINIACEAE	*Senna planitiicola*	sh	5	3			
CAESALPINIACEAE	*Senna sp. (unidentified)*	sh			13		1
CAMPANULACEAE	*Lobelia leucotos*	af				1	
CAPPARACEAE	*Capparis lasiantha*	sh	2	1	4		5
CAPPARACEAE	*Capparis sp. (unidentified)*	sh					1
CAPPARACEAE	*Capparis umbonata*	tr	4				
CAPPARACEAE	*Cleome oxalidea*	af	1				
CAPPARACEAE	*Cleome sp.*	af		1			
CAPPARACEAE	*Cleome viscosa*	af	24	10			
CARYOPHYLLACEAE	*Polycarpaea breviflora*	af	1				
CARYOPHYLLACEAE	*Polycarpaea corymbosa*	af	12				1
CARYOPHYLLACEAE	*Polycarpaea longiflora*	af					5
CARYOPHYLLACEAE	*Polycarpaea sp.*	af	1				
CELASTRACEAE	*Maytenus cunninghamii*	sh					14
CHENOPODIACEAE	*Enchylaena tomentosa*	pf				15	1
CHENOPODIACEAE	*Salsola tragus*	af	3		32	18	
COMBRETACEAE	*Terminalia aridicola*	tr					14
COMBRETACEAE	*Terminalia arostrata*	tr	9	47			
COMBRETACEAE	*Terminalia bursarina*	tr		3			
COMBRETACEAE	*Terminalia canescens*	tr	2				
COMBRETACEAE	*Terminalia oblongata*	tr					2
COMBRETACEAE	*Terminalia volucris*	tr	11	33			
COMMELINACEAE	*Commelina ciliata*	af	1	11			
COMMELINACEAE	*Commelina ensifolia*	af		52	1		1
CONVOLVULACEAE	*Bonamia media*	pf	22		1		1
CONVOLVULACEAE	*Bonamia pannosa*	pf	28	3			

Family	Species	LF	L	C	B	S	A
CONVOLVULACEAE	*Evolvulus alsinoides*	af	31	13		1	22
CONVOLVULACEAE	*Ipomoea diamantinensis*	af		1			
CONVOLVULACEAE	*Ipomoea diversifolia*	af	10	5	10	11	5
CONVOLVULACEAE	*Ipomoea eriocarpa*	af	15	1			
CONVOLVULACEAE	*Ipomoea lonchophylla*	af		10			
CONVOLVULACEAE	*Ipomoea nil*	af		2			
CONVOLVULACEAE	*Ipomoea plebeia*	af		1	2		4
CONVOLVULACEAE	*Ipomoea polpha*	af			20	1	
CONVOLVULACEAE	*Ipomoea polymorpha*	af	25	3	5		
CONVOLVULACEAE	*Ipomoea sp. (unidentified)*	af			32	1	1
CONVOLVULACEAE	*Jacquemontia browniana*	af	1	53			
CONVOLVULACEAE	*Jacquemontia paniculata*	af			6		3
CONVOLVULACEAE	*Operculina aequisepala*	af		1			
CONVOLVULACEAE	*Polymeria ambigua*	af	27	54	14	5	2
CONVOLVULACEAE	*Polymeria longifolia*	af	5	6			
CONVOLVULACEAE	*Polymeria pusilla*	af				1	
CONVOLVULACEAE	*Xenostegia tridentata*	af	8				3
CUCURBITACEAE	*Citrullus colocynthis*	af *	1				
CUCURBITACEAE	*Cucumis anguria*	af				1	
CUCURBITACEAE	*Cucumis melo*	af	2	48			
CUCURBITACEAE	*Mukia maderaspatana*	af			15		
CYPERACEAE	*Bulbostylis barbata*	as	15	16			
CYPERACEAE	*Cyperus bifax*	ps		35			
CYPERACEAE	*Cyperus fulvus*	as				1	
CYPERACEAE	*Cyperus gracilis*	as			18	7	
CYPERACEAE	*Cyperus pulchellus*	as			18	23	5
CYPERACEAE	*Fimbristylis cardiocarpa*	as		4			
CYPERACEAE	*Fimbristylis dichotoma*	ps		2		1	22
CYPERACEAE	*Fimbristylis microcarya*	as	1				
CYPERACEAE	*Fimbristylis schultzii*	as		22			
CYPERACEAE	*Fimbristylis sp. (annual)*	as	1				
CYPERACEAE	*Fimbristylis sp. (unidentified)*	as			4	5	2
CYPERACEAE	*Scleria brownii*	ps				9	
ELATINACEAE	*Bergia pedicellaris*	af		6			
ELATINACEAE	*Bergia trimera*	af			1	7	
ERYTHROXYLACEAE	*Erythroxylum australe*	sh				16	2
EUPHORBIACEAE	*Breynia oblongifolia*	sh			35	5	1
EUPHORBIACEAE	*Cleistanthus sp. unidentified*	af			47	30	1
EUPHORBIACEAE	*Drypetes sp. unidentified*	sh			10	3	2
EUPHORBIACEAE	*Euphorbia alsiniflora*	af		20			
EUPHORBIACEAE	*Euphorbia australis*	af			22	5	
EUPHORBIACEAE	*Euphorbia biconvexa*	sh	27				
EUPHORBIACEAE	*Euphorbia comans*	af	1				
EUPHORBIACEAE	*Euphorbia dallachyana*	af			6		
EUPHORBIACEAE	*Euphorbia drummondii*	af				4	4
EUPHORBIACEAE	*Euphorbia hirta*	af *	1		16	1	
EUPHORBIACEAE	*Euphorbia maconochieana*	af		45			
EUPHORBIACEAE	*Euphorbia mitchelliana*	af				1	1
EUPHORBIACEAE	*Euphorbia schizolepis*	pf		25			
EUPHORBIACEAE	*Euphorbia schultzii*	af			14		
EUPHORBIACEAE	*Euphorbia schultzii / drummondii*	af	22				
EUPHORBIACEAE	*Euphorbia sp.*	af	5				
EUPHORBIACEAE	*Euphorbia sp. JR1*	af	10				
EUPHORBIACEAE	*Euphorbia sp. unidentified*	af			44	20	7
EUPHORBIACEAE	*Euphorbia stevenii*	af		11			
EUPHORBIACEAE	*Euphorbia tannensis*	pf					1

Family	Species	LF	L	C	B	S	A
EUPHORBIACEAE	*EUPHORBIACEAE sp.*	af	1				
EUPHORBIACEAE	*Excoecaria agallocha*	sh			30	10	
EUPHORBIACEAE	*Excoecaria parvifolia*	tr		1			
EUPHORBIACEAE	*Flueggea virosa*	sh	23				
EUPHORBIACEAE	*Leptopus decaisnei*	af	19	1			
EUPHORBIACEAE	*Petalostigma pubescens*	tr					10
EUPHORBIACEAE	*Petalostigma quadriloculare*	tr				6	1
EUPHORBIACEAE	*Phyllanthus carpentariae*	af					4
EUPHORBIACEAE	*Phyllanthus fuernrohrii*	af					3
EUPHORBIACEAE	*Phyllanthus maderaspatensis*	af	14	60	1	16	1
EUPHORBIACEAE	*Phyllanthus novae-hollandiae*	af					1
EUPHORBIACEAE	*Phyllanthus sp.*	af	3	2			
EUPHORBIACEAE	*Phyllanthus virgatus*	af				11	3
EUPHORBIACEAE	*Sauropus elachophyllus*	pf			15		14
EUPHORBIACEAE	*Sauropus trachyspermus*	pf	15	8			1
FABACEAE	*Aeschynomene indica*	af		1			
FABACEAE	*Alysicarpus muelleri*	af	11	41			
FABACEAE	*Crotalaria brevis*	af	1		1		
FABACEAE	*Crotalaria calycina*	pf				3	
FABACEAE	*Crotalaria goreensis*	pf *			2	1	
FABACEAE	*Crotalaria juncea*	pf *			4		
FABACEAE	*Crotalaria medicaginea*	pf	35	34	11		
FABACEAE	*Crotalaria mitchellii*	af			28	14	
FABACEAE	*Crotalaria montana*	pf	16	16	1		3
FABACEAE	*Crotalaria novae-hollandiae*	af			29	1	
FABACEAE	*Crotalaria retusa*	af	1				
FABACEAE	*Crotalaria verrucosa*	af				1	
FABACEAE	*Cullen balsamicum*	sh		3			
FABACEAE	*Cullen plumosum*	af	5				
FABACEAE	*Cullen pustulatum*	pf	4				
FABACEAE	*Desmodium filiforme*	af	3				
FABACEAE	*Desmodium flagellare*	af		5			
FABACEAE	*Desmodium muelleri*	af	3	24	48	33	
FABACEAE	*Flemingia pauciflora*	pf		55			
FABACEAE	*Galactia tenuiflora*	pf	18	1			
FABACEAE	*Glycine falcata*	pf		6			
FABACEAE	*Glycine tomentella*	pf			7	7	14
FABACEAE	*Indigofera colutea*	pf	34	1	6	23	3
FABACEAE	*Indigofera hirsuta*	pf			40	4	
FABACEAE	*Indigofera linifolia*	af	45	37	10	2	2
FABACEAE	*Indigofera linnaei*	pf	25	1	31	9	10
FABACEAE	*Indigofera parviflora*	pf		4	40	24	
FABACEAE	*Indigofera pratensis*	pf			2		
FABACEAE	*Indigofera trita*	pf	9	13			
FABACEAE	*Rhynchosia minima*	pf	29	56		1	14
FABACEAE	*Sesbania cannabina*	af		3			
FABACEAE	*Sesbania simpliciuscula*	af	1	59			
FABACEAE	*Stylosanthes hamata*	pf *	6		1		10
FABACEAE	*Stylosanthes humilis*	pf *					7
FABACEAE	*Stylosanthes scabra*	pf *			18	5	4
FABACEAE	*Stylosanthes viscosa*	pf *			18	15	10
FABACEAE	*Tephrosia brachyodon*	af	2	3			
FABACEAE	*Tephrosia filipes*	af			1		
FABACEAE	*Tephrosia juncea*	af				1	
FABACEAE	*Tephrosia leptoclada*	af			1	10	1
FABACEAE	*Tephrosia rosea*	pf	6	35			

Family	Species	LF	L	C	B	S	A
FABACEAE	*Tephrosia sp.*	pf	1				
FABACEAE	*Tephrosia sp. unidentified*	af			8	1	10
FABACEAE	*Tephrosia supina*	pf	11				
FABACEAE	*Uraria lagopodioides*	af	3		5	6	
FABACEAE	*Vigna lanceolata*	pf	14	1			6
FABACEAE	*Vigna luteola*	pf			25		
FABACEAE	*Vigna radiata*	pf	1		2		
FABACEAE	*Vigna vexillata*	pf			4		
FABACEAE	*Zornia muriculata*	pf	14		6		6
FABACEAE	*Zornia sp. unidentified*	pf			17	16	
GOODENIACEAE	*Goodenia armitiana*	af	2				
GOODENIACEAE	*Goodenia byrnesii*	af	6	39			
GOODENIACEAE	*Goodenia hirsuta*	pf			4		2
GOODENIACEAE	*Goodenia hispida*	af	9				
GOODENIACEAE	*Goodenia odonnellii*	af	9				
GOODENIACEAE	*Goodenia sepalosa*	af		2			
GOODENIACEAE	*Goodenia sp.*	af	4				
GOODENIACEAE	*Scaevola amblyanthera*	pf	2				
HAEMODORACEAE	*Haemodorum coccineum*	pf			39	11	4
HEMEROCALLIDACEAE	*Dianella caerulea*	pf			5	1	
HEMEROCALLIDACEAE	*Tricoryne elatior*	pf			3		5
HERNANDIACEAE	*Gyrocarpus americanus*	tr	26				
LAMIACEAE	*Hyptis suaveolens*	af *	2				
LAMIACEAE	*Ocimum tenuiflorum*	pf		1			
LAMIACEAE	*Teucrium integrifolium*	pf		2			
LAMIACEAE	*unidentified Ocimum*	pf				2	
LAXMANNIACEAE	*Lomandra longifolia*	pf			4		
LAXMANNIACEAE	*Lomandra multiflora*	pf			1		
LORANTHACEAE	*Amyema sanguinea*	sh	1				
LORANTHACEAE	*Lysiana spathulata*	sh	2				
LYTHRACEAE	*Ammannia multiflora*	af	1	14			
MALVACEAE	*Abelmoschus ficulneus*	af		26			
MALVACEAE	*Abutilon andrewsianum*	pf	13	40			
MALVACEAE	*Abutilon otocarpum*	af	23				
MALVACEAE	*Abutilon oxycarpum*	af				1	
MALVACEAE	*Abutilon sp. unidentified*	af				1	1
MALVACEAE	*Gossypium australe*	sh	35				
MALVACEAE	*Hibiscus meraukensis*	af	2		24		3
MALVACEAE	*Hibiscus normanii*	af			8	7	1
MALVACEAE	*Hibiscus panduriformis*	af	1				
MALVACEAE	*Hibiscus pentaphyllus*	af	2	1			
MALVACEAE	*Hibiscus sp. (Emerald S.L.Everist 2124)*	af					3
MALVACEAE	*Hibiscus sturtii*	af					6
MALVACEAE	*Malvastrum americanum*	pf *	6	7			1
MALVACEAE	*Malvastrum coromandelianum*	af *			9	7	
MALVACEAE	*Sida acuta*	pf *	1				
MALVACEAE	*Sida brachypoda*	pf	7				
MALVACEAE	*Sida cordifolia*	pf *	5				2
MALVACEAE	*Sida fibulifera*	pf	30	14	5	9	3
MALVACEAE	*Sida rohlenae*	pf	2				1
MALVACEAE	*Sida sp.*	pf	2				
MALVACEAE	*Sida spinosa*	pf *	36	28		2	19
MALVACEAE	*Sida subspicata*	af			39	27	
MALVACEAE	*Sida trichopoda*	af			4	9	8
MARSILEACEAE	*Marsilea exarata*	af		2			
MELIACEAE	*Owenia acidula*	tr			1		5

Family	Species	LF	L	C	B	S	A
MENISPERMACEAE	*Tinospora smilacina*	pf	26				
MIMOSACEAE	*Acacia ampliceps*	tr		1			
MIMOSACEAE	*Acacia aulacocarpa*	sh			1		
MIMOSACEAE	*Acacia bidwillii*	tr				3	2
MIMOSACEAE	*Acacia colei*	sh	24				
MIMOSACEAE	*Acacia coriacea*	tr	2		4		4
MIMOSACEAE	*Acacia cowleana*	tr	6				
MIMOSACEAE	*Acacia excelsa*	tr					4
MIMOSACEAE	*Acacia farnesiana*	sh *	9				
MIMOSACEAE	*Acacia gonoclada*	sh			2		1
MIMOSACEAE	*Acacia harpophylla*	tr					6
MIMOSACEAE	*Acacia hemignosta*	tr	6				
MIMOSACEAE	*Acacia holosericea*	tr	3	1		1	1
MIMOSACEAE	*Acacia leptocarpa*	sh					1
MIMOSACEAE	*Acacia lysiphloia*	sh	2				
MIMOSACEAE	*Acacia pallidifolia*	tr	1				
MIMOSACEAE	*Acacia sp. unidentified*	sh				1	
MIMOSACEAE	*Acacia victoriae*	tr		4			
MIMOSACEAE	*Dichrostachys spicata*	sh	8	1			
MIMOSACEAE	*Neptunia dimorphantha*	pf	21	15	1	1	1
MIMOSACEAE	*Neptunia gracilis*	pf		8			
MIMOSACEAE	*Neptunia monosperma*	pf		2			
MIMOSACEAE	*Neptunia sp.*	pf	3	6			
MORACEAE	*Ficus aculeata*	tr	1				
MYOPORACEAE	*Eremophila mitchellii*	sh				1	16
MYRTACEAE	*Corymbia citriodora*	tr				1	
MYRTACEAE	*Corymbia clarksoniana*	tr			3	33	9
MYRTACEAE	*Corymbia confertiflora*	tr	7				
MYRTACEAE	*Corymbia dallachiana*	tr					6
MYRTACEAE	*Corymbia erythrophloia*	tr			42	19	
MYRTACEAE	*Corymbia flavescens*	tr	4				
MYRTACEAE	*Corymbia polycarpa*	tr	4		37	8	
MYRTACEAE	*Corymbia sp. (Pentland Hills P.I.Forster+ PIF16644)*	tr			1		1
MYRTACEAE	*Corymbia sp. JR a*	tr	3				
MYRTACEAE	*Corymbia terminalis*	tr	34	22			
MYRTACEAE	*Eucalyptus brownii*	tr			1		16
MYRTACEAE	*Eucalyptus camaldulensis*	tr		1			
MYRTACEAE	*Eucalyptus cambageana*	tr					4
MYRTACEAE	*Eucalyptus chlorophylla*	tr	3				
MYRTACEAE	*Eucalyptus melanophloia*	tr					19
MYRTACEAE	*Eucalyptus patellaris*	tr	2				
MYRTACEAE	*Eucalyptus persistens*	tr				3	
MYRTACEAE	*Eucalyptus pruinosa*	tr	46				
MYRTACEAE	*Eucalyptus shirleyi*	tr				21	
MYRTACEAE	*Eucalyptus sp. (Stannary Hills G.W.Althofer 402)*	tr				22	
MYRTACEAE	*Lophostemon grandiflorus*	tr		2			
MYRTACEAE	*Melaleuca bracteata*	tr		1			
MYRTACEAE	*Melaleuca nervosa*	sh			4	18	5
MYRTACEAE	*unidentified Melaleuca*	sh			1	1	1
NYCTAGINACEAE	*Boerhavia dominii*	pf	16				
NYCTAGINACEAE	*Boerhavia paludosa*	pf	6	41	1		
NYCTAGINACEAE	*Boerhavia schomburgkiana*	pf	4				
NYCTAGINACEAE	*Boerhavia sp.*	pf	6	3			
NYCTAGINACEAE	*Boerhavia sp. unidentified*	pf			6	13	3
OLEACEAE	*Jasminum molle*	sh	4				
ONAGRACEAE	*Ludwigia perennis*	af		4			

Family	Species	LF	L	C	B	S	A
PASSIFLORACEAE	*Passiflora foetida*	pf *	2				
PEDALIACEAE	*Josephinia eugeniae*	af		1			
PITTOSPORACEAE	*Bursaria incana*	tr			9	16	3
PITTOSPORACEAE	*Bursaria tenuifolia*	tr			8	4	1
POACEAE	*Alloteropsis cimicina*	ag			9	10	22
POACEAE	*Aristida calycina*	pg					22
POACEAE	*Aristida holathera*	fpg	26	1	9	19	4
POACEAE	*Aristida hygrometrica*	ag	21				6
POACEAE	*Aristida inaequiglumis*	pg	22				
POACEAE	*Aristida ingrata*	pg					7
POACEAE	*Aristida jerichoensis*	pg			4		1
POACEAE	*Aristida latifolia*	pg	3	61	1	14	1
POACEAE	*Aristida leptopoda*	pg			22		
POACEAE	*Aristida longicollis*	pg			35		
POACEAE	*Aristida perniciosa*	pg			11		
POACEAE	*Aristida pruinosa*	pg	23			4	24
POACEAE	*Aristida sp. unidentified*	pg				29	2
POACEAE	*Astrebla elymoides*	pg		19			
POACEAE	*Astrebla pectinata*	pg		5			
POACEAE	*Bothriochloa bladhii*	pg					1
POACEAE	*Bothriochloa decipiens*	pg			4	1	
POACEAE	*Bothriochloa ewartiana*	pg	3	1	31	34	20
POACEAE	*Bothriochloa pertusa*	fpg *			31	8	15
POACEAE	*Brachyachne convergens*	ag	42	55			
POACEAE	*Cenchrus ciliaris*	pg *	5				14
POACEAE	*Chionachne hubbardiana*	ag		24			
POACEAE	*Chloris lobata*	ag	2				
POACEAE	*Chloris pectinata*	ag				4	3
POACEAE	*Chloris virgata*	ag *			3	3	8
POACEAE	*Chrysopogon fallax*	pg	44	54	1	1	24
POACEAE	*Cymbopogon bombycinus*	pg	3		38	16	1
POACEAE	*Cymbopogon refractus*	pg				4	
POACEAE	*Dactyloctenium aegyptium*	ag *					1
POACEAE	*Dactyloctenium radulans*	ag	1				8
POACEAE	*Dichanthium annulatum*	pg *			12	3	
POACEAE	*Dichanthium fecundum*	pg	19	29	15	1	15
POACEAE	*Dichanthium sericeum*	ag	20	28	31	11	2
POACEAE	*Dichanthium setosum*	pg			32	7	
POACEAE	*Digitaria ammophila*	pg			7		
POACEAE	*Digitaria brownii*	pg				6	23
POACEAE	*Digitaria ciliaris*	ag *				24	
POACEAE	*Digitaria ctenantha*	ag	5				
POACEAE	*Digitaria divaricatissima*	pg			16		6
POACEAE	*Echinochloa colona*	ag		6			
POACEAE	*Enneapogon avenaceus*	fpg					1
POACEAE	*Enneapogon lindleyanus*	fpg			6		3
POACEAE	*Enneapogon pallidus*	pg	17				
POACEAE	*Enneapogon polyphyllus*	fpg	13	3	1	7	21
POACEAE	*Enneapogon purpurascens*	fpg	32	1			
POACEAE	*Enneapogon sp.*	fpg	3	1			
POACEAE	*Enteropogon acicularis*	pg			12	21	6
POACEAE	*Enteropogon ramosus*	pg				2	2
POACEAE	*Eragrostis brownii*	pg			4		
POACEAE	*Eragrostis cilianensis*	ag *				4	
POACEAE	*Eragrostis cumingii*	ag	5				
POACEAE	*Eragrostis lacunaria*	pg			13	1	8

Family	Species	LF	L	C	B	S	A
POACEAE	*Eragrostis setifolia*	pg	1				
POACEAE	*Eragrostis sororia*	pg				20	9
POACEAE	*Eragrostis sp.*	ag	6				
POACEAE	*Eragrostis tenellula*	ag	16	36			
POACEAE	*Eriachne armitii*	ag				8	4
POACEAE	*Eriachne ciliata*	ag	1				
POACEAE	*Eriachne fastigiata*	ag		4			
POACEAE	*Eriachne obtusa*	pg	18	9			9
POACEAE	*Eriochloa crebra*	pg					4
POACEAE	*Eulalia aurea*	pg	14	15			
POACEAE	*Heteropogon contortus*	pg	31				21
POACEAE	*Heteropogon triticeus*	pg			44	28	
POACEAE	*Iseilema ciliatum*	ag		20			
POACEAE	*Iseilema fragile*	ag		42			
POACEAE	*Iseilema macratherum*	ag	10	40			
POACEAE	*Iseilema membranaceum*	ag		1			
POACEAE	*Iseilema vaginiflorum*	ag	3	31			
POACEAE	*Iseilema windersii*	ag		4			
POACEAE	*Melinis repens*	ag *			9	16	
POACEAE	*Mnesithea formosa*	ag	37		32	4	19
POACEAE	*Mnesithea granularis*	ag				10	
POACEAE	*Oxychloris scariosa*	ag				1	5
POACEAE	*Panicum decompositum*	pg	4	54			
POACEAE	*Panicum effusum*	pg	1		18		19
POACEAE	*Panicum laevinode*	ag	13				
POACEAE	*Paspalidium criniforme*	ag			16	6	
POACEAE	*Paspalidium distans*	ag				5	1
POACEAE	*Paspalidium rarum*	ag	6				14
POACEAE	*Paspalidium retiglume*	ag		5			
POACEAE	*Perotis rara*	ag	8		1	1	5
POACEAE	*Pseudoraphis spinescens*	pg		1			
POACEAE	*Sarga annual*	ag	8				
POACEAE	*Sarga ecarinatum*	ag	1				
POACEAE	*Sarga interjectum*	pg	2	1			
POACEAE	*Sarga perennial*	pg	13				
POACEAE	*Sarga plumosum*	pg	3			2	
POACEAE	*Sarga stipoideum*	ag	2				
POACEAE	*Sarga timorense*	ag	3	44			
POACEAE	*Schizachyrium fragile*	ag	16		18		13
POACEAE	*Sehima nervosum*	pg	39	14	6	8	
POACEAE	*Setaria apiculata*	ag	3				
POACEAE	*Setaria surgens*	ag				1	4
POACEAE	*Sporobolus australasicus*	ag	29	10		3	7
POACEAE	*Sporobolus caroli*	fpg			19	14	5
POACEAE	*Thaumastochloa sp. (Morehead River J.R.Clarkson+ 8086)*	ag					1
POACEAE	*Themeda triandra*	pg	9	1	1		6
POACEAE	*Tragus australianus*	ag	1	1	27	19	1
POACEAE	*Tripogon loliiformis*	ag	1		20		15
POACEAE	*Urochloa gilesii*	ag			47	4	
POACEAE	*Urochloa holosericea*	ag			3		
POACEAE	*Urochloa mosambicensis*	ag *				5	5
POACEAE	*Urochloa panicoides*	ag *			17	5	
POACEAE	*Urochloa reptans*	ag		3			
POACEAE	*Urochloa subquadripara*	ag	1		12		7
POACEAE	*Whiteochloa capillipes*	pg	4				
POACEAE	*Whiteochloa cymbiformis*	pg	1				

Family	Species	LF	L	C	B	S	A
POACEAE	*Yakirra majuscula*	ag	3				
POLYGALACEAE	*Polygala A77628 Davenport Ranges*	af	2				
POLYGALACEAE	*Polygala arvensis*	af	1				
POLYGALACEAE	*Polygala rhinanthoides*	af	17	43			
PORTULACACEAE	*Portulaca D16855 Scalded Area*	af	1				
PORTULACACEAE	*Portulaca digyna*	af	6	3			
PORTULACACEAE	*Portulaca filifolia*	af	6	5			
PORTULACACEAE	*Portulaca oleracea*	af	7		16	10	4
PORTULACACEAE	*Portulaca oligosperma*	af	1				
PORTULACACEAE	*Portulaca sp.*	af	6				
PORTULACACEAE	*Portulaca sp. unidentified*	af			6	3	2
PROTEACEAE	*Grevillea dimidiata*	tr	4	3			
PROTEACEAE	*Grevillea parallela*	tr			15	6	14
PROTEACEAE	*Grevillea pteridifolia*	tr			1		2
PROTEACEAE	*Grevillea striata*	tr	1	1			3
PROTEACEAE	*Hakea arborescens*	tr	28	3			
PROTEACEAE	*Hakea lorea*	tr	5				
RHAMNACEAE	*Alphitonia excelsa*	tr			1		
RHAMNACEAE	*Ventilago viminalis*	tr	10	1			12
RHAMNACEAE	*Ziziphus mauritiana*	tr				10	
RUBIACEAE	*Canthium attenuatum*	tr			15	1	
RUBIACEAE	*Canthium sp. unidentified*	tr			2		6
RUBIACEAE	*Oldenlandia argillacea*	af	6	19			
RUBIACEAE	*Oldenlandia galioides*	af			4		
RUBIACEAE	*Oldenlandia mitrasacmoides*	af	2			2	1
RUBIACEAE	*Oldenlandia sp.*	af	1				
RUBIACEAE	*Spermacoce auriculata*	af	19	1			
RUBIACEAE	*Spermacoce brachystema*	af			4	1	2
RUBIACEAE	*Spermacoce breviflora*	af	3				
RUBIACEAE	*Spermacoce D139759 dolichosperma*	af	31				
RUBIACEAE	*Spermacoce D23270 occultiseta*	af	1				
RUBIACEAE	*Spermacoce pogostoma*	af		46			
RUBIACEAE	*Spermacoce sp. unidentified*	af			4	8	1
RUBIACEAE	*Spermacoce stenophylla*	af					2
RUTACEAE	*Flindersia maculosa*	tr					4
RUTACEAE	*Geijera parviflora*	tr					2
SANTALACEAE	*Santalum lanceolatum*	sh	1				
SAPINDACEAE	*Atalaya hemiglauca*	tr	10	13			5
SAPINDACEAE	*Cardiospermum halicacabum*	af		5			
SAPINDACEAE	*Dodonaea physocarpa*	sh	1				
SCROPHULARIACEAE	*Buchnera asperata*	af	10	2			
SCROPHULARIACEAE	*Buchnera sp.*	af	1				
SCROPHULARIACEAE	*Stemodia glabella*	pf		9	1		
SCROPHULARIACEAE	*Stemodia lythrifolia*	pf	1				
SCROPHULARIACEAE	*Stemodia tephropelina*	af		13			
SCROPHULARIACEAE	*Striga curviflora*	af		2			
SCROPHULARIACEAE	*Striga squamigera*	af		1			
SOLANACEAE	*Solanum chippendalei*	pf	14				
SOLANACEAE	*Solanum ellipticum*	af			9		
SOLANACEAE	*Solanum quadriloculatum*	pf	16				
STERCULIACEAE	*Brachychiton diversifolius*	tr	6				
STERCULIACEAE	*Brachychiton megaphyllus*	sh	15				
STERCULIACEAE	*Brachychiton populneus*	tr				1	
STERCULIACEAE	*Keraudrenia sp*	pf				23	
STERCULIACEAE	*Melhania oblongifolia*	pf	6				8
STERCULIACEAE	*Melochia pyramidata*	af *	2	3			

Family	Species	LF	L	C	B	S	A
STERCULIACEAE	*Waltheria indica*	pf	17		7		16
THYMELAEACEAE	*Thecanthes punicea*	af	1				
TILIACEAE	*Corchorus aestuans*	af	12	7			5
TILIACEAE	*Corchorus fascicularis*	af		8			
TILIACEAE	*Corchorus macropetalus*	af	2	29			
TILIACEAE	*Corchorus olitorius*	af		13			
TILIACEAE	*Corchorus sidoides*	pf	13	3			
TILIACEAE	*Corchorus sp.*	af	1				
TILIACEAE	*Corchorus sp. unidentified*	af					1
TILIACEAE	*Corchorus tridens*	af	7	21			
TILIACEAE	*Corchorus trilocularis*	af		8			
TILIACEAE	*Grewia orbifolia*	sh	4				
TILIACEAE	*Grewia retusifolia*	sh	17		1		8
VERBENACEAE	*Clerodendrum floribundum*	sh	8		1		
VERBENACEAE	*Premna acuminata*	sh	2				
VERBENACEAE	*Stachytarpheta sp.*	pf		1			
VIOLACEAE	*Hybanthus aurantiacus*	pf	1				
VIOLACEAE	*Hybanthus enneaspermus*	pf	1	18		1	11
VITACEAE	*Cayratia trifolia*	pf	16				
ZYGOPHYLLACEAE	*Tribulopis bicolor*	af	11				
ZYGOPHYLLACEAE	*Tribulopis pentandra*	af	6	1		2	
ZYGOPHYLLACEAE	*Tribulopis sessilis*	af		1			
ZYGOPHYLLACEAE	*Tribulus terrestris*	af *	1				

Ants

FG is functional group (see Table 2), used to group species for analysis (CCS=Cold Climate Specialist, C=Cryptic, DD=Dominant Dolichoderinae, SC=Subordinate Camponotini, HC=Hot Climate Specialist, OP=Opportunist, GM=Generalized Myrmicinae, SP=Specialist Predator. The number of sites in each landtype from which each species was recorded is given (L=NT loam, C=NT clay, B=QLD basalt, S=QLD sedimentary, A=QLD alluvial).

a. NT loam sites

family	Species	FG	L
Cerapachyinae	*Cerapachys ?brevis*	SP	1
Cerapachyinae	*Cerapachys clarki*	SP	1
Cerapachyinae	*Cerapachys sp. A (singularis gp.)*	SP	4
Cerapachyinae	*Cerapachys sp. B (clarki gp.)*	SP	1
Cerapachyinae	*Sphinctomyrmex sp. A*	CR	1
Dolichoderinae	*Iridomyrmex hartmeyeri*	DD	7
Dolichoderinae	*Iridomyrmex pallidus*	DD	21
Dolichoderinae	*Iridomyrmex sanguineus*	DD	28
Dolichoderinae	*Iridomyrmex sp. A (anceps gp.)*	DD	11
Dolichoderinae	*Iridomyrmex sp. B (gracilis gp.)*	DD	25
Dolichoderinae	*Iridomyrmex sp. C (mattiroloi gp.)*	DD	37
Dolichoderinae	*Iridomyrmex sp. F*	DD	7
Dolichoderinae	*Iridomyrmex sp. G (pallidus gp.)*	DD	1
Dolichoderinae	*Iridomyrmex sp. H (cyaneus gp.)*	DD	8
Dolichoderinae	*Iridomyrmex sp. I (bicknelli gp.)*	DD	2
Dolichoderinae	*Tapinoma sp. A (minutum gp.)*	OP	10
Dolichoderinae	*Tapinoma sp. B*	OP	2
Formicinae	*Calomyrmex ?splendidus*	SC	5
Formicinae	*Camponotus dromas*	SC	1
Formicinae	*Camponotus fieldae*	SC	12
Formicinae	*Camponotus sp. A (novaehollandiae gp.)*	SC	13
Formicinae	*Camponotus sp. C (discors gp.)*	SC	20
Formicinae	*Camponotus sp. E (denticulatus gp.)*	SC	10
Formicinae	*Camponotus sp. F (rubiginosus gp.)*	SC	7
Formicinae	*Camponotus sp. G (pellax gp.)*	SC	1
Formicinae	*Camponotus sp. H (rubiginosus gp.)*	SC	1
Formicinae	*Camponotus sp. I (pellax gp.)*	SC	1
Formicinae	*Camponotus sp. J (novaehollandiae gp.)*	SC	12
Formicinae	*Camponotus sp. K (pellax gp.)*	SC	1
Formicinae	*Camponotus sp. L*	SC	1
Formicinae	*Melophorus bagoti*	HC	4
Formicinae	*Melophorus sp. A (Group F)*	HC	3
Formicinae	*Melophorus sp. AA (pillipes gp.)*	HC	6
Formicinae	*Melophorus sp. B (fieldi gp.)*	HC	14
Formicinae	*Melophorus sp. BB (Group B)*	HC	1
Formicinae	*Melophorus sp. C (wheeleri gp.)*	HC	15
Formicinae	*Melophorus sp. CC*	HC	3
Formicinae	*Melophorus sp. D (Group F)*	HC	6
Formicinae	*Melophorus sp. DD*	HC	4
Formicinae	*Melophorus sp. E (aeneovirens gp.)*	HC	35
Formicinae	*Melophorus sp. EE (Group F)*	HC	3
Formicinae	*Melophorus sp. F (Group E)*	HC	5
Formicinae	*Melophorus sp. FF*	HC	9
Formicinae	*Melophorus sp. G (Group A)*	HC	8
Formicinae	*Melophorus sp. H (Group H)*	HC	1
Formicinae	*Melophorus sp. K (mjobergi gp.)*	HC	1
Formicinae	*Melophorus sp. L (Group F)*	HC	8
Formicinae	*Melophorus sp. M*	HC	1

Formicinae	*Melophorus sp. O (Group C)*	HC	22
Formicinae	*Melophorus sp. P (mjobergi gp.)*	HC	7
Formicinae	*Melophorus sp. Q (mjobergi gp.)*	HC	1
Formicinae	*Melophorus sp. R (froggatti gp.)*	HC	1
Formicinae	*Melophorus sp. S (mjobergi gp.)*	HC	9
Formicinae	*Melophorus sp. T (mjobergi gp.)*	HC	1
Formicinae	*Melophorus sp. U*	HC	2
Formicinae	*Melophorus sp. V (froggatti gp.)*	HC	7
Formicinae	*Melophorus sp. W (Group A)*	HC	1
Formicinae	*Melophorus sp. X (Group C)*	HC	2
Formicinae	*Melophorus sp. Y (aeneovirens gp.)*	HC	13
Formicinae	*Melophorus sp. Z*	HC	1
Formicinae	*Opisthopsis haddoni*	SC	22
Formicinae	*Opisthopsis rufoniger*	SC	1
Formicinae	*Paratrechina sp. A (vaga gp.)*	OP	3
Formicinae	*Paratrechina sp. B (obscura gp.)*	OP	3
Formicinae	*Paratrechina sp. C (minutula gp.)*	OP	1
Formicinae	*Polyrhachis inconspicua*	SC	4
Formicinae	*Polyrhachis prometheus*	SC	5
Formicinae	*Polyrhachis schenkii*	SC	2
Formicinae	*Polyrhachis senilis*	SC	5
Formicinae	*Polyrhachis sp. B (obtusa gp.)*	SC	19
Formicinae	*Polyrhachis sp. C (ammon gp.)*	SC	4
Formicinae	*Polyrhachis sp. E (appendiculata gp.)*	SC	1
Formicinae	*Polyrhachis sp. F (appendiculata gp.)*	SC	5
Myrmicinae	*Cardiocondyla sp. A (nuda gp.)*	OP	5
Myrmicinae	*Crematogaster queenslandica*	GM	1
Myrmicinae	*Crematogaster sp. A (queenslandica gp)*	GM	3
Myrmicinae	*Meranoplus ?ajax*	HC	2
Myrmicinae	*Meranoplus ?dimidiatus*	HC	1
Myrmicinae	*Meranoplus ?pubescens*	HC	8
Myrmicinae	*Meranoplus sp. C (Group E)*	HC	1
Myrmicinae	*Meranoplus sp. D (hirsutus gp.)*	HC	2
Myrmicinae	*Meranoplus sp. E (Group C)*	HC	1
Myrmicinae	*Meranoplus sp. F (diversus gp.)*	HC	4
Myrmicinae	*Meranoplus sp. G (Group E)*	HC	1
Myrmicinae	*Meranoplus sp. H (Group C)*	HC	3
Myrmicinae	*Monomorium anderseni*	GM	5
Myrmicinae	*Monomorium disetigerum*	GM	23
Myrmicinae	*Monomorium fieldi*	GM	41
Myrmicinae	*Monomorium sp. A (rothsteini gp.)*	HC	16
Myrmicinae	*Monomorium sp. B (laeve gp.)*	GM	18
Myrmicinae	*Monomorium sp. C (rothsteini gp.)*	HC	1
Myrmicinae	*Monomorium sp. E (sordidum gp.)*	GM	18
Myrmicinae	*Monomorium sp. F (nigrium gp.)*	GM	5
Myrmicinae	*Monomorium sp. G (carinatum gp.)*	GM	19
Myrmicinae	*Monomorium sp. H (bifidum gp.)*	GM	2
Myrmicinae	*Monomorium sp. I (laeve gp.)*	GM	2
Myrmicinae	*Monomorium sp. J (laeve gp.)*	GM	17
Myrmicinae	*Monomorium sp. K (rothsteini gp.)*	HC	11
Myrmicinae	*Monomorium sp. L (insolescens gp.)*	GM	1
Myrmicinae	*Pheidole impressiceps*	GM	3
Myrmicinae	*Pheidole sp. A (mjobergi gp.)*	GM	20
Myrmicinae	*Pheidole sp. B (Group B)*	GM	4
Myrmicinae	*Pheidole sp. C (Group B)*	GM	1
Myrmicinae	*Pheidole sp. D (Group A)*	GM	3
Myrmicinae	*Solenopsis sp. A =Kak. sp. 1*	CR	1

Myrmicinae	*Tetramorium sp. A (spininode gp.)*	OP	4
Myrmicinae	*Tetramorium sp. B (striolatum gp.)*	OP	15
Myrmicinae	*Tetramorium sp. C (striolatum gp.)*	OP	2
Myrmicinae	*Tetramorium sp. D (striolatum gp.)*	OP	1
Myrmicinae	*Tetramorium sp. nr. sjostedti*	OP	1
Ponerinae	*Leptogenys adlerzi*	SP	3
Ponerinae	*Leptogenys exigua*	SP	2
Ponerinae	*Odontomachus sp. B (ruficeps gp.)*	SP	14
Ponerinae	*Odontomachus sp. nr. turneri*	SP	11
Ponerinae	*Platytherea sp. A (parallela gp.)*	SP	3
Ponerinae	*Rhytidoponera borealis*	OP	14
Ponerinae	*Rhytidoponera reticulata*	OP	27
Ponerinae	*Rhytidoponera sp. C (aurata gp.)*	OP	16
Ponerinae	*Rhytidoponera sp. D (convexa gp.)*	OP	6
Ponerinae	*Rhytidoponera sp. E (tenuis gp.)*	OP	9
Ponerinae	*Rhytidoponera sp. F (tyloxys gp.)*	OP	1
Ponerinae	*Rhytidoponera sp. G (Group A)*	OP	2
Ponerinae	*Rhytidoponera trachypyx*	OP	1

b. NT clay sites

Family	**Species**	**FG**	**C**
Cerapachyinae	*Cerapachys clarki*	SP	3
Cerapachyinae	*Cerapachys* sp. nr. *edentatus*	SP	1
Dolichoderinae	*Doleromyrma* spA	OP	13
Dolichoderinae	*Iridomyrmex* Kak1 (*anceps* gp.)	DD	27
Dolichoderinae	*Iridomyrmex* Kak2 (*mattiroloi* gp.)	DD	2
Dolichoderinae	*Iridomyrmex sanguineus*	DD	14
Dolichoderinae	*Iridomyrmex* spC (*anceps* gp.)	DD	51
Dolichoderinae	*Iridomyrmex* spD (*mattiroloi* gp.)	DD	37
Dolichoderinae	*Iridomyrmex* spE (*gracilis* gp.)	DD	16
Dolichoderinae	*Tapinoma* spA	OP	20
Formicinae	*Camponotus* Kak9 (*novaehollandiae* gp.)	SC	39
Formicinae	*Camponotus* spA (*nigroaeneus* gp.)	SC	32
Formicinae	*Camponotus* spC (*discors* gp.)	SC	16
Formicinae	*Melophorus* spA (Group F)	HC	11
Formicinae	*Melophorus* spB (*aeneovirens* gp.)	HC	14
Formicinae	*Melophorus* spC (Group A)	HC	39
Formicinae	*Melophorus* spD (*mjobergi* gp.)	HC	6
Formicinae	*Melophorus* spE (*mjobergi* gp.)	HC	32
Formicinae	*Melophorus* spF (Group C)	HC	2
Formicinae	*Opisthopsis haddoni*	SC	1
Formicinae	*Opisthopsis rufoniger*	SC	7
Formicinae	*Paratrechina* spA (*vaga* gp.)	OP	2
Formicinae	*Paratrechina* spB (*minutula* gp.)	OP	1
Formicinae	*Polyrhachis* (*chariomyrma* gp.)	SC	7
Formicinae	*Polyrhachis crawleyi*	SC	2
Formicinae	*Polyrhachis inconspicua*	SC	2
Formicinae	*Polyrhachis* Kak. sp. 3 (*ammon* gp.)	SC	1
Formicinae	*Polyrhachis* sp. nr. *obtusa*	SC	2
Myrmicine	*Cardiocondyla* spA (*nuda* gp.)	OP	4
Myrmicine	*Crematogaster queenslandica*	GM	24
Myrmicine	*Meranoplus* ?*ajax*	HC	2
Myrmicine	*Meranoplus* ?*pubescens*	HC	29
Myrmicine	*Meranoplus* spA (*diversus* gp.)	HC	36
Myrmicine	*Meranoplus* spB (*mjobergi* gp.)	HC	7
Myrmicine	*Meranoplus* spD	HC	3
Myrmicine	*Meranoplus* spE (*hirsutus* gp.)	HC	1

Family	Species	FG	C
Myrmicine	*Monomorium ?fieldi*	GM	46
Myrmicine	*Monomorium anderseni*	GM	8
Myrmicine	*Monomorium* Ka24 (*laeve* gp.)	GM	43
Myrmicine	*Monomorium* sp.C (laeve gp.)	GM	6
Myrmicine	*Monomorium* spE (*rothsteini* gp.)	HC	6
Myrmicine	*Monomorium* spF (*rothsteini* gp.)	HC	11
Myrmicine	*Pheidole impressiceps*	GM	45
Myrmicine	*Pheidole* spB (Group C)	GM	3
Myrmicine	*Pheidole* spC (Group D)	GM	25
Myrmicine	*Pheidole* spD (Group A)	GM	3
Myrmicine	*Podomyrma adelaidae*	TC	2
Myrmicine	*Solenopsis* spA	CR	1
Myrmicine	*Tetramorium* spA (*striolatum* gp.)	OP	1
Myrmicine	*Tetramorium* spB (*striolatum* gp.)	OP	24
Ponerinae	*Leptogenys adlerzi*	SP	11
Ponerinae	*Odontomachus* spA (*ruficeps* gp.)	SP	7
Ponerinae	*Rhytidoponera* spA (*convexa* gp.)	OP	40
Ponerinae	*Rhytidoponera* spB (Group A)	OP	11

b. Queensland sites

family	Species	FG	B	S	A
Cerapachyinae	*Cerapachys sp. A (brevis gp.)*	SP	0	0	1
Cerapachyinae	*Sphinctomyrmex sp. A*	C	1	0	0
Dolichoderinae	*Dolichoderus scrobiculatus*	CCS	0	0	1
Dolichoderinae	*Iridomyrmex ?septentrionalis*	DD	0	0	14
Dolichoderinae	*Iridomyrmex agilis*	DD	3	1	0
Dolichoderinae	*Iridomyrmex hartmeyeri*	DD	0	1	1
Dolichoderinae	*Iridomyrmex pallidus*	DD	30	7	0
Dolichoderinae	*Iridomyrmex sanguineus*	DD	7	5	16
Dolichoderinae	*Iridomyrmex septentrionalis*	DD	5	7	0
Dolichoderinae	*Iridomyrmex sp. A (anceps gp.)*	DD	45	28	0
Dolichoderinae	*Iridomyrmex sp. A (rufoniger gp.)*	DD	0	0	12
Dolichoderinae	*Iridomyrmex sp. B (rufoniger gp.)*	DD	0	0	5
Dolichoderinae	*Iridomyrmex sp. D (anceps gp.)*	DD	0	0	20
Dolichoderinae	*Iridomyrmex sp. D (pallidus gp.)*	DD	17	10	0
Dolichoderinae	*Iridomyrmex sp. E (rufoniger gp.)*	DD	19	21	0
Dolichoderinae	*Iridomyrmex sp. F (mattiroloi gp.)*	DD	0	0	15
Dolichoderinae	*Iridomyrmex sp. G (pallidus gp.)*	DD	0	0	1
Dolichoderinae	*Iridomyrmex sp. H (gracilis gp.)*	DD	0	0	1
Dolichoderinae	*Iridomyrmex sp. H (mattirolia gp.)*	DD	30	6	0
Dolichoderinae	*Iridomyrmex sp. I (suchieri gp.)*	DD	5	18	0
Dolichoderinae	*Iridomyrmex sp. K (pallidus gp.)*	DD	6	1	0
Dolichoderinae	*Iridomyrmex sp. M (gracilis gp.)*	DD	3	0	0
Dolichoderinae	*Iridomyrmex sp. O (suchieri gp.)*	DD	0	0	1
Dolichoderinae	*Iridomyrmex spadius*	DD	4	1	1
Dolichoderinae	*Ochetellus sp. A (glaber gp.)*	OPP	1	2	0
Dolichoderinae	*Papyrius sp. A*	DD	1	0	0
Dolichoderinae	*Tapinoma sp. A*	OPP	11	9	0
Dolichoderinae	*Tapinoma sp. A (minutum gp.)*	OPP	0	0	3
Dolichoderinae	*Tapinoma sp. B*	OPP	8	1	0
Formicinae	*Calomyrmex ?splendidus*	SC	0	1	1
Formicinae	*Camponotus bigenus*	SC	1	1	1
Formicinae	*Camponotus confusus*	SC	1	0	0
Formicinae	*Camponotus dromas*	SC	4	0	1
Formicinae	*Camponotus fieldae*	SC	2	1	9
Formicinae	*Camponotus rubiginosus*	SC	0	1	1

family	Species	FG	B	S	A
Formicinae	*Camponotus sp. A (novaehollandiae gp.)*	SC	10	13	6
Formicinae	*Camponotus sp. B (denticulatus gp.)*	SC	7	1	0
Formicinae	*Camponotus sp. C (denticulatus gp.)*	SC	0	0	1
Formicinae	*Camponotus sp. C (rubiginosus gp.)*	SC	1	0	0
Formicinae	*Camponotus sp. D (pellax gp.)*	SC	0	0	2
Formicinae	*Camponotus sp. D (sponsorum gp.)*	SC	0	2	0
Formicinae	*Camponotus sp. E (dentculatus gp.)*	SC	0	0	2
Formicinae	*Camponotus sp. E (novaehollandiae gp.)*	SC	3	2	0
Formicinae	*Camponotus sp. F (pellax gp.)*	SC	0	0	0
Formicinae	*Camponotus sp. F (rubigenosus gp.)*	SC	0	0	1
Formicinae	*Camponotus sp. G (rubiginosus gp.)*	SC	0	1	0
Formicinae	*Camponotus sp. H (discors gp.)*	SC	5	3	0
Formicinae	*Camponotus sp. J (discors gp.)*	SC	0	0	1
Formicinae	*Camponotus sp. L*	SC	1	0	0
Formicinae	*Camponotus sp. M (subnitidus gp.)*	SC	1	0	0
Formicinae	*Camponotus sp. O*	SC	4	0	0
Formicinae	*Camponotus sp. P (ephippium gp.)*	SC	1	0	0
Formicinae	*Camponotus sp. R (claripes gp.)*	SC	1	1	0
Formicinae	*Camponotus sp. S (pellax gp.)*	SC	1	0	0
Formicinae	*Camponotus sp. U (subnitidus gp.)*	SC	1	0	0
Formicinae	*Melophorus sp. A (aeneovirens gp.)*	HCS	42	14	17
Formicinae	*Melophorus sp. B (froggatti gp.)*	HCS	30	3	0
Formicinae	*Melophorus sp. B (Group F)*	HCS	0	0	2
Formicinae	*Melophorus sp. C (mjobergi gp.)*	HCS	25	5	0
Formicinae	*Melophorus sp. C (pillipes gp.)*	HCS	0	0	2
Formicinae	*Melophorus sp. D (Group D)*	HCS	0	0	3
Formicinae	*Melophorus sp. D (pillipes gp.)*	HCS	17	0	0
Formicinae	*Melophorus sp. E (wheeleri gp.)*	HCS	13	6	0
Formicinae	*Melophorus sp. F*	HCS	31	2	0
Formicinae	*Melophorus sp. F (fieldi gp.)*	HCS	0	0	0
Formicinae	*Melophorus sp. G*	HCS	6	1	0
Formicinae	*Melophorus sp. H (mjobergi gp.)*	HCS	13	4	0
Formicinae	*Melophorus sp. I (Group A)*	HCS	0	0	17
Formicinae	*Melophorus sp. J (Group F)*	HCS	2	16	0
Formicinae	*Melophorus sp. K (Group D)*	HCS	3	5	0
Formicinae	*Melophorus sp. K (wheeleri gp.)*	HCS	0	0	8
Formicinae	*Melophorus sp. L (Group J)*	HCS	0	0	2
Formicinae	*Melophorus sp. L (mjbergi gp.)*	HCS	1	0	0
Formicinae	*Melophorus sp. M*	HCS	2	3	0
Formicinae	*Melophorus sp. N (bruneus gp.)*	HCS	1	6	3
Formicinae	*Melophorus sp. N (Group E)*	HCS	0	0	0
Formicinae	*Melophorus sp. O (pillipes gp.)*	HCS	3	0	0
Formicinae	*Melophorus sp. P (froggatti gp.)*	HCS	4	1	0
Formicinae	*Melophorus sp. P (Group A)*	HCS	0	0	1
Formicinae	*Melophorus sp. R (Group B.)*	HCS	0	0	0
Formicinae	*Melophours sp. R (mjobergi gp.)*	HCS	1	0	0
Formicinae	*Notoncus sp. A (enormis gp.)*	CCS	3	1	0
Formicinae	*Opisthopsis haddoni*	SC	9	4	0
Formicinae	*Opisthopsis pictus*	SC	2	0	1
Formicinae	*Opisthopsis rufithorax*	SC	0	0	0
Formicinae	*Paratrechina hookeri*	SC	3	1	0
Formicinae	*Paratrechina inconspicua*	SC	0	1	0
Formicinae	*Paratrechina lata*	SC	0	2	0
Formicinae	*Paratrechina lydiae*	SC	2	0	0
Formicinae	*Paratrechina prometheus*	SC	2	4	0
Formicinae	*Paratrechina schenkii*	SC	3	0	0

family	Species	FG	B	S	A
Formicinae	*Paratrechina senilis*	SC	0	1	0
Formicinae	*Paratrechina sp. A (obscura gp.)*	OPP	12	14	0
Formicinae	*Paratrechina sp. A (vaga gp.)*	OPP	0	0	2
Formicinae	*Paratrechina sp. B (obscura gp.)*	OPP	0	0	13
Formicinae	*Paratrechina sp. B (vaga gp.)*	OPP	14	9	0
Formicinae	*Paratrechina sp. C (minutula gp.)*	OPP	0	0	1
Formicinae	*Paratrechina sp. nr. inconspicua*	SC	3	6	0
Formicinae	*Paratrechina trapezoidea*	SC	3	0	0
Formicinae	*Polyrhachis (chariomyrma) sp. D*	SC	1	0	0
Formicinae	*Polyrhachis senilis*	SC	0	0	6
Formicinae	*Polyrhachis sp. E (gab gp.)*	SC	1	10	0
Formicinae	*Polyrhachis sp. L (appendiculata gp.)*	SC	1	0	0
Formicinae	*Stigmacros (campostigmacros) sp. B*	CCS	0	1	0
Formicinae	*Stigmacros (stigmacros) sp. D*	CCS	1	0	0
Formicinae	*Stigmacros aciculata*	CCS	0	1	0
Formicinae	*Stigmacros sp. nr. aemula*	CCS	1	0	0
Myrmeciinae	*Myrmecia formosa*	SP	2	0	0
Myrmeciinae	*Myrmecia picta*	SP	1	0	0
Myrmeciinae	*Myrmecia varians*	SP	2	0	0
Myrmicinae	*Cardiocondyla sp. A (nuda gp.)*	OPP	26	5	0
Myrmicinae	*Colobostruma sp. A (alinodis gp.)*	SP	0	1	0
Myrmicinae	*Crematogaster queenslandica*	GM	0	0	0
Myrmicinae	*Crematogaster queenslandica*	GM	2	2	0
Myrmicinae	*Crematogaster sp. A (australis gp.)*	GM	0	0	4
Myrmicinae	*Crematogaster sp. A (laeviceps gp.)*	GM	11	16	0
Myrmicinae	*Crematogaster sp. C (queenslandica gp.)*	GM	0	0	2
Myrmicinae	*Crematogaster sp. C (queenslandica gp.)*	GM	2	0	0
Myrmicinae	*Meranoplus ?pubescens*	HCS	1	3	0
Myrmicinae	*Meranoplus ajax*	HCS	1	0	0
Myrmicinae	*Meranoplus sp. B*	HCS	0	1	0
Myrmicinae	*Meranoplus sp. C (diversus gp.)*	HCS	1	6	0
Myrmicinae	*Meranoplus sp. C (mjobergi gp.)*	HCS	0	0	1
Myrmicinae	*Meranoplus sp. E*	HCS	1	0	0
Myrmicinae	*Meranoplus sp. F (diversus gp.)*	HCS	0	0	6
Myrmicinae	*Meranoplus sp. J (fenestratus gp.)*	HCS	0	0	0
Myrmicinae	*Meranoplus sp. K (dimidiatus gp.)*	HCS	0	0	2
Myrmicinae	*Monomorium ?fieldi*	GM	0	0	18
Myrmicinae	*Monomorium disetigerum*	GM	0	0	4
Myrmicinae	*Monomorium fieldi*	GM	24	20	0
Myrmicinae	*Monomorium sp. A (rothsteini gp.)*	HCS	0	0	4
Myrmicinae	*Monomorium sp. B (laeve gp.)*	GM	5	10	0
Myrmicinae	*Monomorium sp. C (laeve gp.)*	GM	14	16	0
Myrmicinae	*Monomorium sp. C (sordidum gp.)*	GM	0	0	2
Myrmicinae	*Monomorium sp. D (laeve gp.)*	GM	0	0	3
Myrmicinae	*Monomorium sp. D (rothsteini gp.)*	HCS	3	8	0
Myrmicinae	*Monomorium sp. F (laeve gp.)*	GM	0	7	0
Myrmicinae	*Monomorium sp. F (nigrius gp.)*	GM	0	0	4
Myrmicinae	*Monomorium sp. G (laeve gp.)*	GM	0	0	14
Myrmicinae	*Monomorium sp. G (nigrium gp.)*	GM	2	3	0
Myrmicinae	*Monomorium sp. H*	GM	0	3	0
Myrmicinae	*Monomorium sp. H (laeve gp.)*	GM	0	0	3
Myrmicinae	*Monomorium sp. I (centrale gp.)*	HCS	0	0	2
Myrmicinae	*Monomorium sp. I (centrale gp.)*	HCS	0	3	0
Myrmicinae	*Monomorium sp. J (laeve gp.)*	GM	0	2	0
Myrmicinae	*Monomorium sp. L (rothsteini gp.)*	HCS	1	0	0
Myrmicinae	*Monomoruim sp. E (sordidum gp.)*	GM	4	12	0

family	Species	FG	B	S	A
Myrmicinae	*Pheidole impressiceps*	GM	7	15	0
Myrmicinae	*Pheidole sp. A (Group C)*	GM	0	0	9
Myrmicinae	*Pheidole sp. A (Group E)*	GM	33	26	0
Myrmicinae	*Pheidole sp. B (Group D)*	GM	0	0	21
Myrmicinae	*Pheidole sp. B (Group E)*	GM	32	3	0
Myrmicinae	*Pheidole sp. C (Group D)*	GM	0	0	8
Myrmicinae	*Pheidole sp. C (Group E)*	GM	1	0	0
Myrmicinae	*Pheidole sp. D (ampla gp.)*	GM	0	0	2
Myrmicinae	*Pheidole sp. E (Group D)*	GM	0	0	12
Myrmicinae	*Pheidole sp. E (longiceps gp.)*	GM	0	4	0
Myrmicinae	*Pheidole sp. F (longiceps gp.)*	GM	0	5	0
Myrmicinae	*Pheidole sp. F (variabilis gp.)*	GM	0	0	7
Myrmicinae	*Pheidole sp. G (Group A)*	GM	2	13	0
Myrmicinae	*Pheidole sp. G (Group C)*	GM	0	0	12
Myrmicinae	*Pheidole sp. H (Group E)*	GM	0	3	0
Myrmicinae	*Pheidole sp. H (variabilis gp.)*	GM	0	0	2
Myrmicinae	*Pheidole sp. I Group B)*	GM	2	2	0
Myrmicinae	*Pheidole sp. J (Group A)*	GM	0	2	0
Myrmicinae	*Pheidole sp. K (longiceps gp.)*	GM	0	1	0
Myrmicinae	*Pheidole sp. L (mjobergi gp.)*	GM	4	0	0
Myrmicinae	*Pheidole sp. M (Group B)*	GM	3	0	0
Myrmicinae	*Solenopsis sp. A*	C	0	6	3
Myrmicinae	*Tetramorium ?sjostedti*	OPP	0	0	0
Myrmicinae	*Tetramorium lanuginosum*	OPP	0	2	0
Myrmicinae	*Tetramorium sp. A (spininode gp.)*	OPP	0	0	2
Myrmicinae	*Tetramorium sp. A (striolatum gp.)*	OPP	6	5	0
Myrmicinae	*Tetramorium sp. B (striolatum gp.)*	OPP	0	0	0
Myrmicinae	*Tetramorium sp. C (striolatum gp.)*	OPP	0	0	1
Myrmicinae	*Tetramorium sp. D (impressum gp.)*	OPP	0	0	1
Myrmicinae	*Tetramorium sp. H (striolatum gp.)*	OPP	0	0	11
Myrmicinae	*Tetraponera sp. nr.punctulata*	TCS	1	0	0
Ponerinae	*Anochetus rectangularis*	SP	1	0	0
Ponerinae	*Bothroponera sp. A (sublaevis gp.)*	SP	7	0	0
Ponerinae	*Bothroponera sp. B (porcata gp.)*	SP	0	4	0
Ponerinae	*Brachyponera lutea*	C	1	3	0
Ponerinae	*Hypoponera sp. A*	C	0	2	0
Ponerinae	*Leptogenys adlerzi*	SP	5	14	0
Ponerinae	*Leptogenys cornigera*	SP	7	20	1
Ponerinae	*Leptogenys exigua*	SP	0	5	0
Ponerinae	*Leptogenys sp. C (clarki gp.)*	SP	0	1	0
Ponerinae	*Odontomachus sp. A (ruficeps gp.)*	OPP	0	0	12
Ponerinae	*Odontomachus sp. B (ruficeps gp.)*	OPP	4	12	0
Ponerinae	*Odontomachus turneri*	OPP	19	1	0
Ponerinae	*Rhytidoponera ?convexa*	OPP	35	32	20
Ponerinae	*Rhytidoponera ?hilli*	OPP	0	0	10
Ponerinae	*Rhytidoponera anceps*	OPP	0	0	0
Ponerinae	*Rhytidoponera lamellinodis*	OPP	1	24	12
Ponerinae	*Rhytidoponera sp. B (metalica gp.)*	OPP	46	8	0
Ponerinae	*Rhytidoponera sp. C (convexa gp.)*	OPP	36	22	0
Ponerinae	*Rhytidoponera sp. D (spoliata gp.)*	OPP	8	2	0
Ponerinae	*Rhytidoponera sp. D (tenuis gp.)*	OPP	0	0	3
Ponerinae	*Rhytidoponera sp. E (mayri gp.)*	OPP	0	0	0
Ponerinae	*Rhytidoponera sp. E (tenuis gp.)*	OPP	0	0	0
Ponerinae	*Rhytidoponera sp. F (metallica gp.)*	OPP	0	0	13
Ponerinae	*Trachymespus darwinii*	C	1	0	0

Birds

G is foraging guild (see Table 2), used to group species for analysis (AI=Aerial Insectivore, AQ=Aquatic, FI=Foliage or Trunk Insectivore, FIN=Foliage Insectivore / Nectarivore, FR=Frugivore, NE=Nectarivore, GI=Ground or Low Undergrowth Insectivore, GIG=Ground Insectivore / Granivore, GIO=Ground Insectivore / Omnivore, GR=Granivore, FR=Frugivore, RA=Raptor). The number of sites in each landtype from which each species was recorded is given (L=NT loam, C=NT clay, B=QLD basalt, S=QLD sedimentary, A=QLD alluvial).

Name	Species	FG	L	C	B	S	A
australian owlet-nightjar	*Aegotheles cristatus*	AI	9		15	6	15
black-faced woodswallow	*Artamus cinereus*	AI	30	34	18		5
dollarbird	*Eurystomus orientalis*	AI			1		
fairy martin	*Hirundo ariel*	AI	3				
grey fantail	*Rhipidura fuliginosa*	AI				7	
jacky winter	*Microeca fascinans*	AI	5		20	1	12
leaden flycatcher	*Myiagra rubecula*	AI				2	
little woodswallow	*Artamus minor*	AI	4		3		
masked woodswallow	*Artamus personatus*	AI	7	12			
rainbow bee-eater	*Merops ornatus*	AI	6			2	
restless flycatcher	*Myiagra inquieta*	AI	6	6			
spotted nightjar	*Eurostopodus argus*	AI	1			1	
tree martin	*Hirundo nigricans*	AI		6			
white-browed woodswallow	*Artamus superciliosus*	AI	1	1			
willie wagtail	*Rhipidura leucophrys*	AI	30	13	16	3	8
great crested grebe	*Podiceps cristatus*	AQ			1		
little curlew	*Numenius minutus*	AQ			1		
white-faced heron	*Egretta novaehollandiae*	AQ		1			
white-necked heron	*Ardea pacifica*	AQ		2			
banded honeyeater	*Certhionyx pectoralis*	FIN	8	5			
black-chinned honeyeater	*Melithreptus gularis*	FIN	2				
blue-faced honeyeater	*Entomyzon cyanotis*	FIN			10	11	8
brown honeyeater	*Lichmera indistincta*	FIN	10	15	4		
grey-fronted honeyeater	*Lichenostomus plumulus*	FIN	17				
lewin's honeyeater	*Meliphaga lewinii*	FIN			1		
little friarbird	*Philemon citreogularis*	FIN	15	3	32	21	3
noisy friarbird	*Philemon corniculatus*	FIN			2	33	
noisy miner	*Manorina melanocephala*	FIN			8	24	
rufous-banded honeyeater	*Conopophila albogularis*	FIN		1			
rufous-throated honeyeater	*Conopophila rufogularis*	FIN	9	12	3		
singing honeyeater	*Lichenostomus virescens*	FIN	25	21			5
striped honeyeater	*Plectorhyncha lanceolata*	FIN			2		2
white-throated honeyeater	*Melithreptus albogularis*	FIN			6	12	
yellow-throated miner	*Manorina flavigula*	FIN	15	29	30	6	17
yellow-tinted honeyeater	*Lichenostomus flavescens*	FIN	9	1			
great bowerbird	*Chlamydera nuchalis*	FR	8		1	3	2

Name	Species	FG	L	C	B	S	A
mistletoebird	*Dicaeum hirundinaceum*	FR	20	1	27	5	
black-eared cuckoo	*Chrysococcyx osculans*	FI					2
black-faced cuckoo-shrike	*Coracina novaehollandiae*	FI	10	27	38	31	23
black-tailed treecreeper	*Climacteris melanura*	FI	20				
brown treecreeper	*Climacteris picumnus picumnus*	FI			24	7	19
brush cuckoo	*Cacomantis variolosus*	FI				1	
channel-billed cuckoo	*Scythrops novaehollandiae*	FI			1	9	
cicadabird	*Coracina tenuirostris*	FI				3	
grey shrike-thrush	*Colluricincla harmonica*	FI	14		2	2	
horsfield's bronze-cuckoo	*Chrysococcyx basalis*	FI			14	7	
little bronze-cuckoo	*Chrysococcyx minutillus*	FI			1	4	
olive-backed oriole	*Oriolus sagittatus*	FI			6	16	1
pallid cuckoo	*Cuculus pallidus*	FI	1		1	4	6
red-browed pardalote	*Pardalotus rubricatus*	FI	4				
rufous whistler	*Pachycephala rufiventris*	FI	23	3	13	9	16
silvereye (eastern)	*Zosterops lateralis cornwalli*	FI					1
striated pardalote	*Pardalotus striatus*	FI	4		35	24	24
varied sittella	*Daphoenositta chrysoptera*	FI	7		2	3	
varied triller	*Lalage leucomela*	FI				1	
weebill	*Smicrornis brevirostris*	FI	2	5	25	31	24
western gerygone	*Gerygone fusca*	FI			18		
white-bellied cuckoo-shrike	*Coracina papuensis*	FI	9		3	13	
white-throated gerygone	*Gerygone olivacea*	FI	2		2	18	4
white-winged triller	*Lalage sueurii*	FI	20	16	17	5	
yellow thornbill	*Acanthiza nana*	FI					1
masked lapwing	*Vanellus miles*	GI		3			
richard's pipit	*Anthus novaeseelandiae*	GIG			2		
singing bushlark	*Mirafra javanica*	GIG	11	46	7		
apostlebird	Struthidea cinerea	GIO			9	7	8
australian bustard	*Ardeotis australis*	GIO	4	9	2	3	
australian magpie	*Gymnorhina tibicen*	GIO			44	26	22
brolga	*Grus rubicunda*	GIO		3		1	
emu	*Dromaius novaehollandiae*	GIO			1	5	4
pheasant coucal	*Centropus phasianinus*	GIO		1	11	5	
flock bronzewing	*Phaps histrionica*	GR		4			
little button-quail	*Turnix velox*	GR		2			1
red-chested button-quail	*Turnix pyrrhothorax*	GR		10			
bar-shouldered dove	*Geopelia humeralis*	GR	2		1		
black-throated finch	*Poephila cincta cincta*	GR			1		
brown quail	*Coturnix ypsilophora*	GR	2	7	3		1
budgerigar	*Melopsittacus undulatus*	GR	3	20	3		
chestnut-breasted mannikin	*Lonchura castaneothorax*	GR			2		

Name	Species	FG	L	C	B	S	A
cockatiel	*Nymphicus hollandicus*	GR	10	5	17		12
common bronzewing	*Phaps chalcoptera*	GR			2	2	1
crested pigeon	*Ocyphaps lophotes*	GR	13	30	13	3	5
diamond dove	*Geopelia cuneata*	GR	7	4			1
double-barred finch	*Taeniopygia bichenovii*	GR	2			3	11
galah	*Cacatua roseicapilla*	GR	9	27	15	5	9
little corella	*Cacatua sanguinea*	GR	6	4			
long-tailed finch	*Poephila acuticauda*	GR	4				
masked finch	*Poephila personata*	GR	3				
pale-headed rosella	*Platycercus adscitus adscitus*	GR			20	14	17
peaceful dove	*Geopelia striata*	GR	12	12	5	10	2
pictorella mannikin	*Heteromunia pectoralis*	GR		8			
red-tailed black-cockatoo	*Calyptorhynchus banksii*	GR	3	5	4	1	
red-winged parrot	*Aprosmictus erythropterus*	GR			7	1	
squatter pigeon	*Geophaps scripta scripta*	GR					2
stubble quail	*Coturnix pectoralis*	GR		1			
sulphur-crested cockatoo	*Cacatua galerita*	GR			2		1
zebra finch	*Taeniopygia guttata*	GR	3	16	9		1
brown songlark	*Cincloramphus cruralis*	GI	1	5	5	1	
crested bellbird	*Oreoica gutturalis*	GI	1				
grey-crowned babbler	*Pomatostomus temporalis*	GI	20	7	2	16	11
ground cuckoo-shrike	*Coracina maxima*	GI			1		3
magpie-lark	*Grallina cyanoleuca*	GI	8	25	23	14	15
red-capped robin	*Petroica goodenovii*	GI	1				
rufous songlark	*Cincloramphus mathewsi*	GI	2	7	26	6	1
clamorous reed-warbler	*Acrocephalus stentoreus*	GI			2		
golden-headed cisticola	*Cisticola exilis*	GI		25	7		
red-backed fairy-wren	*Malurus melanocephalus*	GI	34	46	18	14	5
tawny grassbird	*Megalurus timoriensis*	GI			2		
variegated fairy-wren	*Malurus lamberti*	GI					5
rainbow lorikeet	*Trichoglossus h. haematodus*	NE			23	18	2
scaly-breasted lorikeet	*Trichoglossus chlorolepidotus*	NE				1	
varied lorikeet	*Psitteuteles versicolor*	NE	1	9			
australian hobby	*Falco longipennis*	RA	1	4			3
australian raven	*Corvus coronoides*	RA			36	8	
barn owl	*Tyto alba*	RA			2		6
black kite	*Milvus migrans*	RA	7	5			1
black-breasted buzzard	*Hamirostra melanosternon*	RA	1	1		1	
black-shouldered kite	*Elanus axillaris*	RA		1			
blue-winged kookaburra	*Dacelo leachii*	RA	4		7	1	4
brown falcon	*Falco berigora*	RA	5	14	3	4	3
brown goshawk	*Accipiter fasciatus*	RA	3	2			

Name	Species	FG	L	C	B	S	A
collared sparrowhawk	*Accipiter cirrhocephalus*	RA					1
crow unidentified	*Corvus sp*	RA					24
forest kingfisher	*Todiramphus macleayii*	RA	1		2	10	
grey butcherbird	*Cracticus torquatus*	RA			8	26	8
laughing kookaburra	*Dacelo novaeguineae*	RA			6	15	
nankeen kestrel	*Falco cenchroides*	RA		4	10	1	7
pied butcherbird	*Cracticus nigrogularis*	RA	36	44	44	31	24
pied currawong	*Strepera graculina graculina*	RA			5	1	
red-backed kingfisher	*Todiramphus pyrrhopygia*	RA	9	9	18	2	8
sacred kingfisher	*Todiramphus sanctus*	RA	1		1		
southern boobook	*Ninox novaeseelandiae*	RA			9	1	
spotted harrier	*Circus assimilis*	RA		6	1		
tawny frogmouth	*Podargus strigoides*	RA	2		7	4	5
torresian crow	*Corvus orru*	RA	17	29	2	30	
wedge-tailed eagle	*Aquila audax*	RA	3	3	4	4	2
whistling kite	*Haliastur sphenurus*	RA	4	4	2	1	1

Reptiles

GP is taxonomic/functional group (see Table 2), used to group species for analysis (AGA=agamid, GEK=gekkonid, PYG=pygopodid, SCI=scincid, SNA=snake, VAR=varanid). The number of sites in each landtype from which each species was recorded is given (L=NT loam, C=NT clay, B=QLD basalt, S=QLD sedimentary, A=QLD alluvial).

Common Name	Species	GP	L	C	B	S	A
Nobbi	*Amphibolurus nobbi nobbi*	AGA					9
Frilled Lizard	*Chlamydosaurus kingii*	AGA				1	1
Tommy Roundhead	*Diporiphora australis*	AGA			6	11	
Two-Lined Dragon	*Diporiphora bilineata*	AGA	22				
Yellow-sided Dragon	*Diporiphora magna*	AGA	13				
Two-line Dragon	*Diporiphora sp*	AGA			2		
Gilbert's Dragon	*Lophognathus gilberti*	AGA	7	2			
Bearded Dragon	*Pogona barbata*	AGA				3	
Lined Earless Dragon	*Tympanocryptis lineata*	AGA		3			
Uniform Earless Dragon	*Tympanocryptis uniformis*	AGA		1			
Crowned Gecko	*Diplodactylus stenodactylus*	GEK		3			
Fat-tailed Gecko	*Diplodactylus conspicillatus*	GEK				2	1
Box-patterned Gecko	*Diplodactylus steindachneri*	GEK			2	6	
Northern Dtella	*Gehyra australis*	GEK	2	1			
Dubious Dtella	*Gehyra dubia*	GEK			42	22	17
Bynoe's Gecko	*Heteronotia binoei*	GEK	7	29	2	17	18
Northern Velvet Gecko	*Oedura castelnaui*	GEK			11	10	1
Ocellated Velvet Gecko	*Oedura monilis*	GEK			3		
Zig-zag Gecko	*Oedura rhombifer*	GEK		1	13	6	
Rusty-topped Snake-lizard	*Delma borea*	PYG	3				
Black-necked Snake-lizard	*Delma tincta*	PYG		10	1	2	
Two-Spined Rainbow Skink	*Carlia amax*	SCI	1				
Tree-base Litter-skink	*Carlia foliorum*	SCI			3	2	
Striped Rainbow Skink	*Carlia munda*	SCI	10		33	13	23
Open-litter Rainbow-skink	*Carlia pectoralis*	SCI					1
Robust Rainbow-Skink	*Carlia schmeltzii*	SCI			6	9	
Three-Spined Rainbow Skink	*Carlia triacantha*	SCI	1				
Tussock Rainbow-skink	*Carlia vivax*	SCI			10	1	
Aboreal Snake-Eyed Skink	*Cryptoblepharus plagiocephalus*	SCI	17	8	19	6	
Snake-eyed Skink	*Cryptoblepharus sp*	SCI					17
Cream-striped Snake-eyed Skink	*Cryptoblepharus virgatus*	SCI			17	4	
Plain Ctenotus	*Ctenotus inornatus*	SCI	4				
Leopard Ctenotus	*Ctenotus pantherinus*	SCI	3				
VRD Blacksoil Ctenotus	*Ctenotus rimacola*	SCI		16			
Robust Ctenotus	*Ctenotus robustus*	SCI	1		6	1	1
Spalding's Ctenotus	*Ctenotus spaldingi*	SCI	5			16	
Strauch's Ctenotus	*Ctenotus strauchii*	SCI				7	1
Copper-tailed Skink	*Ctenotus taeniolatus*	SCI			8		

Common Name	Species	GP	L	C	B	S	A
Tree Skink	*Egernia striolata*	SCI			30	1	
Eastern Lerista	*Lerista orientalis*	SCI	2				
Grey's Menetia	*Menetia greyii*	SCI	6		12	21	22
Main's Menetia	*Menetia maini*	SCI	24	5			
Fire-tailed Skink	*Morethia taeniopleura*	SCI			9	11	16
Kinghorn's Snake-Eyed Skink	*Proablepharus kinghorni*	SCI		21			
Slender Snake-Eyed Skink	*Proablepharus tenuis*	SCI	15	30	3	11	4
Orange-naped Snake	*Furina ornata*	SNA	1		1		
Black-headed Python	*Aspidites melanocephalus*	SNA			2		
Collared Whip Snake	*Demansia torquata*	SNA		3			
Pale-headed Snake	*Hoplocephalus bitorquatus*	SNA			1		2
Eastern Brown Snake	*Pseudonaja textilis*	SNA			2		
Black-headed Scaly-foot	*Pygopus nigriceps*	PYG				1	
Proximus Blind Snake	*Ramphotyphlops proximus*	SNA			1		
Blind Snake	*Ramphotyphlops sp.*	SNA		4	1		
Coral Snake	*Brachyurophis australis*	SNA				1	
Curl Snake	*Suta suta*	SNA		2	1		
Storr's Goanna	*Varanus storri*	VAR		6			
Black-tailed Goanna	*Varanus tristis*	VAR	2		2	1	3

Mammals

GP is taxonomic/functional group (see Table 2), used to group species for analysis (MON=monotreme, DAS=dasyurid, PER=peramelid, ARB=arboreal, MAC=macropod, MUR=murid, INT=introduced). The number of sites in each landtype from which each species was recorded is given (L=NT loam, C=NT clay, B=QLD basalt, S=QLD sedimentary, A=QLD alluvial).

Common Name	Species	GP	L	C	B	S	A
Echidna	*Tachyglossus aculeatus*	MON			4	1	1
Long-tailed Planigale	*Planigale ingrami*	DAS	1	34			
Common Planigale	*Planigale maculata*	DAS			2	2	2
Stripe-faced Dunnart	*Sminthopsis macroura*	DAS	4	7			2
Northern Brown Bandicoot	*Isoodon macrourus*	PER			1		
Greater Glider	*Petauroides volans*	ARB			1	1	
Sugar Glider	*Petaurus breviceps*	ARB			2	1	
Common Brush-tailed Possum	*Trichosurus vulpecula*	ARB			2	2	
Rufous Bettong	*Aepyprymnus rufescens*	MAC			13	5	5
Spectacled Hare-wallaby	*Lagorchestes conspicillatus*	MAC	2		2		
Agile Wallaby	*Macropus agilis*	MAC	1				
Antilopine Wallaroo	*Macropus antilopinus*	MAC	7	3			
Eastern Grey Kangaroo	*Macropus giganteus*	MAC			17	24	6
Euro	*Macropus robustus*	MAC		1		9	
Red Kangaroo	*Macropus rufus*	MAC		1			
Northern Nailtail Wallaby	*Onychogalea unguifera*	MAC	6	5			
Hoary Wattled Bat	*Chalinolobus nigrogriseus*	-	1				
Short-tailed Mouse	*Leggadina lakedownensis*	MUR	2		1		6
Eastern Chestnut Mouse	*Pseudomys gracilicaudatus*	MUR			1		
Western Chestnut Mouse	*Pseudomys nanus*	MUR	10				
Long-haired Rat	*Rattus villosissimus*	MUR		4			
Dingo	*Canis lupus dingo*	-				1	
Cat	*Felis catus*	INT			1	1	
Rabbit	*Oryctolagus cuniculus*	INT			1	1	
Pig	*Sus scrofa*	INT			1		
Donkey	*Equus asinus*	INT				1	

APPENDIX 4

EFFECTS OF AN INTRODUCED PASTURE SPECIES ON BIODIVERSITY IN A TROPICAL SAVANNA WOODLAND

Alex S. Kutt[1] *and Alaric Fisher*[2]

Tropical Savannas Management CRC and
1. Environmental Protection Agency, PO Box 5391, Townsville, Qld 4810
2. Department of Infrastructure, Planning and Environment, PO Box 496, Palmerston, NT 0810.

INTRODUCTION

In Queensland, Grazing Land Management packages are becoming widely adopted as a tool for assessing land condition, and the relative "health" of country. Within these packages, land condition indices are based on the extent of perennial grasses, bare ground and woody thickening. However, there is uncertainty whether these factors are also adequate surrogates for biodiversity status. In many cases there is considerable commonality between perceptions of healthy landscapes from both pastoral and biodiversity perspectives (relating to, for example, maintenance of a high cover and diversity of perennial grasses). Conversely these perspectives may substantially diverge. One example is the impacts of introduced pastures on landscape health. Areas with a high cover of palatable, perennial, introduced pasture grass are likely to be considered in good condition by the pastoral sector; but in poor condition from a biodiversity perspective. In this paper we present data from a study in northern Queensland savanna that illustrates this divergence.

METHODS

A flora and fauna survey was conducted in the Dalrymple Shire (20°S, 146°E, Einasleigh Uplands bioregion) between November 2002 and March 2003. A total of 48 one-hectare sites were located on five properties dominated by open *Eucalyptus* woodland on ferrosols (basalts), with the sites sampling a range of condition classes. The native groundcover was dominated by *Heteropogon* spp., *Bothriochloa* spp. and *Dichanthium* spp., but approximately half of the sites contained varying cover of the introduced pasture Indian Bluegrass *Bothriochloa pertusa*, a species considered palatable, perennial and productive. Mammals, reptiles, birds, ants, vascular plants, vegetation structure and other habitat attributes were sampled within each site.

RESULTS

A total of 138 vertebrate species (86 birds, 29 reptiles, 10 amphibians and 13 mammals), 152 species of vascular ground cover plants and 106 species of ant were recorded from the study sites. The relative cover of *B. pertusa* at these sites had a pronounced influence on composition of vertebrates, in particular birds (Fig. 1). Species such as Rufous Songlark, Weebill, Red-backed Fairy-wren, Western Gerygone and Golden-headed Cisticola were less abundant, and Pied Butcherbird, Yellow-throated Miners, Australian Raven, Australian Magpie and Black-faced Woodswallow more abundant, in sites dominated by *B. pertusa*.

The species richness of both vertebrates and plants was significantly greater at sites with low cover (<5%) of *B. pertusa* compared to sites with high cover (>5%). Within the birds, the diversity of some guilds (e.g. ground/understorey insectivores) was markedly lower in high cover sites. The richness of other guilds (e.g. granivores) did not differ, but there was a clear turnover in dominant species (Red-winged Parrot and Zebra Finch were abundant in sites with <5% *B. pertusa*, while Cockatiel and Galah were abundant in sites with >5%).

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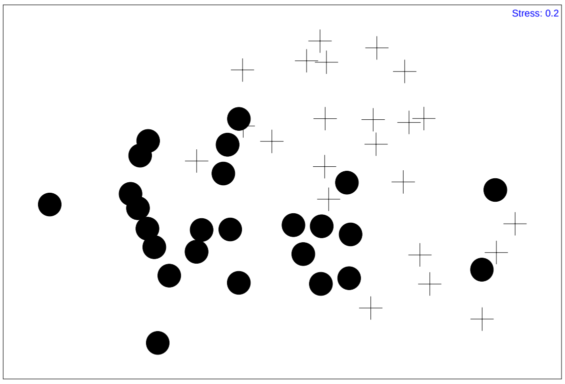

Figure 1. Two-dimensional ordination (multidimensional scaling) indicating the change in bird species composition between sites with <5% (solid circles) and >5% (crosses) *B. pertusa* cover.

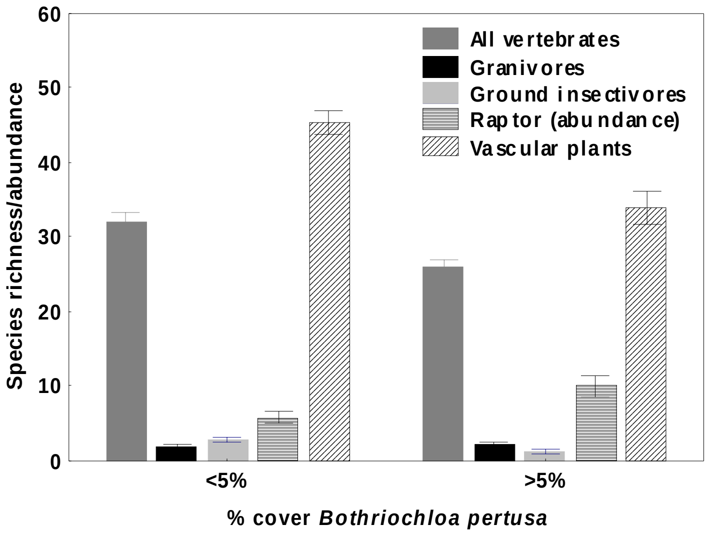

Figure 2. Mean richness or abundance (+ s.e.) of selected fauna and flora groups at sites with <5% and >5% *B. pertusa* ground cover.

DISCUSSION

The implications of this study are to some extent self-evident - we must be careful about the context when discussing the relationship between land condition and biodiversity. At our sites, the relationship between biodiversity status and "land condition" was dependent on whether a high cover of *B. pertusa* was considered to indicate "good" or "poor" condition. When the condition of sites are assessed from pastoral perspective the presence of perennial, productive and palatable introduced pasture grasses such as *Cenchrus ciliaris* and *Bothriochloa pertusa* are considered desirable, but this assessment ignores the substantial impacts of these introduced pastures on native biota. If conventional methods for monitoring land condition, including remotely-sensed cover-change analyses, are to be adapted as broader indicators of landscape health (including biodiversity status) in rangelands, then they must be sufficiently flexible to take into account the ecological differences between native and introduced perennial pastures.

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APPENDIX 5

THE INFLUENCE OF DIFFERENT GRAZING STRATEGIES ON THE PATTERNS OF VERTEBRATE FAUNA IN A TROPICAL SAVANNA WOODLAND

Alex S. Kutt[1], *Alaric Fisher*[2] *and Peter O'Reagain*[3]

1. Tropical Savannas Management CRC and Environmental Protection Agency, PO Box 5391, Townsville, Qld 4810
2. Tropical Savannas Management CRC and Department of Infrastructure, Planning and Environment, PO Box 496, Palmerston, NT 0810.
3. Department of Primary Industries, PO Box 976, Charters Towers, Qld 4820.

INTRODUCTION

The tropical savannas of northern Australian are characterised by high climatic variability, with corresponding impacts on annual resource availability. The native biota is adapted to these patterns, but variability in rainfall and forage production is a major challenge to the cattle industry. Despite this variability, many properties tend to set-stock, sometimes exceeding their 'safe' long-term carrying capacity and causing resource degradation. Typically, resource degradation refers to the impact on productivity and profitability of grazing enterprises, though the manner in which native fauna changes with different management strategies is a significant issue from a conservation perspective. In this paper we examine variation in the composition of the vertebrate fauna over a 6-year period in a large grazing trial being conducted in tropical savanna woodlands in north-eastern Queensland.

METHODS

In 1997, a grazing trial was established on Wambiana Station (20° 34' S 146° 07' E) near Charters Towers in North Queensland, in order to examine ways of better managing for rainfall variability. The objective was to test, at a paddock scale, the relative impacts on resource condition and animal production of five grazing strategies – light stocking, heavy stocking, variable stocking, variable-SOI stocking and rotational spelling. The trial had a replicated design using ten, 100 ha paddocks, each with similar proportions of three land types dominated by open *Eucalyptus* and *Acacia* woodland.

In addition to the standard pasture condition assessments undertaken during the trial, sites for monitoring vertebrate fauna were established in 1998 to provide pre-treatment baseline data. Sixteens sites were sampled using standardised one-hectare quadrats, representing two land types (box *Eucalyptus brownii* and ironbark *E. melanophloia* open woodlands) in two replicates of four of the grazing treatments (heavy, light, variable, rotational). These sites, and an additional eight sites in box woodlands were re-sampled in 2003/4. Mammals, reptiles, birds, amphibians, ants, vascular plants, vegetation structure and other habitat attributes were recorded within each quadrat plot.

RESULTS

A total of 98 species comprising 64 birds, 20 reptiles, 4 amphibians and 10 mammals have been recorded to date within the grazing trial. Examination of the dry season bird sample indicates that the composition of the avifauna has changed markedly from the baseline to the resample (Figure 1). Species such as Rufous Whistler and Red-backed Fairy-wren were less abundant in the resample, and Weebill and Striated Pardalote more abundant.

The lower mean dissimilarity (Bray-Curtis index using both the baseline and resample scores) in the heavily grazed sites compared to the light and rotational and variable (category=mid) stocking treatments (Fig. 2) suggests the imposition of more conservative grazing regimes has resulted in a greater degree of change in the fauna composition. Some preliminary trends indicate that species that have declined across the trial since the baseline survey (e.g. fairy-wrens) were in fact still abundant in the lightly grazed treatments.

APPENDIX 5

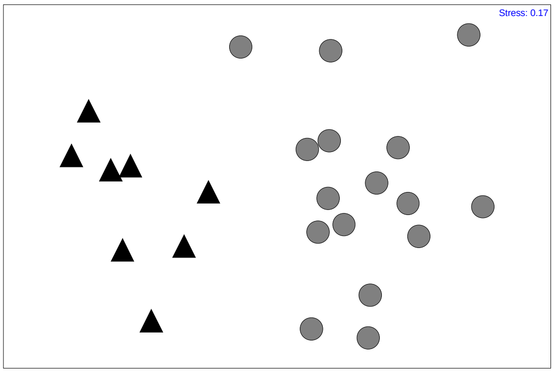

Figure 1. Two-dimensional ordination (multidimensional scaling) indicating the change in bird species composition (dry season sample only) between sample sites between the baseline survey (solid triangles) and the resample (grey circles) in the *Eucalyptus brownii* woodland.

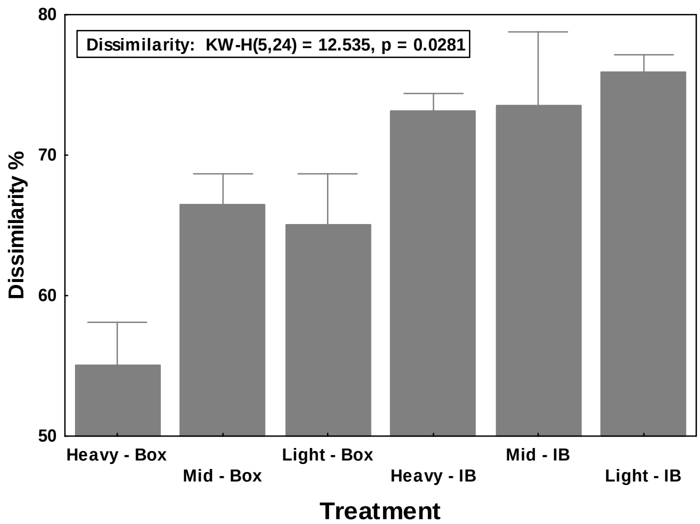

Figure 2. Mean compositional dissimilarity (Bray-Curtis) for each vegetation type and treatment using bird species composition (dry season sample only) data.

DISCUSSION

The pattern of change in the vertebrate fauna abundance and composition across the Wambiana grazing trials is likely due to the imposition of the grazing treatments, combined with climatic variation. However there are marked differences manifesting between the extreme and more moderate stocking strategies. The implication of this is that conservative grazing does have biodiversity benefit. This data also suggests that the local decline of some species may be useful indictors of management that is gradually impacting on native wildlife.

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