Rangelands Monitoring:

Developing an Analytical Framework for Monitoring Biodiversity in Australia's Rangelands.

Background paper 2.
A review of pastoral monitoring programs and their real and potential contribution to biodiversity monitoring.

Tropical Savannas CRC
Cooperative Research Centre for the Sustainable Development of Tropical Savannas

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Summary

(1) Major pastoral monitoring programs exist in each rangeland jurisidiction. The programs are relatively well institutionalised and (in most states & the Northern Territory) there is an ongoing program of reassessment. There are many consistencies between these programs in approach, protocol, sampling intensity and in data collected, but also some disparities.

(2) Together, these programs have some distributional biases, most notably (at a broad-scale) low representation of non-pastoral bioregions and habitats, and (at a finer-scale) poor representation of ecotones and riparian areas. This sampling inequity constrains the possible use of the existing plot-based pastoral monitoring programs for national rangeland biodiversity monitoring. At least theoretically this problem could be overcome with establishment of additional sites in these poorly represented habitats and regions.

(3) The pastoral monitoring programs have an explicit purpose of reporting on trends. The large number of established plots gives these programs the capacity to detect underlying trends, despite the characteristic marked fluctuation of many rangeland environments in response to periods of rainfall extremes. The ability to separate signal from the considerable background noise may be particularly relevant to biodiversity monitoring. However, techniques for separating anomalous, management-induced change from background variation driven by unmanaged environmental variation (e.g. climate) need to be further developed and widely adopted.

(4) The biodiversity of Australia's rangelands has been substantially diminished over the last 200 years. Conceptually this loss may be related to rangeland degradation. As pastoral monitoring programs have the objective of recording trends in the condition of the pastoral areas of Australia's rangelands, this objective (and the information derived from the programs) should be useful for at least broad inference about the state of rangeland biodiversity. However, the link between rangeland condition (or health) and biodiversity remains unproven, or at least not calibrated. Further study is needed to establish the parameters and constraints in interpretation of any such link, and hence the validity of any measures derived from pastoral monitoring to act as surrogates of biodiversity. Monitoring programs explicitly designed to facilitate linkage of different indicators of rangeland condition and other measures of the status of biological diversity could make an important contribution to improved understanding.

(5) There are some direct measures of biodiversity attributes currently recorded in plot-based pastoral monitoring programs. These are almost all parameters relating to vegetation (or floristics). Some of these are clearly useful and amenable to reporting on trends in biodiversity, although there are some notable caveats (especially in relation to the general omission of annual plants in pastoral monitoring protocols). The large number of plots sampled in many programs renders some of these biodiversity data bases particularly powerful for assessments of large parts of the landscape. However, biases in plot placement towards sites "representative" of preferred grazing lands means that they may miss important processes occurring in landscape elements that are particularly significant for

biological diversity (riparian areas, wetlands, ecotones, other topographically-disjunct regions).

(6) Remote-sensing technologies now offer the opportunity to generalise condition assessment from a plot scale to paddock, property or regional scale, and to incorporate landscape variation into the assessment. Remote-sensing based condition assessment is now being implemented, at least on a trial basis, in most rangeland States and Territories and is based on either the identification of differential responses of vegetation to major rainfall events along grazing gradients or interpretation of indices of vegetation cover across multi-temporal sequences of images. While these approaches primarily identify changes in total ground cover, some inferences about changes in floristic composition, particularly the perennial / annual ratio can also be drawn. Remote-sensing technologies with very fine resolution (eg. airborne videography) can allow the quantification of additional attributes of landscape function and patch structure.

(7) All remote-sensed pasture condition assessment methods require substantial landscape stratification, operator experience and ground-based validation to ensure accurate interpretation, especially when applied to new regions or land types. The 'grazing-gradient' approach has been best validated but is probably inappropriate for substantial portions of the Australian rangelands, where there is high landscape complexity and/or small paddock sizes. While remote-sensing can be used to generalise observations made on existing pastoral monitoring plots, these plots are not sufficiently representative in most regions (see above) to provide adequate validation at a regional scale and additional targeted ground-based sampling is therefore always likely to be required.

(8) Remote-sensed condition assessment provides no direct information on biodiversity values, but conceptually there are useful links between remote-sensed measures of pasture condition or landscape function and biodiversity attributes. Most of these links require extensive validation before they can be adopted as surrogates for biodiversity values; to determine which components of biodiversity can be monitored remotely; and to what extent these linkages can be generalised geographically or must be tailored to each rangeland type. In addition to its use for 'pastoral' condition assessment, remote-sensing may provide much other useful spatial data, such as extent and rates of land-clearing, mapping of fires, etc that can be also linked to biodiversity values.

(9) Recent research has demonstrated that piosphere gradients (with the implicit assumption that these correspond to grazing gradients) may serve as useful surrogates for at least some elements of biodiversity in some rangelands, with plant, vertebrate and invertebrate taxa showing increaser or decreaser responses along the gradient, and some taxa being found only at the water-remote limit of the gradient. It is possible that remote-sensing of grazing gradients in some rangelands may provide a more sensitive monitoring tool than simple distance-from-water mapping, although this remains to be demonstrated.

(10) Analysis of monitoring data from existing plot-based programs (when it has been attempted at all) has lagged behind their implementation. The utility of these schemes would be improved by standardised reports to a group charged to

undertake a common analysis on a combined date set or meta-analyses by IBRA region, vegetation type or some other stratification. A National coordination of state & Northern territory analyses would also achieve a more consistent product for a national reporting framework. In the Adaptive Framework, we recommend improvements to reporting and analyses arising from these monitoring programs that may provide greater insight into trends in biodiversity values.

(11) To optimise the contribution of existing plot-based pastoral monitoring programs to a biodiversity monitoring framework, some enhancement of the existing programs are required. Important features for enhanced plot-based schemes will be:

- expansion of the range of landscape elements and grazing regimes sampled, and improving comprehensiveness of sampling amongst bioregions
- nesting within remote sensing or similar studies which offer the potential to scale up beyond the property to catchment or regional scales
- further validation studies to link measured attributes of pasture condition or landscape function to biodiversity attributes, both for plot-based and remote-sensed programs

(12) Pastoral monitoring schemes operating in isolation cannot in themselves offer an adequate framework for monitoring biological diversity of rangelands. However, by careful design and linkage to other work they can provide a significant component of a useful framework.

1. Introduction

This paper aims to provide a review of the applicability and relevance of existing pastoral monitoring programs to the establishment of a biodiversity monitoring program for Australia's rangelands. In companion background papers we:

- review trends in biodiversity across the rangelands;
- review existing programs which have the direct and explicit purpose of monitoring at least some components of biodiversity in at least some rangeland areas; and
- review the practice and success of extensive biodiversity monitoring programs and approaches in operation elsewhere in the world.

These three streams will be brought together to guide the development of a proposal for the establishment of a national monitoring scheme for biodiversity in Australia's rangelands, an outcome explicitly recommended in the *National Principles and Guidelines for Rangeland Management* (ANZECC & ARMCANZ 1999).

The review we present here provides a summary overview of the existing pastoral monitoring programs, with special focus on aspects related to biodiversity. More comprehensive reviews of these programs are provided in SLWRMC (1997), in Task 4.1 of the Rangeland Theme of the Audit and in Tongway and Hindley (1999), with the latter review notably examining the value of these schemes for the provision of information about *ecosystem function* (*sensu* Ludwig et al 1997). While this attribute is sometimes treated as a component of biodiversity, and is obviously a critical foundation for other aspects of biodiversity, we recognise that the treatment given in Tongway and Hindley (1999) is authoritative and hence do not include it in further discussion here.

2. A review of existing pastoral monitoring programs

All rangeland States and Territories have at least one rangeland pastoral monitoring program. Typically, these programs are multi-faceted, entailing various combinations of fixed plots monitored quantitatively at intervals, photographic monitoring schemes, remote sensing, and lease and regional assessments (Table 1). The purpose of this section is to outline the characteristics of the main programs.

2.1. Overview of the structure of plot-based programs

Identity, history and broad location

The four rangeland States all have a substantial commitment to plot-based monitoring of pasture condition (Fig. 1, Table 2). There are many commonalities in the data recorded by these programs (SLWRMC 1997, Tongway & Hindley 1999, to be addressed in Task 4.1 of the Audit), particularly in the collection of soil data and plant species frequency. SLWRMC (1997) considered it would be possible to integrate the plot-based programs into a national program of pasture monitoring. Tongway & Hindley (1999) concluded that there were some possibilities for biome-level assessment of landscape function based primarily on the soil data collected by the programs. There are also substantial differences between programs, particularly in the history, mode and intent of landscape sampling, plot layout and recording frequency.

Western Australia has two plot-based sub-programs, ***WARMS Shrublands*** and ***WARMS Grasslands***. These correspond broadly to arid/semi-arid and tropical regions respectively, but with overlap in the Pilbara (Fig. 1) where site type depends on vegetation type (Ian Watson *pers. comm.*). In **Grassland** sites, perennial species frequency and the crown cover of woody species are estimated. In **Shrubland** sites, the population dynamics and size of individual woody species are recorded by direct census.

Queensland has a nested set of three programs. ***QGraze*** is designed specifically to monitor trends in pasture condition. ***TRAPS*** is intended to monitor the spread and dynamics of woody weeds and vegetation thickening and to quantify rates of carbon sequestration (Burrows *et al.* 1998). Hence, at TRAPS sites, data about woody vegetation dynamics is collected in addition to the standard set of data about non-woody vegetation collected using the full QGraze methodology. The ***Grasscheck*** program uses a major subset of the QGraze methodology including frequency of perennials and site photography, but data are collected and administered by landholders. Historically, Grasscheck was developed as a methodological sub-set of QGraze, which was in turn developed as a methodological sub-set of TRAPS (Eric Anderson *pers. comm.*).

Table 1. Major components of existing State and Territory rangeland pasture monitoring programs.

State	Component	Method*	Key attributes recorded	Assessment interval	Interpretable scale	Reference/source **
Queensland	TRAPS	fixed plots	dynamics of woody plants, frequency of perennials, soil surface condition	2 - 5 years	regional/plant community	Back et al. (1997, 1999)
	QGraze	fixed plots	frequency of perennials, soil surface condition	3 - 5 years	regional/plant community	Cliffe & Hoffmann (1999)
	Grasscheck	fixed plots, photography	frequency of perennials	c. 1 - 5 years	paddock/property	O'Sullivan & Lithgow (1999), Pegler (1997)
New South Wales	Rangeland Assessment Program	fixed plots	frequency of perennials, soil surface condition	1 year	regional/range type	Rob Richards pers. comm.
South Australia	Land Condition Index	assessment at points on transect	pasture condition rating	c. 14 years	property	Maconochie & Turner (1999), R. Tynan pers. comm. Lange *et al.* (1994)
	Photopoints	fixed plots	frequency of perennials	2 - 7 years	property/regional	ditto

Table 1. Continued

State	Component	Method*	Key attributes recorded	Assessment interval	Interpretable scale	Reference/source **
Western Australia	WARMS Grasslands	fixed plots	frequency of perennials, crown cover of woody spp, soil surface condition	3 years	regional/plant community	Holm (1993), Novelly & Watson (1999)
	WARMS Shrublands	fixed plots	size & popn. dynamics of woody plants, soil surface condition	5 years	regional/plant community	ditto
	Pastoral Lease Reporting	traverse assessments	pasture & soil condition rating	5-6 years	property	ditto
	Pastoralists Photo Monitoring	photography	perennial plants, soil surface	variable	property	ditto
	Regional Rangeland Survey	various	various	once-off	regional/landsystem/ landscape	ditto
Northern Territory	Tier 1	photography	cover	3 - 5 years	property	R. Karfs, pers. comm.
	Tier 2	remote sensing (fixed plots)	cover, frequency of perennials, soil surface condition	1 - 5 years	regional/land unit	Karfs (1999), R. Grant pers. comm.

* all fixed plot programs are complemented with photography and augmental remote sensing programs are under development.

** in all cases, the State Representative of the NRMCC, pers. comm.; for all fixed plot programs, SLWRMC (1997) and Tongway & Hindley (1999).

Figure 1. The distribution of pasture monitoring plots in Australia, by State and sub-program.

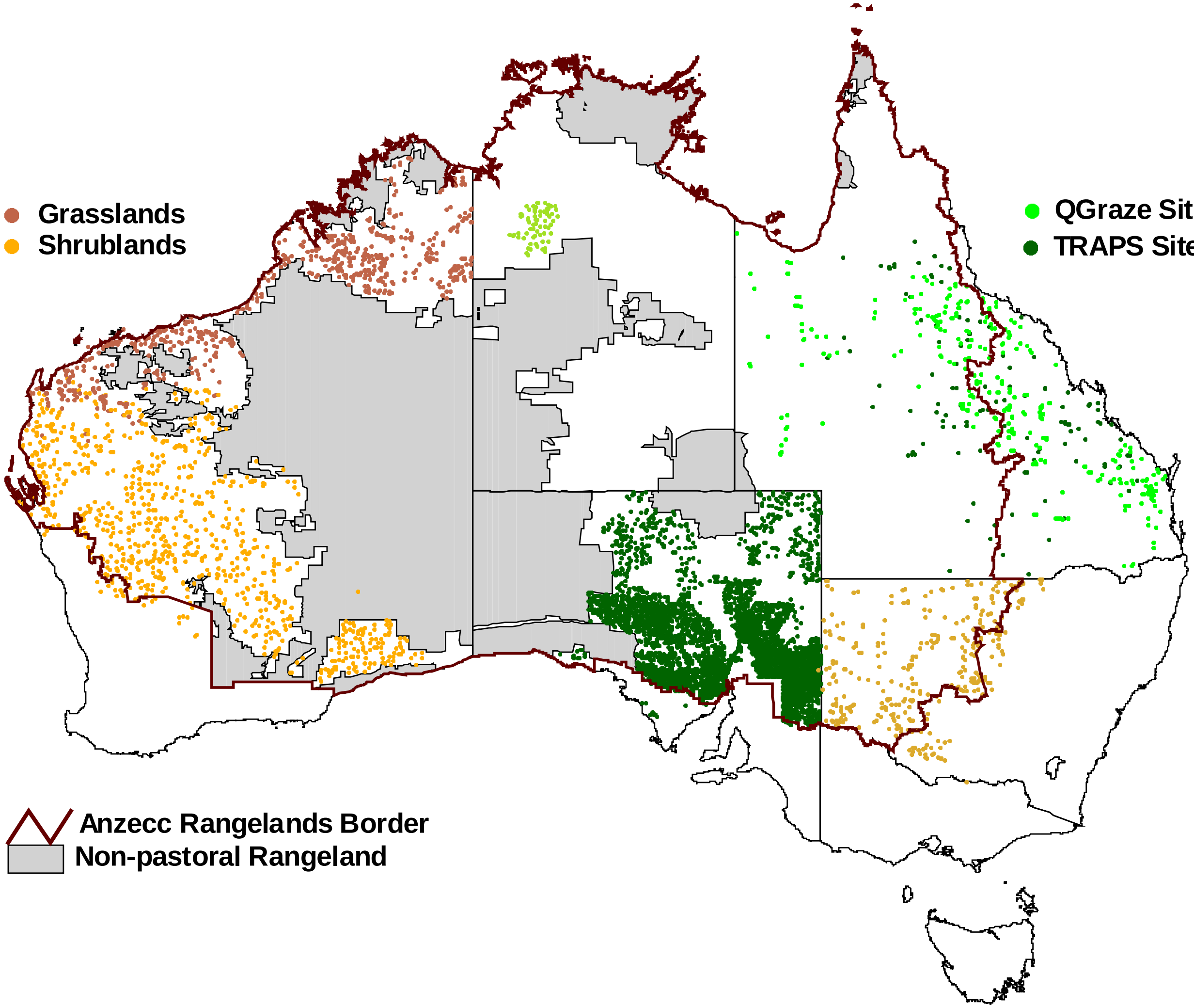

Table 2. Key literature for State and Territory plot-based pasture monitoring programs.

State (Program)	Review / Summary / Introduction	Manual	Trend analysis (region; IBRAs*)
All states/ territories	SLWRMC (1997); Tongway & Hindley (1999)	not applicable	-
Queensland QGraze TRAPS	 Cliffe & Hoffmann (1999) Back *et al.* (1999)	 Anonymous (no date *a.*); Anonymous (no date *b.*) Back *et al.* (1997)	 Cliffe & Hoffmann (1999) (central highlands, DEU) Ksiksi & Fry (1999) (Dalrymple Shire, BBN) Burrows *et al.* (1998)
New South Wales RAP	 -	 Green *et al.* (1994); Hart *et al.* (1997)	 Eldridge & Stafford (1999) (western Riverina, RIV)
South Australia photopoints	 Maconochie & Turner (1999)	 yes (unpublished)	 -
Western Australia WARMS shrublands WARMS grasslands	 Holm *et al.* (1987); Hacker *et al.* (1990); Holm (1993); Duckett *et al.* (1996); Novelly & Watson (1999)	 Shrubland = Anonymous (1995) Grassland = Environment & Climate Impact Group (1998)	 Duckett *et al.* (1996) (Carnarvon, Kalgoorlie, Meekatharra; MUR, COO, CAR, GAS) Duckett & Novelly (1999) (East Kimberley black soil: VB) Duckett *et al* 1999a (Halls Creek; OVP, TAN) Duckett *et al* 1999b (Fitzroy Crossing; DL, OVP)
Northern Territory Tier 2**	 Karfs (1999)	 -	 -

* Interim Biogeographic Regionalisation for Australia (Thackway and Cresswell 1995). In no case were the IBRAs stated in the report; definition of the study areas varied from precise to vague, the stated IBRAs are at times presumed.

** Tier 2 is not a plot-based monitoring program, but does have permanent plots in the Victoria River District established to ground-truth remote sensing results.

The Northern Territory is included in this review on the basis of 69 fixed plots in the Victoria River District and a current program to extend these to the Sturt Plateau. However, a somewhat different approach to pasture monitoring has been adopted in the Northern Territory. The ***Centralian Range Assessment Program*** (Bastin 1989) was probably the first large-scale pasture monitoring program to be established in Australia. It originated with assessments and surveys in the late 1960s and progressed to the establishment of *c.* 700 monitoring plots mainly from 1977 to the mid-1980s (Bastin *et al.* 1983, Holm *et al.* 1987). However, the program was eventually abandoned when it became clear that it was incapable of permitting discrimination between seasonal conditions and long-term trends (Russell Grant, Rod Applegate, *pers. comm.*; see also Foran *et al.* 1986, Friedel *et al.* 1988). Current efforts in the Northern Territory are directed towards monitoring by remote sensing, with programs at various stages of development in the Victoria River District, Sturt Plateau, Barkly Tableland and Alice Springs regions. Although all programs require extensive ground-truthing, permanent monitoring plots are being established only in the sub-humid tropics.

The historical and anticipated development of the State and Territory programs is summarised in Table 3. Establishment of sites for the New South Wales program commenced in 1989 and was completed in 1994. In Western Australia, the last of the plots were installed in late 1999. All plots for the South Australian program should be installed and assessed by the end of 2000, whilst Queensland and the Northern Territory are still well short of completion. Approximately 4,900 WARMS plots were established prior to 1992, but 3,400 of these were "abandoned" (but data and sites are retrievable) following a major review in 1992 (Holm 1993, Ian Watson *pers. comm.*). Future site establishment objectives are doubtless subject to review and funding vagaries in all States where development is not complete. The number of sites to be established in Queensland is the subject of specific review.

Re-sampling of plots is advanced in New South Wales, Western Australia and the Northern Territory, moderately advanced in Queensland and only just commencing in South Australia. In New South Wales, plots are assessed annually. In Western Australia and the Northern Territory, plots are assessed at fixed intervals of either three or five years. In Western Australia, it is the intention to assess all sites in a given Land Conservation District in the same year, an intention that has been implemented with more success in the Kimberley (see for example Duckett *et al* 1999a,b) than elsewhere (Ian Watson *pers. comm.*). Protocols for repeat assessment are not fully resolved in Queensland and South Australia and have involved, or are expected to involve, variable intervals.

Table 3. Number of pasture monitoring plots in State and Territory pasture monitoring programs

		No. of plots		
State/Territory	**Year of commencement**	**1996 *[1]**	**1999 *[2]**	**Projected total**
Queensland (QGraze & TRAPS)	1992	400	490*[3]	*c.* 800
New South Wales	1989	340	340	340
South Australia	*[4]	3,000	5,160	5,500
Western Australia (WARMS Shrublands & Grasslands)	1984 *[5]	800	1,525 *[6]	1,550
Northern Territory (Tier 2)	1994	40	69	*c.* 400 *[7]
TOTAL		4,580	7,584	*c.* 8,590

*[1] source: mostly SLWRMC (1997)
*[2] source: data provided to us by each State/Territory agency
*[3] comprising 354 QGraze-only sites and 136 TRAPS sites
*[4] a few plots were established in the early 1950s; the program was substantially upgraded in 1983, and the rate of establishment of plots peaked in 1992
*[5] but with major changes commencing in 1994, which included a substantial reduction in the number of plots from a peak of 4,900
*[6] comprising 942 Shrublands and 583 Grassland sites
*[7] to cover the semi-arid tropics

Program objectives and beneficiaries

There has been considerable confusion over the objectives and beneficiaries of the plot-based pasture monitoring programs, and this confusion appears to have influenced the development of some programs. The literature consistently reflects the perceived need for data to facilitate and improve management, and this has often been interpreted as requiring the provision of data/feedback to pastoralists to influence management at property and paddock scales (e.g. Holm *et al.* 1987, Wilcox 1988, Burnside & Chamala 1994, Phelps 1999). In Western Australia, range monitoring in the 1970s and 1980s "*was crippled by a perceived need to satisfy both the institutional demands of reporting to government ... plus the individual station management needs*" (Novelly & Watson 1999). The outcome of a review of this program (also called WARMS at the time) was a substantial shake-out of the program in 1992 (Holm 1993) with the implementation of a more focussed monitoring system clearly aimed at providing information at broad spatial scales only (Table 1). The planned and actual number of monitoring plots in WARMS was substantially reduced, and the purpose of WARMS clearly defined as "*to inform parliament, its agencies and the community on changes in condition of the State's pastoral rangelands at the regional to state scale*." (Novelly & Watson 1999). This confusion of objectives probably persists across a number of rangeland States, being more obvious in Western Australia only because they have explicitly confronted the problem.

The intensity of sampling is greatest in South Australia, with an average of *c.* 20 monitoring plots per property (Paul Gould *pers. comm.*). This may permit quantitative property-level assessments and should in no way inhibit quantitative assessments at larger spatial scales. None of this, of course, excludes the use and value of plot data as a basis for discussion with landholders about property management issues. Property- and paddock-scale assessment is beyond the scope of this report.

Site selection

In Queensland, New South Wales and Western Australia, sites are selected after initial stratification by vegetation or range type (Table 4), with sites concentrated in those vegetation types that are either particularly productive pastures and/or considered particularly vulnerable to grazing impacts. In South Australia, coverage is more spatially comprehensive and property oriented. Most sites have been established in grazed areas on pastoral properties and most programs make no formal use of control or reference sites. Note, however, that this was not the case for the Centralian Range Assessment Program or for the WARMS Shrublands program prior to 1992 (Holm *et al.* 1987, Hacker *et al.* 1990), which both initially included reference exclosure sites. For the latter program, these exclosed sites have not been assessed since 1994; none has as yet been incorporated into the ongoing re-sampling regime; the use of the physical exclosure and the existing data are in abeyance until the rest of the WARMS schedule is on track (Ian Watson *pers. comm.*); and trend analysis (Duckett *et al.* 1996) has been conducted without their use. Obviously the absence of "control" sites complicates interpretation, particularly given that analysis of grazed plot condition is rarely able to be linked to good data on trends in density of grazing animals, duration of exposure to different grazing pressures, or long term grazing history. Existing exclosure sites would not act as true 'controls' for most of the monitoring sites given the wide distribution of the latter and the spatial variability of rainfall, but they would add considerably to ecological understanding of rates and patterns of change.

At local scales, sites in all State programs are selected to represent "typical" grazed conditions, avoiding "sacrifice" zones near watering points and sites remote from water (Table 4); although in Western Australia there is some attempt to select a range of condition sites, including some sites remote from water (I.Watson, pers. comm.). However, these selection criteria are not always rigidly applied, as may be seen by comparing these criteria with data for five bioregions in Figure 2. In all five bioregions examined there are a small percentage of sites within 1 km of permanent water. In all but Murray-Darling Depression (NSW section) there are a few sites more than 6 km from water, although the considerable majority are between 1 and 3 km from permanent water in all except the South Australian Channel Country. The very different sampling strategies utilised in the sheep (Gawler) and cattle (Channel Country) rangelands in South Australia is evident, but there is little difference in sampling strategies in these rangeland types in Western Australia (Murchison *cf* Dampierland). The greater dispersion of distances from water in Murchison and Dampierland in Western Australia and especially Channel Country in South Australia compared to Gawler and Murray-Darling Depression may reflect larger paddock sizes in the former areas.

With the exception of South Australia, the departments responsible for pasture monitoring are quite separate from those responsible for the management of conservation reserves and biological diversity. In South Australia, the pasture monitoring program has been formally extended to three rangeland conservation reserves, with *c.* 140 plots established in the Flinders Ranges, Lake Gairdner and Gammon Ranges National Parks in the mid- to late- 1990s (Brendan Lay pers. comm.). All three parks have a history of grazing by stock and/or a significant current problem with grazing by feral animals. Flinders Ranges National Park is the subject of a major vegetation and fauna recovery project (Operation Bounceback), of which the monitoring plots are an integral part (Lay *et al.* 1999).

Approximately 16 (4.7%) New South Wales RAP sites are in conservation reserves, a proportion that closely reflects the proportion of the Western Division that is reserved. However, this proportionality is coincidental (Rob Richards *pers. comm.*). The intent when establishing RAP sites was to sample the range of grazing regimes in the Western Division, and parks and reserves were included on the basis that they provided representation of grazing regimes entailing either or both native or feral animals but not domestic stock.

In Queensland, a small number of QGraze sites have been established in ungrazed areas (Eric Anderson *pers. comm.*). In Queensland and Western Australia, monitoring of parks is managed quite separately from the rangelands program, although in the Queensland case, where parks monitoring is limited and organised regionally, monitoring programs in the north under current development utilise a modified TRAPS methodology (Gabriel Crowley, Paul Williams, Leasie Felderhof *pers. comm.*). The more extensive Western Australian parks monitoring system is discussed in more detail in Background Paper 3 & the Gascoyne-Murchsion case-study.

Figure 2. Distance of pasture monitoring plots from permanent water for five bioregions. Note that we have assumed that where distance = 0 on the database that this means the distance has not been recorded. Sample sizes are the number of plots with non-zero values

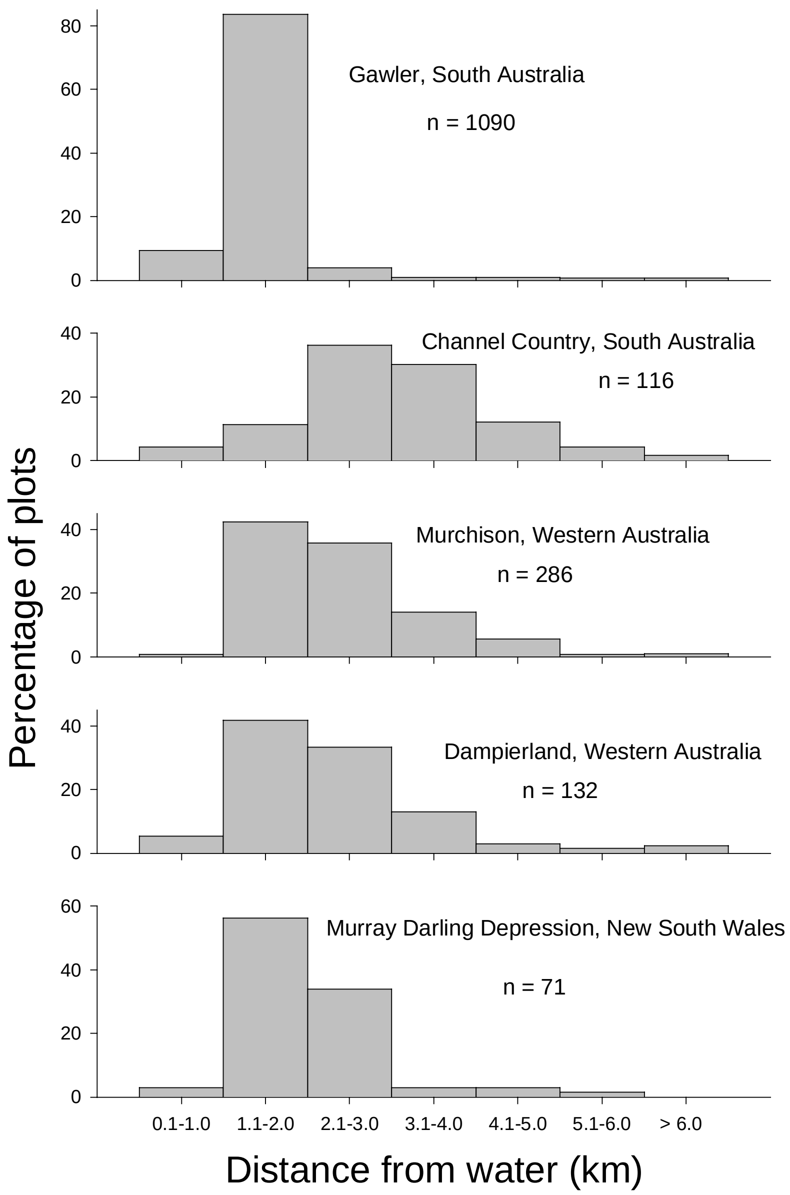

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Table 4. Environmental site selection criteria for pasture monitoring plots in State pasture monitoring programs. The major source is the summary of Tongway & Hindley (1999).

State	**Regional criteria**	**Local criteria**	
		Distance from water	**Other criteria**
Queensland (QGraze)	stratified by native pasture communities, with more intense sampling of those subject to adverse grazing impacts	if rainfall > 500 mm: 0.5 - 1.5 km; otherwise: 1 - 3 km (alternatively, > 0.3 km, Paul Back, pers. comm.)	representative of normal average grazing in paddock; currently grazed; internal uniformity
New South Wales	stratified by range types; only pastorally productive types vulnerable to degradation are sampled (7/11 types)	> 1.5 km	represent range of condition from "excellent" to"severely degraded"; average paddock size; representative of paddock
South Australia	by property/paddock throughout	most within stock grazing range; some beyond (sheep country, mostly 1- 3 km; cattle country, 3 - 5 km)	one plot per grazed paddock (sheep country), one plot per watering point (cattle country); representative of paddock/piosphere
Western Australia (WARMS Shrublands & Grasslands)	stratified by vegetation or pasture type, with more intense sampling of types with higher productivity and fragility ratings	> 1.5 km, except for saline conditions, where > 1 km	geographic evenness; representation of range of vegetation states and land units; preference for centre of large, relatively uniform grazed areas
Northern Territory	Victoria River District only	2-3km	representative of range of "functional states"

The distribution of plots at large spatial scales

The ability of plot-based programs to provide bioregional and rangeland-wide environmental information and measures of trends hinges fundamentally on the way in which the landscape is sampled. In this section, we provide summary data on the distribution of plots by bioregions and vegetation types at large spatial scales.

As illustrated in Figure 1, the *c.* 7,500 existing monitoring plots are distributed very unevenly across the rangelands. We could identify only four monitoring plots in the 42% of the rangelands that comprises the major non-pastoral areas. Approximately 7% of the plots are outside the area defined as rangeland by ANZECC (1996), with the majority (398) of these in Queensland, where the rangelands and agricultural lands overlap and intergrade extensively and the appropriate definition of rangeland is ambiguous. As previously mentioned, there are few plots in the Northern Territory, and these are currently concentrated in just one bioregion, the Ord-Victoria Plains. There are no plots on Cape York Peninsula nor in a major area of south-western Queensland. Coverage of pastoral rangeland areas in New South Wales, South Australia and Western Australia is more uniform. However, there are large differences between these States in the density of plots, with density greatest in the South Australian pastoral rangelands and least in New South Wales.

There are major differences between bioregions in the density of plots (Fig. 3*a*). Note that in the figure, the scale is logarithmic. Ten rangeland bioregions contain no monitoring plots at all, three contain only one plot and four more contain less than 10 plots (Table 5). This unevenness is somewhat, but not greatly, reduced when the major non-pastoral rangeland areas are excluded from the analysis (Fig. 3*b*). After exclusion of non-pastoral rangeland areas, eight rangeland bioregions still have no monitoring plots.

Figure 4 and Table 6 also illustrate sampling biases in the location of pastoral monitoring sites. Five vegetation types, including three categories prominent in the rangelands, have greater than 2.5 monitoring plots per 1,000 km^2, with chenopod shrublands the best-represented vegetation type. However, two vegetation types have fewer than 0.05 monitoring plots per 1,000 km^2, and four have fewer than 0.25 monitoring plots per 1,000 km^2. The latter class includes eucalypt woodland and *Acacia* with hummock grass, which between them occupy 28.6% of the rangelands as defined by ANZECC (1996). Eucalypt open woodland and Mitchell Grass, which occupy a further 23.6% of the rangelands, are also poorly represented. Three rangeland vegetation types are each represented by three or fewer plots, although all are vegetation types of *relatively* restricted occurrence - there is 99,000 km^2 of eucalypt forest with just one monitoring plot, and a further three vegetation types are represented by fewer than 100 plots, including Mitchell Grass with 69 plots.

Figure 3. The density of State and Territory pasture monitoring plots by bioregions, including (*a.*) and excluding (*b.*) the major non-pastoral rangeland areas. Beyond the ANZECC rangelands boundary, bioregions are not shown unless they contain monitoring plots. In *b.*, the density is for that portion of the bioregion that is in the pastoral zone (as defined on the map).

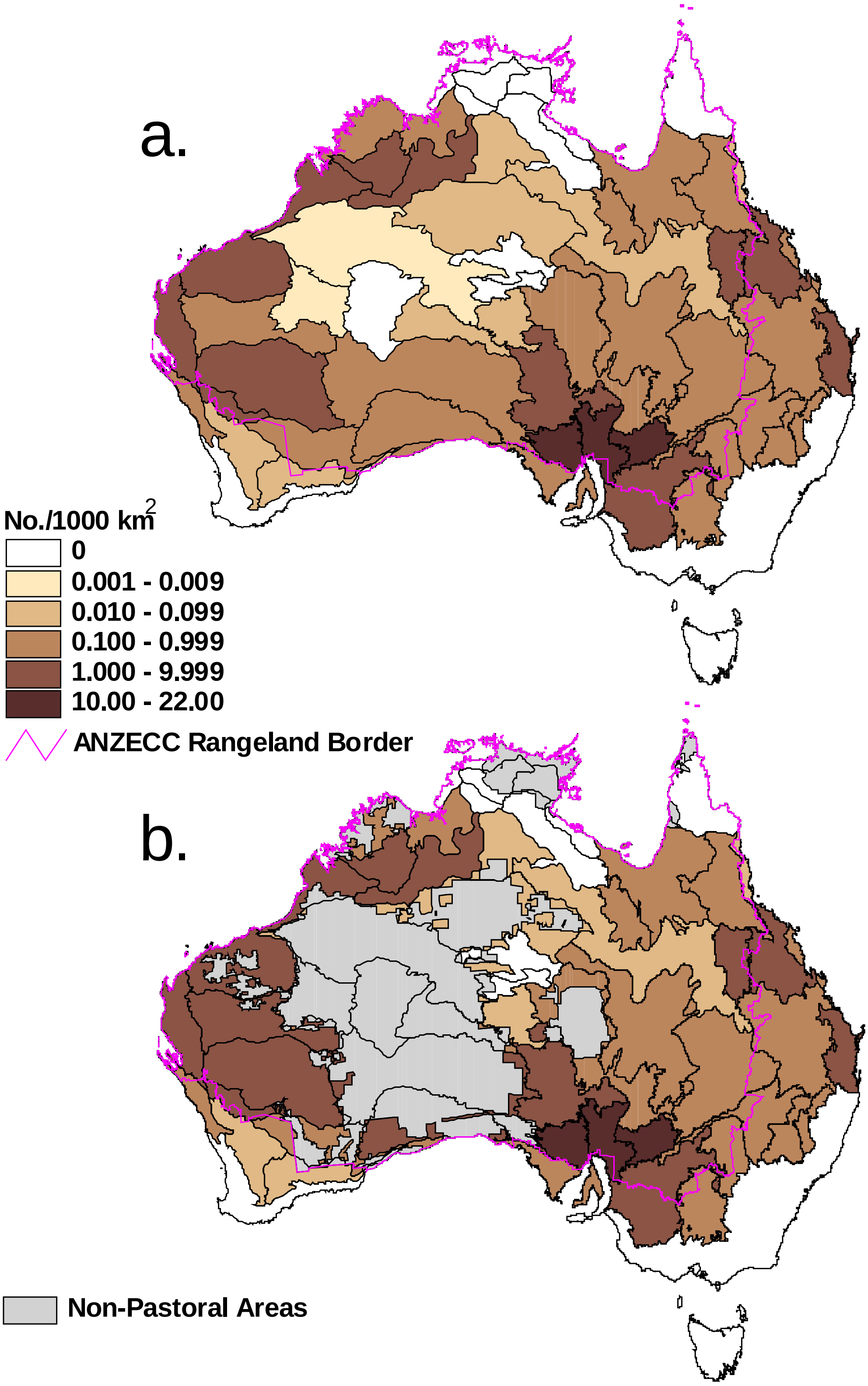

Table 5. The distribution of pasture monitoring plots across those IBRA bioregions included within the rangelands (as defined by ANZECC 1966). Note that our calculations of bioregion areas differ slightly from those of Thackway & Cresswell (1995).
*** = bioregion is <85%; ** <20% within the ANZECC rangelands. Bioregions which mostly comprise non-pastoral areas are indicated with square brackets.**

Bioregion	Area (km^2)	No. of plots	Density (plots /1000 km^2)
Burt Plain (BRT)	70,530	0	0
[Central Arnhem (CA)]	38,045	0	0
Cape York Peninsula (CYP)	119,101	0	0
Daly Basin (DAB)	21,428	0	0
[Gibson Desert (GD)]	152,154	0	0
Gulf Fall and Uplands (GFU)	120,162	0	0
Gulf Coastal (GUC)	28,236	0	0
MacDonnell Ranges (MAC)	36,211	0	0
[Pine-Creek Arnhem (PCA)]	53,253	0	0
[Top End Coastal (TEC)]	71,724	0	0
[Great Sandy Desert (GSD)]	388,653	1	<0.01
[Central Ranges (CR)]	94,773	1	0.01
[Little Sandy Desert (LSD)]	107,279	1	0.01
[Tanami (TAN)]	313,503	3	0.01
Mallee (MAL) **	78,728	2	0.03
Sturt Plateau (STU)	100,502	3	0.03
Wet Tropics (WT) *	18,215	1	0.05
Avon Wheatbelt (AW) **	92,359	6	0.06
Finke (FIN)	73,399	5	0.07
Mitchell Grass Downs (MGD)	315,240	31	0.10
Nandewar (NAN) **	26,726	3	0.11
Mulga Lands (ML)	251,808	35	0.14
Hampton (HAM)	11,654	2	0.17
Mount Isa Inlier (MII)	65,902	13	0.20
Victoria Bonaparte (VB)	73,585	15	0.20
Central Mackay Coast (CMC) **	14,374	3	0.21
Geraldton Sandplains (GS) **	36,930	8	0.22
Northern Kimberley (NK)	87531	22	0.25
Gulf Plains (GUP)	211,436	60	0.28
Eyre and Yorke Blocks (EYB) **	60,112	19	0.32
[Simpson-Strzelecki Dunefields (SSD)]	271,543	95	0.35
Coolgardie (COO) *	123,013	46	0.37

Bioregion	**Area (km^2)**	**No. of plots**	**Density (plots /1000 km^2)**
[Great Victoria Desert (GVD)]	413,819	159	0.38
Darling Riverine Plains (DRP) *	103,280	53	0.51
Riverina (RIV) **	90,072	51	0.57
Brigalow Belt South (BBS) **	273,935	166	0.61
[Nullabor (NUL)]	191,026	121	0.63
Channel Country (CHC)	298,631	190	0.64
Einasleigh Uplands (EIU)	127,807	101	0.79
Gascoyne (GAS)	177,212	162	0.91
Cobar Peneplain (CP) *	72,234	69	0.96
Central Kimberley (CK)	77,224	81	1.05
Murchison (MUR)	271,728	299	1.10
Ord-Victoria Plains (OVP)	125,467	144	1.15
Brigalow Belt North (BBN) **	111,007	130	1.17
Pilbara (PIL)	176,410	207	1.17
Desert Uplands (DEU)	67,670	83	1.23
South Eastern Queensland (SEQ) **	66,977	91	1.36
Yalgoo (YAL) *	35,267	48	1.36
Carnarvon (CAR)	88,843	144	1.62
Dampierland (DL)	89,350	163	1.82
Murray-Darling Depression (MDD) *	195,788	366	1.87
Stony Plains (STP)	177,430	1173	6.61
Broken Hill Complex (BHC)	56,025	591	10.55
Flinders and Olary Ranges (FOR)	76,116	1484	19.50
Gawler (GAW)	59,231	1232	20.80

Figure 4. The density of monitoring plots by vegetation types (see Table 6) with the rangelands as defined by ANZECC (1996).

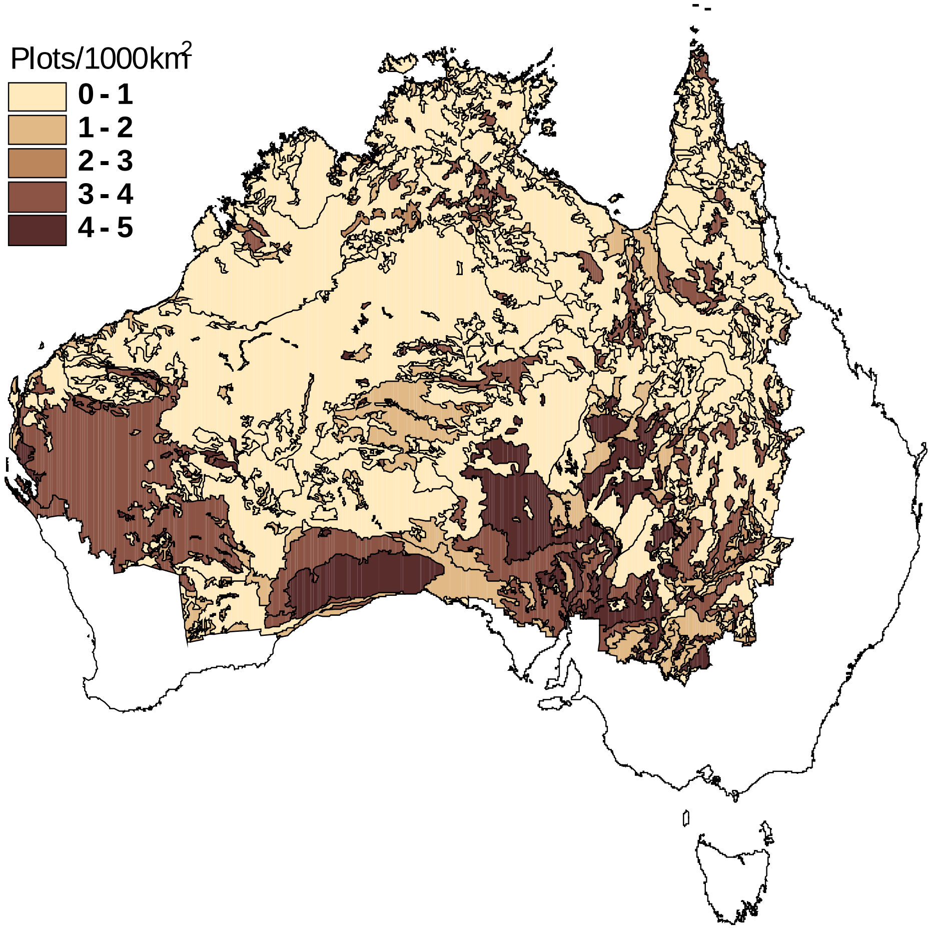

Table 6. The distribution of pasture monitoring plots across vegetation types within the rangelands as defined by ANZECC (1996). The vegetation types are as modified by Simon Bennett (pers. comm.) from Carnahan's vegetation map.

Habitat type	Area (km2)	No. of plots	Density (plots / 1000 km^2)
Chenopod	436,051	1,932	4.43
Remnant *Acacia*	5,901	21	3.56
Acacia with shrub or no understorey	708,390	2,477	3.50
Other shrub and woodland	188,211	629	3.34
Remnant eucalypt/other	37,180	104	2.80
Mallee	131,453	239	1.82
Other grasses and sedges	173,963	202	1.16
Lakes	59.346	65	1.10
Casuarina and *Allocasuarina*	209,326	226	1.08
Acacia with tussock grass	661,606	386	0.58
Remnant mallee	4,070	2	0.49
Eucalypt open woodland	1,152,379	461	0.40
Mitchell Grass	224,185	69	0.31
Eucalypt woodland	534,382	130	0.24
Acacia with hummock grass	1,131,925	215	0.19
Melaleuca	73,746	3	0.04
Eucalypt forest	99,299	1	0.01

Site data attributes

The attributes recorded in plots have been reviewed by SLWRMC (1997) and Tongway & Hindley (1999) (see also Back *et al.* 1997, 1999 for the additional data recorded as part of the TRAPS program), and although not repeated in detail here are summarised in Table 1. Task 4.1 of the Audit will also review these more formally.

All States except South Australia quantify soil surface condition. However, the rigour and detail of those descriptions vary among jurisdictions.

All programs except WARMS Shrublands record frequency of woody and some non-woody species, though the number, size and spatial distribution of transects & quadrats used varies. However, annual plants are either not systematically recorded (e.g. Western Australia: Holm *et al.* 1987; Paul Novelly *pers. comm.*), listed for a loosely defined area around the monitoring plot but not quantified (South Australia: Rodger Tynan *pers. comm.*), or systematically recorded but plots are deliberately sampled at times of the year when annuals are least likely to be in evidence (e.g. New South Wales: Rob Richards *pers. comm.*). All programs record the size of woody plants, and all except QGraze also record their density. In WA Shrubland sites the location of individual woody plants along fixed transects is recorded to provide a direct census of the population.

Holm *et al.* (1984) and Tongway & Hindley (1999) regarded plant frequency and density (*cf* cover) as the only measures of vegetation that are robustly repeatable over time and between observers, although Tongway & Hindley also argued that these have "*several shortcomings in methodology, scope and predictive power*". Friedel (1990) argued that species composition is generally the most useful measure of long-term trend, but yield (biomass) is useful in slow-growing systems (i.e. shrublands lacking a perennial grass/herb layer).

All States photograph the site with each assessment, all characterise its recent fire history and all except WARMS Shrublands characterise the recent history of grazing at the site. These categorisations of fire and grazing history are mostly somewhat crude, being based on (i) current seasons only (ii) recollections of local managers (iii) visible on-site evidence. All sites in all programs are characterised in terms of land unit/land system, topography, position in landscape and distance from water, and all are permanently marked and GPS located.

Database management

Most States have a central database of records, but South Australia has 15 interlinked regional databases. However, some of the data storage and collection remains problematic. In one State, c. 7% of plots had no geo-reference, and in another the corresponding figure was 19%, possibly reflecting establishment prior to the ready availability of GPS units. Western Australia is now actively cleaning up the geocoding for their monitoring sites (Ian Watson, pers. comm.). We also encountered fairly numerous cases of duplicate site numbers with different georeferences, and duplicate georeferences with different site numbers. These problems arose notwithstanding that at least three States have a data entry manual (Table 2). Clearly, database management is an issue that would require substantial attention before consistent regional, State and national summaries could be produced. Failure to update these records is also indicative of a generally low emphasis on analysis and the time lags that often appear to occur between data collection and analysis. Failure to make timely use of monitoring data implies that its application to management problems is not a high priority with those on whose properties the sites are located or the agencies who collect the data; or that the programs are inadequately resourced.

2.2. Approaches to trend analysis from the plot-based pastoral monitoring programs

Formal analysis of trends in the State plot-based pasture monitoring programs is in its infancy, as sufficient re-sampling of plots has become available only relatively recently. The process is most advanced in Western Australia, with some results also available for Queensland and New South Wales (see references in Table 2).

The fundamental problem with pastoral monitoring programs in the Australian rangelands is that of the isolation and identification of longer-term trends and impacts of land use for an environmental system which may be responding in complex, often substantial, and sometimes unknown ways to shorter-term variation in rainfall. This problem besets all monitoring programs, but may be especially pronounced and critical in the Australian rangelands, where ecological processes are largely driven by climatic events (Griffin and Friedel 1985; Friedel *et al*. 1990).

Methods of analyses and the identification of change

The three classes of trends sought or detected in analyses of these data thus far are:

a) shifts in means for a parameter (e.g. frequency of a species or group of species, total cover) across all plots in a given regional vegetation type;

b) the extent of change in an individual plot for any given parameter; and

c) the extent of change in an individual plot for a synthetic measure of a range of parameters from a multivariate data set.

Analysis and interpretation of type *(a)* analyses are superficially straightforward, with detection of change contingent on standard statistical theory and a threshold $\propto$ such as $P < 0.05$ for identification of variation that will be treated as significant. However, there is likely to be a number of complications - including skewed distributions of data values, handling of repeated measures, incorporation of mixes of random and fixed factors as explanatory variables, and various forms of bias associated with the details of design (the design effect) - that render specification of a standard approach all but impossible.

Further, because the audience to whom analysis is to be directed remains unclear, there is rarely an explicit statement of the extent of change that will be regarded as reflecting inappropriate management or, perhaps more reasonably, justifying careful investigation.

Figure 5. An example of a simple analysis showing changes over time in frequency of selected plant species (from Cliffe & Hoffmann 1999).

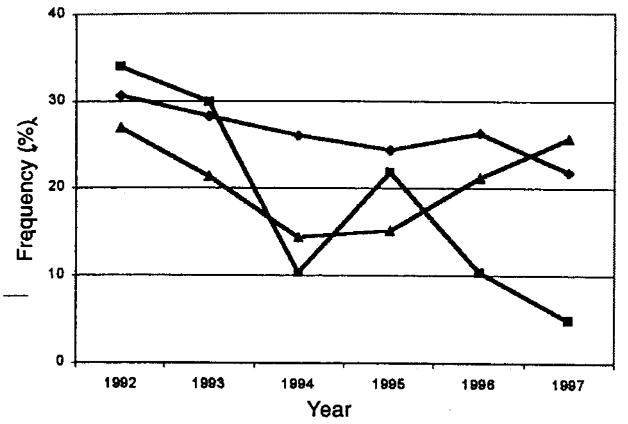

Fig. 1. Changes in the frequency (%) of *Aristida* spp. (▲), *Bothriochloa ewartiana* (♦) and *Heteropogon contortus* (■) in *Aristida–Bothriochloa* pasture community sites in the Central Highlands, between 1992 and 1997

Figure 6. An example of the use of "change ordinations" to analyse WARMS Grassland monitoring data (from Duckett & Novelly 1999)

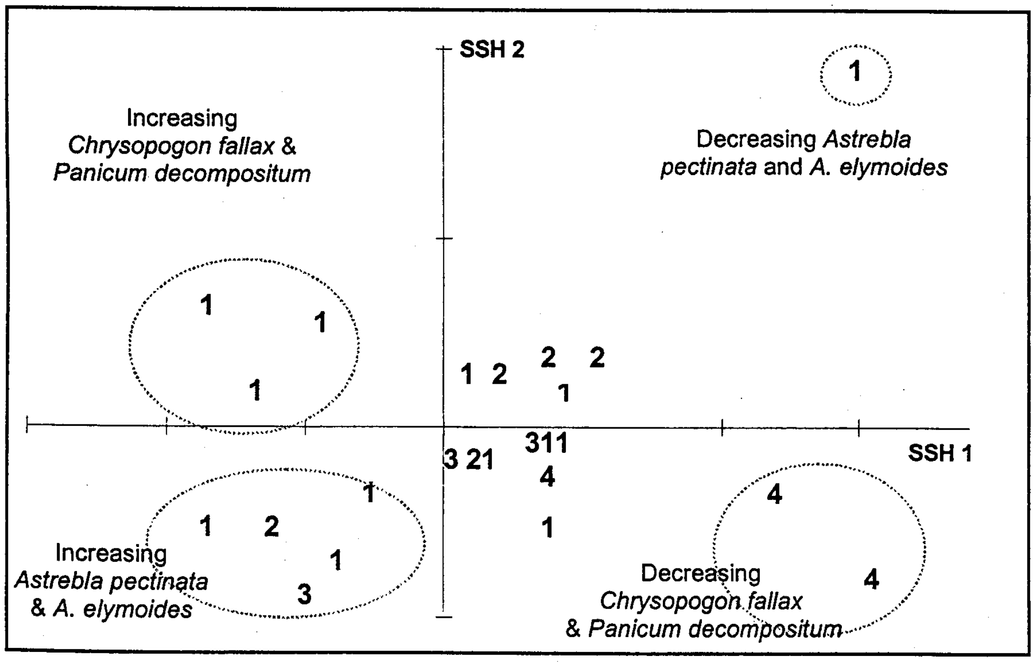

Fig. 1. Annotated change ordination plot of the East Kimberley data showing the sites from four pastoral leases (numbered 1 to 4) and the major species trends. Note that all grass species shown are considered to be desirable for cattle production. Those sites which have shown identifiable trends over time are circled.

Thus analyses of types *(b)* and *(c)* have used arbitrary criteria, and in practice these have been based on identifying change outliers in a group of plots within a given regional vegetation type. The process is illustrated by Duckett & Novelly (1999). For univariate measures of change, they accepted as significant any change that was greater than twice the mean absolute change for that parameter (e.g. frequency of a given species) in a set of plots. For multivariate analyses (ordination of perennial plant species frequencies), they accepted as significant any change that averaged more than 5% of the axis length per year along any of the first three ordination axes.

A problem with arbitrary criteria for a plot that is dependent on the values in other plots is that, if there is little change in any of the plots, some will nevertheless still be identified as changing "significantly", a problem encountered in one of a number of Kimberley grasslands analyses (Duckett et al 1999*b*). Arbitrary decisions about the statistical or practical significance of change in somewhat arcane indicators are unlikely to satisfy any audience that management actions can or should be based on their outcomes. However, making the data analysis path and accompanying assumptions clear at least allows others to reinterpret the extent of change based on other sets of thresholds.

Analyses of trends in Western Australia to date have all been based on comparisons of two annual assessments. Eldridge & Stafford (1999) analysed eight consecutive years of data from the western Riverina in New South Wales using linear regression to determine the significance of change. Although this application of linear regression appears to have been successful, it is unlikely to be an appropriate model for interpreting change through multiple climatic cycles. Cliffe & Hoffmann (1999) used means for that sub-set of plots that were assessed in a given year to "detect" rainfall-correlated trends from QGraze data, a process dependent upon assumptions about the randomness of the small annual sample and relative homogeneity of the plots. In one of the "classic" studies on which current multivariate techniques are based, Foran *et al.* (1986) presented some independent evidence to support the notion that plots in central Australia showing large trend vectors were over-grazed whereas those with small trend vectors were not, but interpretation of the size of the trend vector was graphic and entirely dependent on comparisons between plots across a range of management regimes. Foran *et al.* (1986) argued that large trend vectors indicated floristic instability which was a precursor to a change of vegetation state. Using a combination of ground-based plots and remotely-sensed images, Karfs (1999) has established a relationship between range condition and the extent of between-year variation in measures of cover in the Victoria River District of the Northern Territory.

There are at least two approaches to multivariate analysis involving synthetic approaches such as classification or ordination. Whereas Foran *et al.* (1986) and Martens *et al.* (1990) ordinated each assessment of each plot and then plotted a trend pathway along consecutive assessments, Duckett and Novelly (1999) preferred the use of "change ordinations" for the analysis of WARMS data. In change ordinations, each plot appears only once in the ordination, the nature and extent of change being measured as the distance from the axes intersection. These plots are easier to understand principally because there are fewer points in the ordination, but it is unclear how more than two assessments would be incorporated into such an analysis. Use of only the first and last or any other pair of assessments and discarding intervening assessments is likely to involve considerable loss of information.

All analysts to-date have reported "significant" change over time in some parameters in spite of the relatively short time-frame for assessing change, implying that the type of data collected and the analytical methods employed are capable of detecting change. We note, however that type *(a)* analyses are only likely to be useful (i.e. of adequate statistical power) for species or species groups that are frequently dominant and occur consistently across a given vegetation type. See Duckett *et al.* 1999*a* for trial analyses of the frequency of woody species in grassland systems where woody plants occur at low frequencies.

A problem with analysis of data focused on woody species is that change may occur more slowly than for perennial grasses and herbs. Gardiner & Norton (1983) and Watson (1999) demonstrated how a population modelling approach to shrub dynamics could permit the identification of significant change within a single woody plant species in as little as a single plot in a five year period.

A number of authors have argued that pasture monitoring and trend analysis should reflect state-and-transition models of vegetation dynamics (e.g. Friedel 1990,1991; Phelps 1999). Foran *et al.* (1986) also argued the necessity, but we are unclear how their method does so beyond highlighting relative "instability" in the floristics of a plot and assuming that these fall into two classes. Phelps (1999) has proposed a quite different approach to the interpretation of monitoring plot data in Queensland. He has identified, using samples independent of the formal monitoring programs, a series of vegetation states in central and northern Mitchell grasslands which can be related to a "degradation gradient" and interpreted at plot scales. There appears to have been no trial application of Phelps' methods to the interpretation of QGraze (or Grasscheck or TRAPS) data but, in theory, and subject to adequate identification and interpretation of all possible "states" in a given vegetation type, any plot assessment could readily be characterised as in a given "state"; and any change in "state" at a subsequent assessment readily interpreted as degradation or improvement. However, in common with other approaches to analysis of trend, choices of methodology involve a measure of subjectivity and, most importantly, some prior decisions about the purpose of the monitoring scheme, its audience, and preliminary identification of thresholds indicating undesirable change which can be refined through experience (eg. Payne *et al.* 1974) and the debate that will be generated by their application (Hacker 1992).

Interpreting the direction of change

Analyses of types *(b)* and *(c)* (above) have been used to produce regional summaries of the number of plots that have deteriorated, remain unchanged or improved in condition (e.g. Duckett & Novelly 1999). Identification of "significant" change is the first step in this process; the second is to identify the direction of that change. As already noted, in general there are no "control" or "reference" sites available for formal use in analysis, such as might aid interpretation of direction. In Western Australia, assessment of the direction of change is based on empirical experience of vegetation dynamics, some of which is described in 'Range Condition Guides' (Payne *et al.* 1974).

All interpretations of trends derived from State pasture monitoring programs have used pre-classification of perennial plant species as "desirable" or "undesirable" (and sometimes also "intermediate"). In univariate analyses, it is possible to assess each plant species separately but interpretation is simpler if all species in a class are combined. In multivariate analyses, the direction of trends has been determined by examining correlations between "desirable" and "undesirable" plants and the ordination axes, and thus classifying quadrants of the ordination (in a two-dimensional presentation) as corresponding with increases or decreases in sets of species. This approach has been illustrated by Duckett & Novelly (1999). These analyses can produce the range of results and interpretations identified in Table 7.

Table 7. Summary and interpretation of the direction of trends from pasture monitoring plots. Adapted from Eldridge & Stafford (1999) and Duckett et al. 1999a.

Plant category		**Interpretation of plot trend**
Desirable	***Undesirable***	
increasing	decreasing	improvement
increasing	no change	improvement
increasing	increasing	? probably improvement
no change	decreasing	improvement
no change	no change	unchanged
no change	increasing	declining
decreasing	decreasing	? probably declining
decreasing	no change	declining
decreasing	increasing	declining

At least three problems can and have arisen with such interpretations. If both desirable and undesirable species exhibit the same trend, then the interpretation is unclear (Table 7), a problem encountered by Duckett *et al.* 1999 *b*). Univariate and multivariate analyses can produce differing results, as may any given analytical technique with the addition or deletion of particular species. The latter two problems generally only affected interpretation for a minority of plots, but occasionally the problems were severe (Duckett et al 1999*a*).

Obviously, interpretations of the direction of trend are heavily dependent on the value placed on particular plant species, and confusion can at least partly be resolved by being clear about how species are assessed as (un)desirable. Most analyses thus far have used the value placed on species by pastoral interests. The data could readily be reanalysed from a different (e.g. biodiversity) perspective, and different results obtained. Recognising this, Duckett *et al.* (1999*a,b*) also reported trends assessed using mean frequency of all perennial grasses (with or without the inclusion of perennial forbs and sub-shrubs), and percent crown cover of all and selected groups of woody species. The former was considered a general approximation to a landscape function perspective, and resulted in the identification of some "significant" trends. The analyses of woody shrubs also produced some evidence of significant change, with increases in cover of *Acacia* and *Eucalyptus* spp. in Soft Spinifex pastures of the Halls Creek area attributed to recovery following fire (Duckett *et al.* 1999a). The absence of more widespread trends may be real, but we note also that as cover percentages were invariably low (always < 10% and mostly < 3%), zero frequencies are likely to have occurred frequently and the statistical power of the analysis is likely to be low in consequence.

It is possible that the explicit state-and-transition approach of Phelps (1999) may permit a simpler and more universal determination of the direction of change, although such an approach will still have to incorporate concommitant increases on both 'desirable' and 'undesirable' species.

Distinguishing climate-induced from management-induced trends

A clear intention of States in undertaking a pasture monitoring program has been to identify impacts attributable to management. A problem with all Australian rangelands systems and especially those of central Australia is to distinguish these effects from effects attributable to within- and between-year seasonal conditions. This is no small challenge. Depending on rainfall histories, long-term trends in vegetation may emerge independent of management regimes. Furthermore, under a long-term management regime that is insufficiently responsive to cycles of drought and plenty, pasture condition may, at least theoretically, improve or partially recover when climatic conditions are favourable. Although all States provide some characterisation of seasonal and stocking conditions as part of a plot assessment, quantification of these parameters is difficult. Rainfall data are generally available only from the property homesteads or towns, which in some cases may be large distances from the monitoring plot and of dubious relevance, or can be obtained only indirectly from satellite imagery. Grazing pressure may be characterised through discussion with landholders and/or dung and footprint counts, but the applicability of the former at plot levels is dubious, as also is the relevance of the latter for annual and especially longer intervals. Other disturbances such as recent and longer fire history and relative abundance of native vertebrate and invertebrate herbivores will be even less easily quantified.

Pasture monitoring programs as presently implemented are not controlled experiments to assess grazing impacts. They measure trend; determination of the cause of the trend is only possible by *post hoc* inference and interpretation (e.g. Watson 1999). The likelihood of converting all or a proportion of these schemes to rigorously designed and implemented experiments is small, because property managers need to respond rapidly to changing circumstances in ways that will conflict with good experimental design. However, greater clarity about the objectives of the various schemes may allow at least some of them to be set up as adaptive management experiments (Walters 1986), where the monitoring schemes provide data to test predictions about responses to variation in management practice. Genuine application of the adaptive management paradigm will require a level of measurement and description of prevailing management practice and its variability that many landholders may find intrusive.

Steps can and have been taken to minimise the consequences of seasonal conditions on outputs both during data collection and analysis stages. A primary goal of all State and Territory programs is to assess trends in *residual perennial cover*, which may be understood as that amount of perennial vegetation remaining prior to the onset of a new growing period. To this end and in strongly seasonal climates, plot assessments are often performed at the end of the non-growing period - at the end of the summer or early autumn in winter rainfall areas, or towards the end of the "winter" dry season in summer-rainfall areas. This practice is especially well-developed in New South Wales and the Northern Territory. In New South Wales, where the dichotomy of rainfall zones dissects the State's rangeland, sites are allocated to either a spring or autumn sampling regime according to range type, the regime for the range type being determined by the predominant rainfall pattern in which most of the type occurs. Approximately 85% of assessments are achieved in the identified 3-month "window" (Rob Richards *pers. comm.*). Nevertheless, there is marked variation between years in the timing of assessment of individual plots (Worsley *et al.* 1997, Fig. 10). Practical constraints on this strategy include the difficulties of concentrating large amounts of human resources into a small period of the year, and unpredictable variability in the timing of the change in seasons. This approach is even more problematic in less seasonal climates such as central Australia, where an alternative model of pasture condition is more applicable to remotely sensed data than infrequently monitored plots.

During analysis, the effects of seasonal conditions may be diminished by exclusion of annuals and short-lived perennials from the analysis. This is routine practice in all trend analyses conducted to date. Especially in comparisons of mean frequencies, selection of previously identified "key species" known to be susceptible to grazing but relatively immune to seasonal conditions is possible (Phelps 1999). Use of functional groups (Friedel *et al.* 1988) rather than species may reduce seasonal "noise", but at the risk of losing key information (Friedel 1990). Choice of variables for analysis may also assist - frequency data and densities of long-lived perennials are likely to be more robust to seasonal impacts than cover, whilst measures such as biomass are extremely vulnerable to seasonal effects (see for example Eldridge & Stafford 1999). The demographies of long-lived shrubs vary little in response to either good or poor seasons over annual time scales, except possibly during climatic extremes (Watson *et al.* 1997).

Nevertheless, the effect of seasonal conditions is likely to remain in any analysis, and in most of the trend analyses to date, rainfall has been invoked as explaining a substantial proportion of the results. Some useful information on management-induced trends can be inferred by identifying individual plots or groups of plots whose trend runs counter to that of the mainstream of plots or counter to the direction predicted by seasonal conditions (Martens *et al.* 1990). Eldridge & Stafford (1999) found no overall decline in shrub (mainly chenopod) density in the western Riverina of New South Wales in spite of a long run of adverse years that produced a major decline in biomass, and interpreted the result as indicating stable management in the face of drought conditions.

Conversely, a decline in long-lived perennials during periods of adequate rainfall and in the absence of fire, could be attributed with some confidence to management effects.

The analyses conducted so far have spanned as little as three and no more than 8 years. When data become available for much longer periods, it should be possible to distinguish longer-term trends uncorrelated with seasonal conditions from short- and medium-term variation that is correlated with seasonal conditions. However, the problem then will be to relate longer-term trends to management regimes that may well have changed substantially over the period (and are probably most often poorly documented). This is not a crippling problem if the primary aim of monitoring is to say whether change has occurred, and attributing causality is only secondary. But if observation of change is to trigger remedial action, then accurate identification of causal factors will be vital.

We are aware of no attempts to apply time series analysis or other forms of local regression to detect temporal patterns in plot data, and so account for seasonal or other longer term climatic variation. However, in the absence of control sites or very much better data on a wide range of management-related covariates, there will always be severe limitations on interpretation, regardless of the level of sophistication of the statistical theory or practice brought to bear.

There is a great deal of scope to improve the quality of analysis of pastoral monitoring data to detect trends. Improvement is needed on two fronts. First, specific goals need to be set for the monitoring programs and decisions reached on the nature and extent of change that will be regarded as justifying management response. The audience for the analysis and the actions they are expected to base on it also need to be clearly specified. Until this is done, the second need, to develop and apply statistically robust techniques cannot be attempted. There will be no base for designing procedures that are capable of reliably detecting relevant levels of change, nor of specifying the risk of Type I error (falsely concluding there has been change) or Type II errors (falsely concluding there has been no change) that are likely to be acceptable to decision-makers.

This improvement need not take place in a single step, because decision-makers will most likely need exposure to the range of models for risk management that statistical analysis can provide, before they settle on a preferred model. However, if the pastoral monitoring process is to realise its potential, it is essential that commitments be made to develop systems of analysis that are sufficiently robust to serve as a base for reliable and hence defensible decision-making. This need will become even more acute if the systems are to be incorporated in frameworks that contribute to assessments of the status of biological diversity and the factors that have influenced it.

Extrapolating across spatial scales

All of the analyses we have encountered that applied data from pasture monitoring plots have implicitly or explicitly sought to generalise from the observations. Thus data have often been grouped according to some shared characteristic to permit extrapolation to the wider landscape.

The basic unit for aggregation of monitoring plots for analysis has been vegetation or pasture type. Indeed, the first step in an analysis is to identify consistent vegetation or pasture types (Foran *et al.* 1986, Martens *et al.* 1990, Bosch & Gauch 1991, Duckett *et al.* 1996) if this is not clearly evident *a priori*. The reason for this is straightforward - most analyses, whether univariate or multivariate, have been based on floristics, and there is no point in aggregating and comparing floristically disparate plots (with the notable exception, perhaps, of those whose floristic disparity is attributable largely to management practices). However, even extensive vegetation and pasture types aggregate to smaller spatial units than those with which this study is concerned - bioregions, States and the rangelands as a whole. Reporting at a regional scale requires meta-analysis of monitoring data – summarised statements of change based on aggregated analyses of selected groups of plots.

Generalising from plot-based data could occur either prior to, or after analysis. If prior to analysis, then the variables assessed for trend would need to be other than floristic. Even functional groups of plants (*sensu* Friedel *et al.* 1988) have limited applicability because there is little point in comparing tree cover in woodlands and grasslands, or perennial grass cover in grasslands and shrublands. Examples might be percent cover/bare ground and mean frequency of perennial cover, but even use of these variables will lead to the combination of very disparate plots.

Much of the core biodiversity data are likely to be lost in exercises of scaling up. For example, West (1999) noted that species-specific information from many plots may be "*only useful at fine scales … (at larger scales) such abundant and diverse data become overwhelming. That problem has traditionally been solved by reducing detailed data to condition classes.*" Scaling up after analysis requires the simple pooling of classes of "improvement", "unchanged" and "declining" but requires consideration of the consistency with which trends are interpreted.

But there are other, equally fundamental problems in moving from the plot to generalise to larger spatial scales. Perhaps the most significant is that samples are most often deliberately located to avoid high or low grazing pressures. Positions near water sources, fencelines or other features which may cause cattle to aggregate are avoided. Plots tend to be placed entirely within the dominant pasture type and avoid sparsely distributed vegetation types or ecotones. Thus when aggregated the samples provide some sort of median measure of the effects of grazing on some attributes of the regionally more common vegetation or landscape types. Obviously, generalising from such a sample to the wider landscape confronts a number of logical and procedural challenges, especially if the results are to be used to inform management decisions in regard to biological diversity.

Some of these difficulties are:

1) Insensitivity of monitoring indices to potentially profound variation in spatial patchiness of grazing, so that plot-derived trends in a region grazed uniformly at the "middle-level" intensity are indistinguishable from one that has a proportion grazed at this level, and equivalent areas ungrazed or much more heavily grazed, or a mix of the two.

2) The assumption that a series of samples subjected to "middle-level" grazing intensity reliably index mean impacts over larger scales would appear to require that any negative impacts of overgrazing on parts of a site are neatly balanced by positive effects in other, relatively "under-grazed" areas. We are aware of no studies that test this assumption in regard to phenomena of special interest to pasture managers, let alone biodiversity values.

3) Failure to deal with less common habitat types, that are the very areas that are most likely to support habitat specialists and hence be important sites for interaction between grazing and biodiversity values.

In addition to these substantial sampling-related problems, there are other severe conceptual difficulties facing interpretation of pasture monitoring programs for biodiversity. Understanding relationships among patterns, processes, and spatial scale has been recognised for many years as a fundamental challenge for ecology (Wiens 1989), but little progress has been made in developing theory or empirically-based practice to permit prediction from one spatial scale to another. Detecting changes in pattern at one spatial scale may not permit prediction at other spatial scales. For example, local changes in the abundance of organisms may result from local change in quality of habitat in which observations are made, a different (say breeding) habitat, regional population dynamics unrelated to local conditions, or habitat change within the organism's range but quite distant from the site being examined. We are aware of no comprehensive studies of the scale-dependency of the phenomena commonly measured in pastoral monitoring plots or the way in which those dependencies may interact with processes with different scale dependencies.

Moreover, even for phenomena for which scale is explicitly considered, such as landscape function analysis (e.g. Ludwig *et al.* 1997) there are no widely endorsed standards for defining acceptable levels or quality of function at different spatial scales. Certainly none of the pastoral monitoring schemes that apply these techniques contain such specifications as (for example) the maximum average fetch length (bare ground) in a paddock, or the proportion of a paddock or property that could exhibit fetch lengths exceeding a given level and still be regarded as functional. Less progress has been made in developing processes for cross-scale assessment of biological diversity values, although some attempts have been made to define standards at different spatial scales for the tropical savannas (Whitehead *et al.*, in prep.).

Some of these issues may be resolved as remotely-sensed methods for landscape condition assessment become better developed, allowing a more spatially and temporally comprehensive view of the landscape. These methods are discussed further below.

Conclusions

The analysis and interpretation of trends in rangeland condition gathered from pasture monitoring plots is still at an early stage of development. There are many issues still to be resolved, and we have identified some of these, though this review was intended only as a precursor for consideration of the challenges facing monitoring of biological diversity. It is certainly not a comprehensive review of issues from a pasture monitoring perspective. Doubtless, many issues will be resolved over time, some by further research and development, and some by developing consensus about standards for data collection and interpretation.

There are no absolute or totally objective measures of pasture trend, and probably never will be (West & Smith 1997, Watson 1998). This was recognized by Foran *et al.* (1986), who wrote that "*... these methods ... reduce subjectivity in range assessment. However, judgements on the basis of experience are still an integral part of the process*" and was echoed two years later by Friedel *et al.* (1988): "*... ecological judgement on the basis of experience is still an integral part of range assessment.*" The "judgements" will depend, in part, on the perspective one is seeking from the data.

This conclusion applies equally strongly to assessment of biodiversity values and their relation to pastoral use. Indeed, there are important lessons for biodiversity monitoring in some of the weaknesses of the pastoral monitoring schemes. Failure to clearly state the objectives of the schemes and the audience at whom they are directed has contributed to some patchiness in standards of maintenance and analysis, because there is generally no structure within which their performance and relevance can be regularly re-assessed and reformed as experience is gained. Similar failure to adequately specify intent and the particular questions to be answered must not be repeated with schemes for the monitoring of biological diversity.

2.3. Other methods of assessing rangeland pasture trends

Remote sensing

Remote-sensing of pasture condition is a rapidly developing field that may offer powerful means to detect changes and trends through time (Wallace & Campbell 1998). The great attraction of remote-sensing techniques are that they allow assessment of condition to be generalised from the plot to landscape scales. In providing a comprehensive 2 or 3 dimensional view of the landscape they can provide details of the spatial and temporal patterns of condition trend that can never practically be obtained from plot–based data alone.

Most of the remote-sensing techniques now operational (reviewed briefly in Wallace & Campbell 1998) rely on the assessment of indices of vegetation cover using either Landsat MSS (80m resolution) or Landsat TM (30m resolution) imagery. While it is theoretically possible to measure absolute cover, condition assessment usually involves deriving relative cover across an image, within grazing gradients or for individual locations across a temporal sequence of images.

The most well-established technique is the grazing gradient approach of Pickup & colleagues (Bastin *et al* 1993, Pickup *et al* 1993, Pickup & Chewings 1994, Pickup *et al* 1994, Bastin *et al* 1996) which was developed in southern Northern Territory and is now being applied to rangeland assessment in northern South Australia (Bastin *et al.* 1998, Tynan 1999) and the Barkly Tableland in the Northern Territory (McGregor *et al.* 1999). The basis for these techniques is that vegetation in 'good' condition will show a strong growth response to infrequent large rainfall events, while degraded pastures have a reduced response. Therefore, while grazing during dry periods may result in a gradient in vegetation cover related to distance from water, after rain the gradient will still only be evident in areas in poor condition. In the wet period average cover method (WPAC), cover indices are averaged for increasing distance intervals from water for each landscape type in each paddock. In the Resilience Method, the change between dry and wet period cover indices is calculated for each pixel and expressed relative to the average change for that land type. Both methods require satellite data sourced after a major rainfall event, while the latter also requires data from prior to the event. The grazing gradient method is therefore directed at longer-term vegetation dynamics and there can be problems in reconciling responses measured after an infrequent rainfall event with vegetation condition observed a number of years subsequently (Bastin *et al.* 1998). Pickup *et al.* (1993) developed an index of vegetation cover for use in central Australia known as PD54, although Worsley *et al.* (1997) felt this index was unsuitable for application in NSW as it required considerable operator judgement and calibration between different analysts.

Application of the grazing gradient method requires quite detailed spatial data, notably location of watering points and fencelines and a stratification of the landscape sufficient to separate landscape types with vegetation that responds differently to grazing and rainfall events. This method is particularly suited to arid rangelands with widely spaced watering point in large paddocks, but could not be applied in western NSW where paddock sizes are generally too small (1200-2500 ha) for grazing gradients to be well developed (Worsley *et al.* 1997).

A second method of remote-sensed assessment may be referred to as 'time-trend analysis' and is based on assessment of cover indices over a multi-temporal sequence of calibrated data (Wallace *et al.* 1994, 1996). This method has been implemented in parts of Western Australia (Wallace *et al.* 1994), the East Kimberley of Western Australia and Victoria River District of the Northern Territory (Karfs 1999) and is being trialled in the Dalrymple Shire in Queensland (Taube 1999). The basis of this method is that pasture in good condition maintains a high cover of perennial grasses, and therefore shows a relatively high and stable cover index (which may be derived from a single band of eg. MSS imagery) over time. In addition to trends in total cover, this technique can infer some information about vegetation composition as annual-dominated areas have a more variable cover 'time-trace' than those dominated by perennials. As for the grazing gradient technique, to be applied at a regional scale time–trend analysis requires adequate stratification of the landscape into areas of comparable soil/vegetation response. Interpretation of cover trends in terms of pasture condition and grazing effects requires considerable operator expertise and ground-truthing for each major land-type (Karfs 1999).

Developing remote-sensing technologies such as airborne videography (eg. Everitt *et al.* 1996, Phinn *et al.* 1996, Grierson *et al.* 1998, Bastin *et al.* 1999) allow the estimation of ground cover and to some extent composition with very fine resolution. They can also be applied to the quantification of additional attributes of landscape function and patch structure, with considerable potential for biodiversity assessment & monitoring (Coops & Catling 1997).

Photographic monitoring

Queensland, the Northern Territory and Western Australia have, in addition to their formal pasture monitoring plots, programs that encourages graziers to photographically and/or quantitatively monitor fixed plots on their properties (Table 1). Given that these plots potentially greatly expand the total number of plots regularly visited and inspected in the landscape, it would appear that there is some potential for photographs to assist in monitoring some trends, for example, in the expansion of certain obvious invasive plant species such as Buffel Grass (*Cenchrus ciliaris*). However, discussion with the relevant agency people in each of these States indicates that the information is either treated as strictly confidential or held by landholders, and therefore not readily available for a State or national monitoring program.

3. Biodiversity and pastoral monitoring programs

The biodiversity in Australia's rangelands has been diminished since European settlement, manifest most notably in the loss of a very large component of the distinctive native mammal fauna. Change and loss is ongoing, although the reporting of this biodiversity change is currently piecemeal and almost haphazard.

Across very extensive areas of the rangelands, the existing pastoral monitoring programs provide a very large amount of information about plant species, vegetation types and soils, and they have been established explicitly to examine trends in some of the parameters describing these components of biodiversity and related attributes of the physical environment. Despite their shortcomings, there are no other programs which provide such an amount of information about Australia's rangeland environments.

Hence, it is obviously pertinent to ask:

(1) what biodiversity information can be extracted from the existing pastoral monitoring programs?

(2) is this enough to provide an adequate biodiversity monitoring program for the rangelands?;

(3) if not, can the pastoral monitoring programs be easily adjusted or supplemented to provide more biodiversity information?

These superficially fairly simple questions appear to attract a variety of responses, which at their extremes can be characterised as:

- a view of the pastoral monitoring programs as restricted, designed simply for only one end, and which shouldn't be overburdened by any additional aims, procedures or requirements; *versus*
- a more pragmatic view that recognises that biodiversity is a myriad of things, of which a substantial number can be assessed or interpreted at some level from pastoral monitoring; and that it may be more achievable to add on to an existing and accepted scheme than to design anew a specialised program which would be unlikely to be as well resourced.

In part we argue the case elsewhere, in the Adaptive Framework of this project. But here, we explore aspects of the first question above, to consider what biodiversity information can be readily obtained from the existing pastoral monitoring, what constraints there are on this information and whether the data are likely to be informative about trends. We also consider what linkages may need to be established between other particular biodiversity attributes of interest and the attributes measure in pastoral monitoring, to assess the potential of the latter to act as surrogates or as correlates of the former.

We note here that we do not consider the ability of the existing pastoral monitoring programs to provide information on landscape function (a fundamental support for biodiversity), as this issue is specifically addressed elsewhere in the Audit (Tongway and Hindley 1999). The link between this measure and other components of biodiversity remains unproven or unquantified, although such links have been suggested, and are at least conceptually reasonable (Hamblin 1991; Ludwig *et al.* 1997; Tongway & Hindley 1999).

3.1. Plot-based pastoral monitoring programs

Biodiversity information extractable from existing programs

The existing plot-based pastoral monitoring programs contain much information about some components of biodiversity. Table 8 lists some biodiversity attributes which may (at least conceptually) be relatively easily derived from these existing measures. These attributes fall into three distinct classes:

- those that seek to use the pastoral monitoring data to derive information on some components of biodiversity which are not directly measured (i.e. to establish surrogates and to proscribe the constraints by which they can be used);
- those that provide information directly on trends in biodiversity, and are directly measured in pastoral monitoring (e.g., *Responses of plants to long-term environmental change; Responses of plants to short-term environmental change*; and *spread of weeds*); and
- those that provide simply collateral information on biodiversity, which may or may not be relevant to the assessment of biodiversity trends; and/or simply use the pastoral monitoring programs as a convenient framework (e.g., *Distributional modelling of individual plant species and vegetation attributes; use of the pastoral monitoring sites as a good template from which to choose sites for wildlife survey/monitoring*).

The first two are the most relevant to this review. The first group, including those approaches which seek to develop surrogates or synoptic measures, is clearly more complex than the second group, and will demand additional carefully orchestrated study before the validity and limitations of any surrogates can be established. Such study should concentrate on the widely-used measures of pasture/land condition/health (most notably the extent of perennial grass and shrub cover), and investigate the extent to which these measures can be informative about other attributes of biodiversity. We will consider this issue in more detail in our main report, and we also provide an example of the approach below, on the derivation of biodiversity information from remote-sensed programs of pastoral monitoring.

The second group, of biodiversity attributes which are directly measured in pastoral monitoring plots, is more straightforward. Some of these are already explicitly reported on in the pastoral monitoring programs. We discuss some of these direct measures, and the limitations of the methodology used, below.

Pastoral monitoring seeks to report on shifts in the floristic composition of vegetation, and especially changes of "state". This is clearly of interest from a biodiversity perspective. However, the limitation from this perspective is that the monitoring programs tend to define such changes in state in terms of high-frequency perennial species (of pastoral value or annoyance). Changes involving annuals, or low-density perennials including structural dominants such as scattered trees in a shrubland or grassland or other functionally significant species (*sensu* Walker 1992, 1995), will not necessarily be identified, although WARMS Shrublands, NSW RAP and Queensland TRAPS sites do assess all perennial species.

The State pasture monitoring programs cannot provide a comprehensive measure of floristic species richness or diversity, because annuals are not adequately censused. Annuals are a natural component of most if not all rangeland ecosystems. The frequent complementary nature of the occurrence (including richness and diversity) of annuals and perennial grasses and forbs is well known in the context of grazing degradation and other disturbance (e.g. McIvor *et al.* 1996, Fensham & Skull 1999, Fensham *et al.* 1999). Hence, we cannot assume that the species richness and diversity of (the measured) perennials is proportional to, or representative of, the floristic richness and diversity of the ecosystem. Furthermore, the quadrat-based methods of recording species frequencies used in the programs may not be the most efficient or accurate approach towards identifying local-scale richness of species present, and will generally be inferior to techniques which are based on direct investigation of the local minimum sampling area (Stohlgren *et al.* 1998). However, with these substantial provisos, trends in species richness or diversity in various perennial functional groups such as palatable perennial grasses or unpalatable sub-shrubs (Friedel *et al.* 1988) may be worth reporting.

With several provisos, the monitoring plots may be useful for tracking trends in the abundance of selected species. These provisos include that only abundant (high frequency) species may be monitored successfully using frequency data, from which it follows that the abundance of a species may only be tracked in that portion of the environment or the species range in which it occurs at high frequencies. Another is that the monitoring time-frames are appropriate to the species. Species that qualify are likely to be only a small proportion of those present in the rangelands.

Trends in total perennial frequency or cover may be tracked over time, and the attribute has ecological meaning. Trends in total frequency or cover of perennial weeds may also be usefully tracked. With the provisos of the previous paragraph, it may also be possible to track the range and distribution of key perennial weed species. Note that the definition of "weed" from a biodiversity perspective may differ substantially from that of a pastoral perspective, including all non-native species and perhaps also some increaser native species whose increase leads to fundamental changes in ecosystem processes (e.g. "increaser" shrubs that invade grasslands). Furthermore, the measures so derived cannot be interpreted as changes in the frequency or cover of weeds *per se* because annual weeds are not systematically recorded.

As touched on earlier, trends in the frequency or cover of selected native perennials in small plots subjected to intermediate grazing pressures are unlikely to provide the information needed to infer ecologically relevant details of the spatial patterning of these plants in the wider landscape. Patterning is likely to strongly influence the role they play in supporting fauna, such as those vertebrates or invertebrates that consume their seeds. Indeed, it can be argued that details of spatial patterning are the only items of interest from a biodiversity perspective, because the relative incidence in scattered plots of individuals of a common grass or shrub species (abundant and widespread enough to make a significant contribution to the grazing industry) is in itself one of the last measures that an observer interested in biodiversity would consider making.

However, the case is very different with invasive species that are thought to have the potential to suppress a wide range of native grasses across a range of environment types. Trends in the appearance and dominance of individual plots by such species – especially agricultural and environmental weeds - may provide crucial information on processes of change across entire grassland systems.

In addition, changes in the incidence of woody plants may be a powerful indicator of significant ecological change. Again, the presence or absence of common species of woody plants in scattered small plots may be of little intrinsic interest, but widespread shifts in their dominance may have profound implications for grassland flora and fauna, whether associated with grazing or other management practice (e.g. of fire).

It is perhaps in these two areas that the pastoral monitoring plots offer the greatest relevance to biodiversity monitoring. These possibilities are considered further in the Adaptive Framework document.

Table 8. Examples of some information relating to biodiversity in the rangelands which may be accessed from the existing pastoral monitoring programs.

biodiversity attribute considered; or value derived	**caveats**	**comments**
1. *Responses of plants to long-term environmental (e.g. climate) change* (including changes in the distribution, abundance and population structure (e.g. age-classes) of individual species, functional types, "tree thickening", etc.)	1) Only possible for the plant groups which are adequately sampled. 2) Plant groups sampled are most likely to be the most common 3) Plots must be re-sampled over long periods. 4) as virtually all monitored sites are grazed, will be difficult to separate effects due to unmanaged environmental variation and management-related disturbance 5) many existing systems do not provide data usable for analysis of changing population structure 6) samples are often confined to a narrow, intermediate fraction of the disturbance regime 7) sampling regimes limit inferences about spatial patterning which may be particularly relevant to faunal use	This can be subsampled by region, veg type, soils, land-use etc to see whether any of these particularly influence long-term change.
2. *Responses of plants to short-term environmental change (e.g. drought, fire)* [including information on recruitment rates, population dynamics, differential mortality between species in response to perturbation, etc.]	1) Only possible for the plant groups which are adequately sampled. 2) Groups most likely to be sampled (perennials) may show limited short-term variation.	Again, can be stratified to consider differences between regions, land use, etc.

3. *Distributional modelling of individual plant species and vegetation attributes (e.g. basal area)*	1) Only possible for the plant groups which are adequately sampled. 2) As virtually all sites are grazed, difficult to make predictions relevant to undisturbed sites 3) As samples are biased to intermediate grazing pressure in "representative" areas, models may encompass limited variation and so be of little predictive value 4) biases may permit derivation of models applicable only at very broad scales that limit their usefulness	This is treating the programs essentially as just one big survey data set (i.e. no temporal component), and would produce the type of useful information Williams *et al*. (1996) derived from analysis of a data set of distributional records from very many quadrats. In the case of pastoral monitoring programs, the soil and other edaphic data may be unusually good, and hence the models unusually precise. Note also that there may be some scope for including the "monitoring" component through comparing predictive distributional models derived from time *a* data and from time *b* data.
4. *Assessment of effect of including land-use/land condition variables in distributional modelling* (3 above), in order to see whether these influence the distributional models of individual species or vegetation attributes.	1) There are statistical problems, but the data set is so large that some inferences may be possible. 2) may require improved quantitative data on sources of disturbance, including grazing 3) bias of samples to intermediate grazing pressures may limit predictive ability for more severe grazing regimes that are of greatest management interest) 4) existing thematic mapping is mostly incompatible with comprehensive extrapolation to all parts of the landscape, limiting utility of models	This may be able to give some indication on the extent to which land use/land condition can distort underlying species distributions etc.
5. *Spread of weeds* (including environmentally	1) Most annual weeds will not have	Arguably one of the strongest potential uses

undesirable plant species, and native woody species).	been (adequately) recorded. 2) Differences of definition and perspective regarding implications of spread of some invasive species may compromise common interpretation and use to direct management responses	of the pastoral monitoring schemes for biodiversity monitoring purposes
6. *Assessments of underlying dynamics of vegetation* (e.g. time to maturity/senescence)	1) May require very long time periods. 2) Not all schemes record relevant data 3) interpretation of records that do not include marked individuals may be highly constrained 4) most useful in situation where entry of new recruits to population has effectively ceased	Over long periods this may provide critical information about aspects such as the lifespand and decline in mulga, quandong, etc.
7. *Comparisons of species richness and dynamics (rate of temporal turnover of species) between environments, land-uses, etc*.	1) Species richness is a pretty arbitrary and ineffective measure of biodiversity. 2) scales at which relevant and informative requires consideration/analysis	This should provide good background information on how these systems work, and over what scales they change.
8. *Plant/environmental responses to regional/property/paddock land management changes* (e.g. what happens when supplementation is added and hence cattle densities increase)	1) This is essentially best addressed via experimental research, but may be able to glean insights from well-spaced monitoring plots. 2) management data may not be easily garnered 3) influences on spatial patterns of grazing may be needed to permit interpretation (e.g. adding a watering point distant from plot may have no	

	effect on grazing pressure in monitored site but great impacts at larger spatial scales)	
9. *Identification of increaser and decreaser species*, and any commonalities in the ecological traits of these.	1) bias to intermediate grazing intensity may compromise interpretation	This may provide clues (e.g. via life history traits) which could be extended to threatened species. It may also provide early warnings for species undergoing regional declines.
10. (With targetted additional data collection) establish whether there is any *relationship between other elements of biodiversity and the indices of environmental condition/health derived from (and the point of) the existing pastoral monitoring programs*	1) This will need additional targeted work to establish whether there is a link. Obviously it won't work for all species.	This seeks to evaluate whether the core information and assessments from pastoral monitoring can be used a surrogates or synoptically to provide information about other biodiversity components.
11. *Simply use the pastoral monitoring sites as a good template from which to choose sites for wildlife survey/monitoring.*	1) matching scales of sampling and context may be difficult and compromise interpretation	These sites provide a ready-made established set of plots, from which a subset of environments etc could readily be selected for sampling. They have the attribute of reasonably well established information on history.

Comprehensiveness of stratification and sampling sites

As noted above, the pastoral monitoring plots are distributed inequitably across the rangelands, a bias which limits the direct applicability of pastoral monitoring programs to rangeland-wide biodiversity monitoring. The major non-pastoral areas of the rangelands such as the Western Deserts, North Kimberley and Arnhem Land, which comprise 42% of the rangelands as defined by ANZECC (1996) contain less than 0.1% of the monitoring plots. Within the defined pastoral zone, bioregions are very unevenly represented. There are no plots within the majority of the Northern Territory, nor on Cape York Peninsula, nor a major portion of south-west Queensland. Non-pastoral Aboriginal lands, conservation reserves and other non-pastoral land-uses are poorly and variably represented. Range types with low stock carrying capacities are not sampled at all in some States. Riparian systems are poorly represented and many other often-localised environments such as rock outcrops and wetlands are not or scarcely sampled. Within paddocks, although a range of distances from waterholes are represented, the sampling strategy differs markedly between States. Plot-scale environmental heterogeneity (which is often important for elements of biodiversity) is avoided.

Some of these "inequities" could be overcome with stratification during analysis, but only if adequate samples of each system at each level of the stratification are available, a situation that is clearly and markedly not the case.

Rather, if a rangeland-wide biodiversity monitoring program is to be developed from the existing pastoral monitoring programs, this would be achieved most effectively by augmenting the pastoral plots with a comparable density of plots newly established across the currently poorly-sampled areas and environments, most notably in ungrazed areas (such as National Parks and some Aboriginal lands), heterogeneous environments and riparian systems. A lead in this direction has already been taken in South Australia, where many plots, monitored in a manner consistent with the already established protocols for pastoral monitoring, have been established recently in conservation reserves (Lay *et al*. 1999); and a similar program is under development in northern Queensland (L. Felderhof, pers. comm.).

In addition, sampling at a wider range of grazing intensities is desirable, so that the full range of potential impacts in different parts of the landscape, and the manner in which they integrate at larger scales, is at least conceptually plausible.

3.2. Grazing gradients and biodiversity

Recent research has demonstrated that piosphere gradients (with the implicit assumption that these correspond to grazing gradients) may serve as useful surrogates for at least some elements of biodiversity, with plant, vertebrate and invertebrate taxa showing increaser or decreaser responses along the gradient, and some taxa being found only at the water-remote limit of the gradient (Andrew & Lange 1986, Westbrooke 1990, Navie *et al.* 1996, Landsberg *et al.* 1997, Ludwig *et al.* 1999, Fisher 1999, James *et al.*

1999, Landsberg *et al.* 1999). The 'grazing-gradient' approach to biodiversity surrogacy is also subject to a number of substantial caveats, most notably:

- it cannot be applied to a significant proportion of biodiversity dependent upon restricted run-on and riparian habitats in arid rangelands, which are either associated with watering points or are grazed preferentially by stock. In many parts of the rangelands, these elements of the biodiversity are those that are also apparently most sensitive to environmental change (eg. Stafford Smith & Morton 1990, Fleischner 1994, Morton *et al.* 1995*a);*
- it cannot be applied where grazing gradients are absent or poorly defined, due to high landscape complexity, small paddock sizes or abundance of natural water;

Despite these reservations, distance-from-water mapping and grazing gradient detection are likely to be a useful and relatively simple monitoring tool for some components of biodiversity in some rangelands (Biograze 2000). It is possible that remote-sensing of grazing gradients in some rangelands (eg. McGregor *et al.* 1999) may provide a more sensitive monitoring tool than simple distance-from-water mapping, although this remains to be demonstrated.

3.3. Remote-sensed condition assessment and biodiversity

Remote-sensed condition assessment provides no direct information on biodiversity values, but conceptually there are useful links between remote-sensed measures of pasture condition or landscape function and biodiversity attributes. Most of these links require extensive validation before they can be adopted as surrogates for biodiversity values; to determine which components of biodiversity can be monitored remotely; and to what extent these linkages can be generalised geographically or must be tailored to each rangeland type.

Fisher *et al.* (unpublished data) examined the relationship between remote-sensed condition trend analysis in the Victoria River District of the NT (Karfs 1999) and the relative abundance of plant, reptile, bird and selected invertebrate species. The composition of both plant and animal species at sample sites was related to a number of variables derived from the time-trend analysis for the sites. As would be expected, these 'condition' variables were strong predictors of the abundance of a number of more abundant perennial and annual grass species. They were also weak predictors of the abundance of a number of bird and reptile species, the influence of site 'condition' on these species being partly overwhelmed by other environmental factors such as canopy height and cover. This approach demonstrated some ability to explicitly link remote condition assessment and biodiversity attributes, but further validation studies are required in a range of land types incorporating a range of 'conditions'.

In addition to its use for condition assessment, remote-sensing may provide much other useful spatial data, such as extent and rates of land-clearing, mapping of fires, etc. that can be also linked to biodiversity values: these are discussed further in Background Paper 3.

4. Enhancing the utility of pastoral monitoring programs for biodiversity monitoring

We have identified a number of important features that demand that existing pastoral monitoring programs be incorporated in any system for monitoring biological diversity in the rangelands:

- their large spatial coverage, compared with any other single activity that is potentially compatible across jurisdictional boundaries;
- related activity to extend the scale and comprehensiveness of assessments through linkage to remotely sensed indices of land condition; and
- relevance to a number of the major threatening processes (e.g. over-grazing, weed invasion, displacement of native perennial grasses).

However, we have also identified several generic problems with these systems at a national scale. The most significant are:

- patchy, incomplete coverage of ecosystem types and bioregions;
- biases in the range of grazing conditions sampled;
- variation in methods, compromising opportunities for cross-jurisdictional/regional comparisons and meta-analysis;
- absence of linkage to biodiversity monitoring programs;
- weak linkage to other data (recent and past stocking rates, fire history, standardised climatic variables) to facilitate interpretation;
- absence of ungrazed controls;
- current difficulties in scaling up from sites to larger spatial units that are relevant to a national program; and in some cases
- failure to analyse data and so test relevance to key production and biodiversity management issues;

Programs vary substantially in the variables recorded. The most useful commonalities are the recording of the presence and absence of woody and non-woody perennial plants, along with some measure of frequency and/or density. The presence/absence data are in themselves useful in that they can provide long-term views of shifts in important components of the rangeland environment at large spatial scales. Combining these data across jurisdictional boundaries would increase the potential to detect significant common trends, such as the invasion of exotic plant species, or changes in distribution of woody plants thought to be related to important threatening processes. Even though such data cannot provide robust demonstrations of cause and effect, emergence of patterns that can be plausibly linked to significant processes may compel greater political and bureaucratic attention – and hence support for more focussed investigation - when they can be shown to be “universal” and cannot be dismissed as localised aberrations.

The obvious weakness of presence-absence measures is that they reveal shifts in spatial patterns of plants as the declining species drop out altogether (become locally or regionally extinct in grazed landscapes) or invaders move into new locations in sufficient numbers to appear in relatively small sample units. Once such unequivocal trends emerge, the processes that led to them may be so entrenched as to be effectively irreversible. We need, therefore, to consider enhancements that increase sensitivity and early detection of important trends.

A number of short-term and longer term enhancements were proposed in the Draft of this document and the Draft monitoring framework (see Box below). These proposals were discussed in some detail at a workshop in Darwin in July 2000, attended by state and NT agency staff with an active involvement in pastoral and biodiversity monitoring programs. Additional feedback on some issues was also sought by an email questionnaire (see Appendix) and these responses are summarised here.

BOX 1: Enhancements proposed in Draft report

Immediate/short term

Simple steps that would greatly enhance the utility of pastoral monitoring programs for biodiversity monitoring without requiring fundamental shifts in their structure (and hence costs) would be to:

(1)standardise plot sizes;
(2)record frequency of all woody and herbaceous plant species within those plots;
(3)standardised measures of soil condition, perhaps based on the simplified LFA of Tongway and Hindley (in preparation);
(4)standardise reporting protocols;
(5)incorporate ungrazed or little grazed sites in order to better understand vegetation dynamics;
(6)submit regular, standardised reports to a group charged to undertake a common analysis and report to each jurisdiction and Federal authorities; or at least have some kind of nationally coordinated standard analysis protocol.

We recognise that the notion of a “one-size fits all” standardisation is probably illusory in the wide range of environments that make up the rangelands. We do not suggest that States or Territories abandon the procedures that they regard as important for their particular conditions and goals. Rather we suggest that by nesting minimum-sized plots within larger sample units or adding a few simple measures to existing suites of variables, utility at large spatial scales and relevance to biodiversity monitoring can be greatly increased.

Additional analyses and insights that might emerge from such a large common set would be:

- the capacity to identify, track and interpret relevant change in (for example) temporal and spatial patterns of relative frequency of native perennial grasses and woody plants over a range of spatial scales, providing earlier warning of adverse change;
- patterns in the relative dominance of exotic pastures or other invasive species within individual sites as well as their invasion of new sites, again providing early warning of broad scale trends;
- greater potential to link pastoral monitoring data to biodiversity monitoring activity to reveal important associations; and
- greater potential to link pastoral monitoring data to remotely-sensed indicators of land condition.

Longer term enhancement

Additional steps that would greatly enhance the usefulness of pasture monitoring programs for interpreting change relevant to biological diversity include:

(1) additional sites to increase the comprehensiveness of sampling in terms of (a) rangeland bioregions (b) landscape types and (c) grazing intensity;
(2) agreement on a suite of climatic variables to be incorporated in analyses of temporal variation;
(3) criteria for rating grazing intensity into a few broad classes (no managed grazing; lightly grazed; moderately grazed; heavily grazed) and their incorporation on reporting protocols; and
(4) explicit linkage to compatibly distributed and sampled biodiversity monitoring sites, maintained until links among various indices of land condition to biodiversity values are validated.

These improvements would permit:

- development of protocols for more robust extrapolation to the landscape at large spatial scales;
- explicit linkage of site based studies to landscape units, their condition and configuration derived from satellite imagery;
- better understanding of the relationship of land condition to climatic variation; and identification of indicators or surrogates for biodiversity that take account of scale and context

4.1. Establishment of additional sites to improve representation of

(i) restricted landscapes such as run-on areas;
(ii) a range of grazing intensities
(iii) regions or ecosystems outside current pastoral use / tenure

There was general agreement that this was highly desirable and seen as important by all agencies, providing that financial and human resources were available. In some states, expansion of monitoring sites to conservation and other lands not subject to stock grazing has commenced (eg. South Australia; Lay *et al.* 1999) or vegetation monitoring with methods comparable to pastoral schemes will be undertaken by conservation agencies (northern Queensland; L. Felderhof pers. comm.). Perceptions of the priority for the location of additional sites were varied, although sampling lands outside the pastoral estate was generally seen as a means of increasing the range of grazing intensities sampled. There was also concern that sampling methods would need to be modified if riparian areas were to be incorporated.

Estimated costs to establish additional sites using current methodologies varied between agencies and probably largely depend on the remoteness of the site and the local density of sites. The median cost/site is c. $500, but may be as low as $250 in South Australia and high as $1350 in the Kimberley. Costs of resampling sites are generally 20-30% less than establishment costs. In addressing (i) and (ii) above it would be most efficient to establish new sites in the vicinity of existing monitoring sites; addressing (iii) is likely to incur the highest costs per site.

4.2. Recording all plant species (with some measure of abundance) within the monitoring plots

While some programs aim to record all plant species (including annuals) present at the time of sampling, this sampling does not necessarily occur during times when annual, and particularly ephemeral species, are most evident. There was a strong view that a requirement to sample <u>all</u> plant species would place impossible demands on current pastoral monitoring protocols, especially in environments where different groups of species respond to different seasonal rains. Limited windows for sampling, restrictions on access and increased misidentification were also contraints. It was estimated that including less obvious or common annuals might double sampling time and increase costs / site by 50-100%.

Considerable doubt was also expressed whether observed changes in floristic composition of annuals/ephemerals could be meaningfully interpreted, except over very long time periods, as the influence of rainfall variation is overwhelming (eg. Hacker 1984).

4.3. Standardising plot sizes and data collection methods

The general response was that methodological changes were unwelcome as they may compromise the use of existing data. Most agencies considered that methodological differences appropriately reflected differences in the environments sampled, and that some effort had already been made to standardise approaches between jurisdictions. In particular, minor differences in the size of sampling units should not be problematic in estimating the frequency or density of more abundant species, and differences in sampling methodologies should not affect meta analyses of condition trends. Differences in the number of sampling units used within a site, and the total area of the site, may have significant effects on measures of species richness and the abundance of uncommon species. However, these differences can be largely overcome if a comparable 'minimum subset' can be extracted from each data set; or analyses largely rely on presence/absence data.

4.4. Conclusions

1) the utility of pasture monitoring programs for interpreting change relevant to biological diversity can most effectively be enhanced by the establishment of additional sites, that improve the representation of a) regions or ecosystems outside current pastoral use / tenure; (ii) the full range of grazing intensities; and (i) restricted landscapes such as run-on areas;

2) elements of biodiversity should be monitored on a selected set of pastoral monitoring sites (or comparably distributed and sampled sites) that incorporate a range of land types and levels of condition, and monitoring maintained until links among various indices of land condition and biodiversity values are validated;

3) the capacity to identify and interpret change in elements of biodiversity from pastoral monitoring data will be improved by agreement on a suite of climatic variables to be incorporated in analyses of temporal variation; incorporation of at least broad criteria for rating grazing intensity at sites; the use of standardised measures of landscape function; and continued adoption of broad-scale remote-sensed assessment of landscape condition;

4) the utility of biodiversity information contained within the exisitng pastoral monitoirng schemes will be maximised if there is a group (within the relevant Ministerial Councils) charged to:

- ensure standardised reporting protocols for all programs
- undertake, or at least coordinate, standard analyses and meta-analyses of monitoirng data and report to each jurisdiction and Federal authorities.

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6. APPENDIX: Questionnaire responses

Responses were sought by email from a number of the participants following the workshop in Darwin, July 2000, in relation to proposals for alterations to the current pastoral monitoring programs. These alterations were suggested in the Draft biodiversity monitoring framework as a means of enhancing the biodiversity information content of pastoral monitoring programs. The responses received are listed below; some have been slightly edited.

NOTE: these are informal responses and should not be quoted directly.

IW = Ian Watson (Agriculture WA; state south of the Kimberley)

AC = Andrew Craig (Agriculture WA; Kimberley region)

BK = Bob Karfs (NT Dept. of Lands, Planning & Environment; principally VRD & Sturt Plateau)

DR = Dave Robson (NSW National Parks & Wildlife Service)

BL = Brendan Lay (SA Dept of Environment & Heritage)

LF = Leasie Felderhof (Qld Parks & Wildlife Service; these comments relate to the establishment of vegetation monitoring sites in Cape York Peninsula)

Two major enhancement were proposed:

1) increase the biodiversity information by recording all plant species within the monitoring plots (plus some measure of abundance)

a) is this a realistic suggestion?

IW: With the best will in the world we would find this a logistical and time consuming nightmare. We would be open for someone else (perhaps CALM) to do it on WARMS sites - but we could never make it part of our normal operations.
There are three groups of flora [in the southern shrublands]:
1) summer germinating; 2) winter germinating; 3) opportunistic. To further complicate matters, there are a few species that only germinate when there is a really good sequence of seasons (summer or winter together generally). … The point is that being on site at the right time to sample all the herbaceous species will be very difficult in southern Australia. Craig James suggested to me that we could get around it by collecting samples of soil from the surface and germinating and identifying in the glasshouse – but this of course introduces another level of complexity to the system as well as substantially adding to the cost.

AC: In my opinion, comprehensive and accurate recording of all vascular plants would be very difficult to manage within the routine monitoring we do in the Kimberley. Capturing the information for a relatively small subset of sites may be more feasible but still presents significant difficulties. We have experience to draw upon, having carried out sampling of annuals on a range of sites used for studies of post-fire regeneration.

BK: I think this is worthwhile at the time of data collection-regular assessement after rainfall to determine every species that might exist on a plot is problematic.

DR: Yes it is a realistic suggestion depending upon how many sites you want to increase data collection from. My experience with NSW monitoring is that one site, monitored for all plant species, takes c. 2 - 3 hours to read. The time depends upon the potential species richness (inherent) of the landscape involved and the condition of the site.

BL: In SA we have agonised over this one while developing our site methods about 10 years ago. It seems that the prevailing view is that it is a law of diminishing returns - we are not trying to do a biological survey, and the more uncommon the species, the more doubt I would have as to the consistent ability of our assessors to find and identify the plant, anyway. Another problem is the seasonal factor, so that even if plants were present, a requirement to record all species would necessarily require all plants to be vouchered, or worse. This is bad for the cost/benefit equation (see below) and worse for our relationships with the Herbarium people! How often do we see miserable bitten-off vegetative material which is simply not able to be reliably identified.

LF: *Corveg* sites already measure full floristics; *SavMon* sites could accommodate full floristics but this would be onerous and may not be warranted.

b) would the data be meaningful in monitoring changes in floristic composition?

IW: We would find it VERY difficult to interpret changes in annuals/ephemerals. They are too much seasonally driven - see eg Hacker (1984). Grazing effects are obvious on some species but not for the majority. Many of the species seem to behave differently in different areas. For example, some of the species highlighted in Landsberg et al's work on distance from water behaved differently for them than my experience in the west Gascoyne. I think it depends on where within their geographical range they sit (are they on the margin of their rainfall, soil etc distribution) and on what other species occur withinthem. Because nearly all species are eaten at some stage, the preference ranking for a particular species depends on what species are also in the community. The same issues arises with perennials - but the floristics and therefore grazing "choices" are much simpler (plus they are still there to see when you go to sample them).

AC: The typically ephemeral nature of many annuals (e.g. appearance depending on recent disturbance by fire or particular seasonal characteristics) will mean that the detection of trends beyond the noise would be expected to take an extremely long time at the current WARMS sampling frequency of 3 years.

BK: I believe this is complimentary to landscape function data and provides data which may be used to interpret responses recorded by satellite.

DR: Without a doubt, if monitored over long enough time period to filter 'noise' (at least a decade) and if readings were timed to pick up environmental pulses and inter-pulses.

BL: probably not, unless the sites were monitored over al long time period, and at the same time of the year (or at least after rainfall events which more-or-less occurred at the same time of the year). The simple truth is that meaningful changes are (in our opinion at least) best determined from the reliable monitoring of the perennial plant component, and/or those more common plants which can serve as indicators of the degrading factors which prevail.

LF: Corveg sites are suitable for detecting floristic change in non-dominant species; SavMon is oriented toward detecting structural change and trends in dominant spp.

c) what are the practical and logistic constraints to achieving this?

IW: Timing of visit when identifiable material is present. May need to visit twice (or more) in one year to get them all. Time it takes to identify them all on-site or back at the ranch (increases site costs substantially). Availability of skilled staff. Increased risk of error in identification and hence interpretation. All species may not be visible in all years - but only there in seed bank.

AC: 1) Field work schedules, taking into account staff and vehicle resources available, extend well through the dry season. This means that quite a number of the annuals will be difficult to identify in the field and/or adequately collect by the time some sites are visited (this can be as late as October in some years). To ensure that all species were adequately collected it might be necessary to plan sampling during both wet and dry seasons, the former likely to require the use of a helicopter for access.

(2) Many grassland annuals are inconspicuous and the number found may be expected to vary significantly between observers. There is also the question of sampling vs. census. In the WARMS procedure we would record species presence within 100 sub-samples (0.5 m^2 or less) from a larger plot of 50 m x 26 m. This would give frequency as some measure of abundance.

(3) An experienced botanist working in conjunction with the relevant State Herbaria would almost certainly be required to assist us to keep up with the major task of correctly identifying annual plants and getting the information into the database in a timely fashion.

BK: We do this within our program and will continue to do so in the foreseeable future.

DR: 1. Selection of the sites (stratification) in which enhanced monitoring is to occur,
2. Training/retraining of observers,
3. Countering staff resistance to changed procedures / increased workloads,
4. Redesigning of data sheets/software to handle additional variables,
5. Catering for changes to field trip logistics (routes, time-away-from-base, accomodation etc) to enable more time to be spent on some/all sites.

BL: Severe; as mentioned above would require all sites to be visited while all material in identifiable condition. (Site size is another factor- see below). The best we could probably do is an approximation of this.

LF: Access to sites (there is a marked wet and dry season in the north and fertile specimens are difficult to obtain as the dry season progresses); time/effort issues (depends on resources in terms of $ and number of people); logistical constraints with physically collecting the data (i.e. covering the range of locations in a very small time frame); plant identification (especially of less common species) is significant rate determining step; data reliability may be a problem if plants are being identified by non-experts *d) how much time/effort would it add to the existing sampling regime?*

IW: Heaps - difficult to estimate - but would have to double time on site plus extensive lab/herbarium work to get it right. Maybe between $300 - $600 per site extra to do properly.

BK: We average 2 sites per day. Obviously we have far less sites than other states however this is deliberate as we want to rely on satellite data to get a picture of what's going on, using sites to calibrate ourselves and understand landscape dynamics.

DR: The impact of the changes would be nil in NSW because DLWC is already collecting data for all species, but it will impact to varying extent in other states.

LF: Collecting all plants would double the time taken to monitor a *SavMon* site

e) if this were implemented for at least some of your pasture monitoring sites, what would be the estimated extra $ cost per site?

IW: Maybe between $300 - $600 per site extra to do properly.

AC: estimated total per site (analysis cost not included) = $485

BK: No extra costs as present. Establishing new sites however is a resource issue.

DR: Nil in NSW

BL: It currently costs an average of about $400 per site to carry out the assessment on a station basis. This figure includes data entry etc. If this was to include all species, the site area would have to be substantially increased (e.g. to the current Biological Survey site of 100 hectares), and much more time spent on both searching for, measuring and identifying the dodgy ones. Estimated increase would be to about $1000 per site for Veg. only (if carried out on a lease or station basis) and $2400 for all biota, as mentioned at previous meeting.

LF: an additional $95 for *SavMon* sites (total $615 per site)

2) establish additional sites to sample variation in the landscape poorly, or not, represented by the existing array of sites. This would include sampling: (i) restricted landscapes such as drainage lines / run-on areas; (ii) a range of grazing intensities; (iii) regions or ecosystems outside current pastoral use or tenure

a) most workshop participants agreed that this was a sensible aim, but the ability to implement it was limited by financial / staffing constraints. Do you think that your organisation would see establishing additional sites to increase environmental coverage as important, should the required amount of money be made available?

IW: We would definitely see it as important - but would need money/help to do it. One of our problems is that if we dilute our site selection criteria within our current funding, we start to lose sample size for statistical testing. Therefore we would be wary about diverting resources from existing work to new sites (despite our enthusiasm for doing so).

AC: In my opinion, AGWEST would carefully consider some extension of its network if external funding were to be made available. I think that AGWEST would need to be convinced that there would be real and long-lasting benefits to land management from taking on this additional work. A formal agreement would presumably be needed covering the objectives, data collection, analysis, reporting and financial arrangements. A key consideration might be whether or not there were good prospects that the network would be supported in the long term. On the other hand a pilot scheme could perhaps be considered as a first step.

BK: Absolutely agree and we've tried to do this via a Cabinet Submission. Right now limited by staffing/financial constraints but working on it, must remember that unfortunately these processes take time to convince decision makers that this is worthwhile funding. We already try to select sites in a range of condition on similar landscapes and some of the other issues would be addressed in proposals for the Tropical Savannas Management CRC.

DR: Yes – without a doubt. In NSW at least, the present sites were located based on a site selection procedure which "averaged" environmental influences such as grazing intensity and topographic position. I have a problem with "averages" in stochastic environments. It also, necessarily, took into account convenience of access. So, differences in nature and condition within a landscape unit (eg, erosion cell) are not observed. However, from a NSW NPWS perspective, it would be probably just as, if not more, informative for the $$ spent, to resource the installation/upgrading of a subset of sites to observe fauna and improved landscape function as it would be to improve the comprehensiveness of sites focussing just on vegetation / flora. The installation of such sites was explored at the workshop, but it may be that you consider this to be a separate component of development of a monitoring system.

BL: Despite the SA coverage being second to none, it is noted that we have relatively few sites in Aboriginal reserves and other areas of Crown Lands. The DEH would certainly see it as valuable to extend the work we are now initiating, in putting more sites on Parks and away from grazed areas.

LF: *Corveg* already provides a thorough coverage of the landscape and sites are located across Queensland. Degraded rangelands would be under-represented, as well as any areas which are extremely weed infested. A small number of additional sites may be warranted in restricted vegetation units.

b) please provide an estimate of how much it costs to establish a new pastoral monitoring site?

IW: $630 per site

AC: $1350 for the Kimberley (assuming access by 4WD)

BK: This is a hard one because we do a lot of analysis prior to site establishment eg GIS & RS staffing etc etc. We have used 3-4 field staff for sampling and 2 vehicles, average times for set up are 1.5 sites per day]

BL: about $250-$500 per site (depending on density and hence distance to be travelled between sites, and how the costs are calculated. It is difficult to generalise about site costs because we have hierarchical classes of sites depending on what is recorded. Getting to any ground-based rangeland site is the main single cost item for us).

LF: *SavMon* (individual woody plants & dominant ground cover): $520 (including site establishment, data entry and plant identification, vehicle access)
Corveg (full floristics): $404

c) and the cost to resample a site?

IW: $630 per site (ball park)
AC: $900 in the Kimberley (assuming 4WD access)
BL: about 25% less [= c. $200-$400]
LF: *SavMon*: $415 (including site establishment, data entry and plant identification, vehicle access)
Corveg (full floristics): $210

d) do you have a feeling as to which of (i), (ii) or (iii) above is the highest priority?

IW: To me, the highest priority is to establish sites using roughly the same criteria as currently - but off the pastoral estate. To sample riparian areas or run on areas properly, we may have to modify or use a new technique. We already sample a reasonable range of grazing intensities, although don't have many sites at the extremes of the range of grazing intensity (unless the whole place is flogged or ungrazed)
AC: WARMS would be most appropriately extended into relatively homogeneous areas subject to low grazing pressure (e.g. additional sites on less productive pastoral country or at long distances from water, or possibly on conservation or unallocated crown lands (by arrangement with the responsible agencies). Restricted areas such as riparian zones would probably need a new methodology.
BK: I believe (ii) a range of condition sites on similar landscapes is essential. Second priority is (i) and third is (iii). In the case of our national parks and places like Arnhem Land, fire is the big modifier [rather than grazing].
DR: If (ii) included exclosed sites, then I think this would be by far the highest priority. I think the national monitoring system should seriously consider funding to install exclosures. The number, stratification, size etc of exclosures still needs to be carefully considered though. Clearly, there would not be enough funding to do many.
BL: Definitely (iii) is of highest priority, and as it stands at the moment will be done within our Dept, even if by another functional workgroup. It is the co-operative approach between workgroups that matters here, and database compatibility too.
LF: If funding was available, QPWS would place a high priority on establishing sites across the landscape, and including different land tenures and land uses.

e) do you think that some of this may more appropriately done by another department (eg 'wildlife' rather than 'pastoral/agricultural'?

IW: Am completely open to suggestions here. Would be happy for another Dept (e.g. CALM) to do it - at the same time would be happy to do it ourselves if we had the resources. Whatever happens, the two Agencies need to liaise/help/collaborate etc.
BK: Cooperation and consistency between depts. should be emphasised otherwise we have two monitoring systems with duplication and additional costs
DR: wrt (iii), it would be good for many reasons for NPWS to monitor sites on national park estate. Such sites, even if they started purely as pastoral-style monitoring sites, could form the basis of upgraded sites later (fauna) and this would reduce

agency inconsistencies. It would, potentially, draw DLWC and NPWS together to adopt standardised procedures, improve liaison X-agency for issues of common interest etc.

BL: as it stands at the moment it will be done within our Dept, even if by another functional workgroup. It is the co-operative approach between workgroups that matters here, and database compatibility too.

Additional comments were also sought on two other issues:

3) Are further improvements in standardising plot/site sizes and data collections methods between jurisdictions feasible or necessary?

IW: ….difficult to do now that most of the sites are installed (i.e. would bugger any pre-existing data). Also, I would need to be convinced (by data or modelling) that the variation in plot sizes is having a detrimental affect in comparing between systems. At this stage, I don't think it is.

….I think this [problem] is over-stated somewhat. Taking density first, plot size (over the range we are talking about) will have little influence on the comparison of densities between systems. With regard to frequency, plot size (over the range we are talking about) will also have little effect. Variations in quadrat size will affect frequency comparisons. This will affect direct comparisons between systems - but should not make much difference to meta analyses between systems, i.e. comparisons of number of plots that improve, decline or remain stable.

….It seems to me that there are three levels of standardisation:

1) Standardised quadrat size - since that affects frequency estimation within each quadrat
2) Standardised number of quadrats - since that affects species accumulation curves
3) Standardised site or plot area - since that might have some affect on what gets recorded, depending on the heterogeneity of the vegetation and patch scale.

I think (3) is a bit of a non-issue, given the range of site area (or plot size) we are talking about - or at least I would need good evidence of it being an issue before I accepted the recommendation to standardise. Don't forget this would mean re-installing all our sites, if we had to standardise to another standard. I think (2) is important - but wouldn't it just be sensible (rather than major changes to existing systems) to run our species accumulation curves up to the least number of quadrats in any of the systems (i.e. least common denominator). I would have to look at the other systems - but I bet they all have a minimum of 50 quadrats. So rather than drop ours back to 50 or lean on the NT people to increase theirs to 100 - I think we just look at the first 50 of ours, or every second one, or some randomly selected subset of 50. Issue (1) is obviously important - and I should check and see what all the quadrat sizes are. I wouldn't mind betting that they are all 0.5 sq m – but I haven't time to check at the moment. Anyway, of all the recommendations for change – I would consider this to be the most important. All of the above refers to quadrats on grassland sites. It is a whole new ballgame for belt transects as are used in the shrublands. In WARMS shrublands we use a direct census method - so you can subsample the transect down to several-centimeter resolution if you want to.

Again, I can't remember the detail of the NSW and SA systems but it might be relatively easy to report by "block" within each belt transect.

BK: its a hard one to get people to change site set-up ingrained over many years. We cut down our sites from 150m to 100m as logistically it was much better. However if people plan to collect additional data eg. spp composition, LFA over a portion of their site eg 1ha this may be workable. I would be loathe to increase our sampling over 1ha as too large an area creates a lot of work.

DR: Certainly, if a landscape type straddles a border, I don't see any technical reason why two states shouldn't agree to adopt the same sampling technique. Differences in size, shape etc of sites should, ideally, be customised for each broad landscape type and this is where the variation should occur, not X-state. However, there are logistical issues involved in this (staff training, parochialism etc) which take considerable organisation to address.

BL: The plots we use are based on the Warms approach but streamlined to include only one transect. The CSR abundance estimates use the site area of about 1-1.5 ha. Increasing this site area would not have a great effect on biodiversity score unless we recorded everything

4) Can you clarify how grazing intensity is rated / quantified at current monitoring sites?

IW: Not done - except as inferred from distance to water. We had some attempts at this in the early days but between operator error was too huge. Also, it can be pretty meaningless on a 5 yr recording cycle.

AC: Grazing intensity is judged at plot scale by the observer's subjective assessment of 'recent grazing'. We have a numerical scale. Dung counts (again reflecting recent grazing only) are a further possibility. Obtaining meaningful data on paddock stocking rates has proved to be very difficult in the Kimberley.

BK: Grazing intensity is estimated into classes. In 1998 we collected dung counts using the point step quarter method (D. Tongway and N Hindley did this for us).

BL: Grazing intensity is not measured at our sites. The surrogate is a vegetation condition score, and presence or absence of dung/sightings/tracks etc of the main herbivores.

LF: outside of immediate sacrifice zones around waters, distance from water is generally a poor surrogate for grazing intensity on Cape York Peninsula. *SavMon* currently uses counts of the number of cowpats in a 50 x 4 m plot to provide an indication of grazing intensity.