Rangelands Monitoring:

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

A manual for biodiversity monitoring.

TROPICAL SAVANNAS CRC

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Introduction

In the master report in this series, we describe and justify the use of nine core components for a biodiversity monitoring program in the Australian rangelands. The purpose of this background paper is to outline procedures which can be used to measure and record those components.

These procedures are given as guidance, rather than providing a single and obligatory directive on measurement. There is obviously great value in the development and application of procedural consistency in a national reporting process, and such consistency should be an objective. However, the derivation of a single uniform procedure will require careful and considered negotiation and assessment of the current operating procedures of those in different agencies and different jurisdictions, and of the resources available for ongoing monitoring. It cannot be imposed by *fiat* across jurisdictions and agencies.

Most agencies involved in biodiversity assessment, monitoring and natural resource management recognise the advantages of national consistency in approach, but the tortuous path of attempts to devise and coordinate a minimum consistent data set for vegetation mapping and monitoring (e.g. Bolton 1992; NVIS) suggests that the realisation of that aspiration may be hampered by entrenched ways of doing things developed idiosyncratically by different agencies. In many cases, such idiosyncracies in methodology reflect the legitimately distinct priorities of individual agencies and/or are justifiable adaptations to local conditions. It is understandable that there may be an unwillingness to change such tailored procedures, and especially so if change then weakens connectivity with substantial existing data banks, which represent major investments of resources.

Fortunately, many of the attributes of this proposed rangeland biodiversity monitoring program are consistent with elements of other, existing, monitoring programs (Table 2) – a deliberately selected outcome resulting from an aspiration to, where possible, harness and/or adapt the most appropriate of existing schemes. In these cases, methodological protocols are more comprehensively described elsewhere.

Note that in many cases below we describe both the measurement procedure for an indicator and a procedure for assessing how the indicator actually relates to biodiversity. Such “link studies” are an essential ingredient in the use and application of indicators generally. They are needed to validate the indicator - to provide confidence for, and to delineate the constraints in, the interpretation of its monitoring, and to detect threshold values beyond which biodiversity may be particularly imperilled. In contrast to monitoring, such link studies are proposed to be generally short-term and highly focussed test cases, and should preferably be conducted in 2-3 bioregions selected to represent the range of rangeland environments and/or land-uses.

In many cases, a coordinated national monitoring program for rangeland biodiversity can be founded upon the network of existing pastoral monitoring sites, albeit with supplementation by new sites to round out representation of environments (e.g. including riparian areas), bioregions (e.g. including non-pastoral areas) and distances to water (e.g. including additional sites both close to and remote from water points) (Background Paper 2 in this series). Table 3 summarises the elements and inter-relationships of the proposed monitoring elements, noting particularly the potential contribution of an enhanced pastoral monitoring program.

Having noted the difficulties confronting a highly prescriptive approach to methodologies, we re-iterate the importance of providing adequate funding for staff dedicated to developing this framework, in cooperation with the States and the Northern Territory. In an attachment to this document, we provide a rough outline of a possible process and an indicative estimate of related costs, to both establish the coordinating and program development capability and to expand the range of data presently being gathered in the States and Northern Territory.

Monitoring procedures for the nine proposed elements (indicators).

1. Progress to a Comprehensive, Adequate and Representative reserve system.

Indicator: progress to CAR

To a substantial extent, this indicator is already being monitored nationally as part of the National Reserve System Program (Commonwealth of Australia 1999) and State of the Environment Reporting (Saunders *et al*. 1998). The NRSP reporting requires the State/Territory conservation agencies to submit biennial reports which quantify the extent of reservation for all identified environments in all bioregions, and thence summed up to jurisidiction. That reporting format is shown in Appendix A.

This system could be adopted readily for rangeland monitoring by simply clipping out non-rangeland bioregions. However, the report is a little cumbersome and doesn't provide a concise obvious measure of progress. We advocate the addition of the procedure outlined below, to derive a single simple measure of this indicator (provided at rangeland bioregion, jurisdiction and national levels).

Calculation of an explicit contribution to comprehensiveness and adequacy

Surprisingly, despite the wide acceptance of the goal of comprehensiveness, adequacy and representativeness in reserve systems, there has been no attempt to score the contribution of individual reserves towards this goal, nor to measure how far a reserve system approaches the goal. Here we describe such a procedure.

Firstly, we set a threshold ("T") which is our goal for adequacy – that is that the reserve system should include, say, 5% of the extent of every environment ("e") within a bioregion. Any reservation of that environment above that percentage affords no contribution towards meeting the goal – it is effectively tipping water into an already full glass. Thus we can calculate readily the current status of adequacy and comprehensiveness of the reserve system as simply:

$$\left[\sum^{n} (r_e / T)\right] / n,$$

where,
r_e is the reservation % of environment e (which has an enforced upper bound of T);
T is the threshold goal given for adequacy; and
n is the number of environments in the bioregion.

This gives a score from 0 (if no environments are reserved) to 1 (if all environments are reserved at least to the threshold value – i.e. the system is both comprehensive and adequate).

A consideration with this simple index is that its values will vary according to how high the threshold/standard is (i.e. whether 5%, 10% or whatever is considered adequate). Because there is no straightforward scientific justification for any particular threshold value, difficulties may arise in achieving consensus on an appropriate target and hence acceptance of the relevance of the index.

A solution to this difficulty is to calculate the score for a number of different threshold values (say 5%, 10%, 20%), and simply average them or chart them for inter-jurisdictional and other comparisons. So long as the threshold values used are specified, then the index can be monitored regularly to chart progress towards CAR. The index can be calculated analogously to chart progress towards adequacy and comprehensiveness at a jurisdictional or national level.

A worked (simple and imaginary) example is given below.

Within bioregion X, the conservation reserve system contains 9% of the bioregional extent of vegetation type *a*, 3% of the extent of vegetation type *b* in the bioregion, 2% of the bioregional extent of vegetation type *d*, 13% of the bioregional extent of vegetation type *f*, but none of the remaining vegetation types (*c* and *e*).

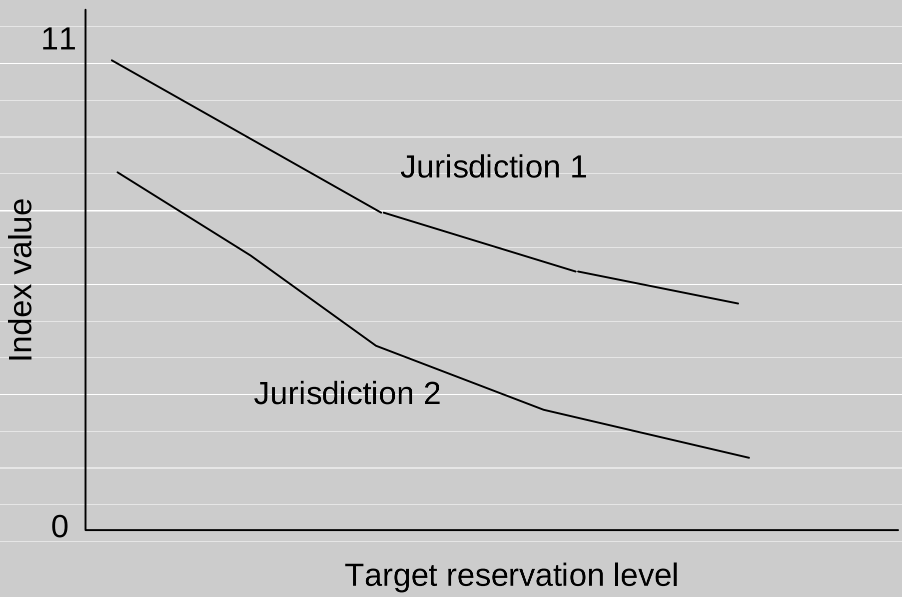
Table 1. Calculation of CAR score for an imaginary bioregion X, which has 6 vegetation types.

vegetation type	% area in reserves	contribution towards threshold		
		for T=5%	T=10%	T=20%
a	9	5	9	9
b	3	3	3	3
c	0	0	0	0
d	2	2	2	2
e	0	0	0	0
f	13	5	10	13
CAR score		**0.5 (=15/5/6)**	**0.4 (=24/10/6)**	**0.23 (=27/20/6)**

Hence, an overall CAR score for this bioregion is the average for progress towards the three nominated target levels (5%,10%,20%), that is 0.377.

An alternative presentation would be to present a simple graph of variation in the values of the index at different target levels (Figure 1)

Figure 1. Index values at different target levels for two jurisdictions.



Assessment of this indicator requires environmental mapping at appropriate scales, preferably at least 1:250,000 for bioregional reporting, and preferably some consistency in this mapping across bioregions and jurisdictions. It also requires up to date GIS coverages of the conservation reserve system.

This indicator could be reported biennially, in line with the current reporting requirements under the National Reserve System program.

Link study: biodiversity consequences of progress to CAR

The assumption of progress towards a CAR network is that this expansion is providing greater conservation security and hence maintaining or enhancing native biodiversity at a regional, State/Territory or national scale.

This assumption should be tested in at least one and preferably two, (bioregional) case studies, with an obvious candidate being the Gascoyne-Murchison area (where the reserve system is expanding relatively rapidly). This link study should be based on comparing biodiversity between sites with ongoing pastoral use and matched sites where this use is being replaced by formal conservation management. At a site level, existing pastoral monitoring plots will provide a reasonable foundation for this monitoring. Some elements (such as census of birds and ants) will need to be added to existing pastoral monitoring at these sites. In addition to this comparison at plot level, more wide-ranging sampling will need to be conducted for some other biodiversity elements, such as mammals, but with this sampling still focused on comparison between ongoing pastoral properties and properties undergoing change to conservation tenure, as well as sites that have been under longer term conservation management.

2. Extent of clearing

Indicator: extent of clearing

This indicator is included within national State of the Environment reporting (Saunders et al. 1998), and detailed descriptions of procedures for its monitoring are presented in Wallace and Campbell (1998) and Saunders et al. (1998). The most well-developed protocol for monitoring clearing in the rangelands areas is that developed by Queensland's Statewide Landcover and Trees Study (QDNR), which is described at:

http://www.dnr.qld.gov.au/resourcenet/veg/slats/meth/meth.html

This procedure should be appropriate for bioregions in other rangeland jurisdictions, where vegetation clearance is occurring.

As with indicator (1) above, monitoring requires environmental mapping at appropriate scale, and with some consistency across the reporting units (bioregion, jurisdiction, national).

Link study: biodiversity consequences of clearance

For at least two trial rangeland bioregions, link studies should be undertaken to examine the responses of rangeland biota to clearance and fragmentation. Note that such studies are currently being conducted (in the Darwin area, and in central Queensland). Any further such studies should consider variation in species composition and diversity, and in the population sizes of selected species, among fragments of varying size, history and landscape configuration, and in cleared areas. Candidate taxa for consideration should include groups which are highly sedentary and localised (such as some plant groups and mygalomorph spiders) and more mobile species (such as nectarivorous and frugivorous birds).

There are probably sufficient studies on the effects of clearance and fragmentation to now accept broad principles for the interpretation of this indicator (e.g. Andren 1994; Debinski and Holt 2000), but rangeland-specific studies will provide greater confidence about such interpretation. Such studies will be particularly important to measure effects at different spatial scales (from those at which indicators are typically reported), provide information on variation associated with configuration of remnants, and details of regrowth and its relevance to rehabilitation of severely damaged sites.

3. Landscape functionality

Indicator: landscape functionality

Landscape functionality (or ecosystem function analysis) is used broadly to monitor "condition" in many pastoral areas of the Australian rangelands (Background Paper 2 in this series), with a well-developed protocol for on-ground assessment and monitoring (Tongway 1994; Ludwig et al. 1997; Tongway and Hindley 1999), now linked (in at least some rangeland bioregions) to assessment based on interpretation of satellite imagery (Wallace et al. 1994; Bastin et al. 1998; Wallace and Campbell 1998), providing a mechanism for well-considered interpolation and extrapolation from plot-based data to landscape and larger scales.

Protocols for assessment and ongoing monitoring of this indicator are described comprehensively in the above publications.

To incorporate this element in national rangeland monitoring, some additional resources may need to be directed towards the establishment of analogues to pastoral monitoring plots, in non-pastoral areas and in environments currently poorly represented in existing pastoral monitoring schemes (Background Paper 2 in this series). This may be particularly needed in those non-pastoral areas where feral animals or changed fire regimes are degrading land condition and functionality.

Link study: biodiversity consequences of landscape functionality

Although there is good implicit rationale for a connection between biodiversity and landscape functionality, that linkage is very far from being adequately and empirically described.

Specific link studies are required to translate monitoring data from landscape functionality assessment to biodiversity consequences. At the site level, this can be done relatively easily through measuring some biodiversity elements (specifically including ants and birds) at pastoral monitoring sites of similar environment but varying in landscape functionality values. Ludwig et al. (1999) provide an example of this type of study.

A similar approach should be used at the landscape level, with assessment of biodiversity elements (again, specifically including ants and birds) in areas of similar environment but varying in trend condition as assessed by interpretation of satellite imagery.

Such link studies will be most informative if conducted in regions where a large range of condition is locally available. Ideally sites examined for both ground-based measures of landscape function and remotely-sensed land condition should include sites ungrazed by domestic stock and managed primarily for conservation. Such studies will be most informative if other data like fire histories are also available.

4. Cover of native perennial grass / native perennial ground layer vegetation

Indicator: cover of native perennial ground layer vegetation

Native perennial grass cover is an important component of existing pastoral monitoring in many rangeland bioregions, and is widely (and with reasonable justification) used as an indicator of health (Background Paper 2 in this series). Although the amount of native perennial grass can be measured in many ways (including cover, frequency, biomass), and the interpretability or link with health may be affected by the actual species composition of the perennial grasses, there is sufficient similarity between jurisdictions in the measurement of this feature to enable (or to develop) consistency in bioregional, jurisdiction-level and national-level reporting.

In some rangeland environments (such as chenopod shrublands) and bioregions (such as the Nullabor and Gascoyne), where grasses may be a relatively insignificant component of the understorey, a more appropriate variation of this indicator will be an assessment of other native perennial understorey life-forms, such as chenopod shrub cover (e.g., Lange *et al*. 1984).

As with indicator (3) above, this feature is currently being monitored almost exclusively in existing pastoral monitoring plots, which provide a biased representation of Australia’s rangeland environments and bioregions. To develop a truly national reporting process, some additional sites analogous to pastoral monitoring plots will need to be etsablished in non-pastoral regions and in those environments not currently well serviced by the existing sites.

Link studies: relationship of biodiversity to cover of native perennial ground layer

Again, as with indicator (3) above, biodiversity link studies can be undertaken relatively simply by measuring some biodiversity elements (specifically including ants and birds) at pastoral monitoring sites of similar environment but varying in values of native perennial ground cover. Such link studies will be most informative if conducted in regions where a large range of cover is locally available.

Such studies can be conducted most efficiently if undertaken synchronously with those suggested above for indicator (3), which would allow a comparison of the biodiversity information content of these two measures.

5. Exotic plant species cover

Indicator: exotic plant species

Monitoring of the occurrence of weed species is a routine responsibility of natural resource management agencies in all rangeland jurisdictions (ARMCANZ, ANZECC & Forestry Ministers 1997), although the extent and comprehensiveness of this activity varies widely.

The indicator proposed here is most directly similar to that proposed as a key Land indicator for National State of the Environment Reporting ("4.1. Rate of extension of exotic species into each IBRA, and of change in their abundance") and a protocol for monitoring that indicator is described in Hamblin (1998).

Through floristic information gathered generally, at monitoring plot level, existing pastoral monitoring schemes generally record the occurrence and some measure of the abundance of exotic plant species, although annual species are unrecorded in many programs (Background Paper 2 in this series). This information can be distilled then aggregated to provide regular reporting (at bioregional, jurisdiction-level and national-level) of the occurrence of exotic plant species across the existing pastoral monitoring plot network, with reporting variables possibly including:

- number of exotic species,
- total cover (and/or frequency) of exotic species,
- the proportion of exotic to native species, and
- specific reporting for individual exotic species.

As with several other indicators considered here, harnessing of information from the existing pastoral monitoring network is a major start, but should be supplemented by information from analogous monitoring plots established in non-pastoral areas and in environments currently poorly serviced by the existing network.

With such expansion of the monitoring plot network, a measure of change in distribution of weed species over large spatial scales may be retrieved. However, these sites are but pinpricks in the rangeland landscapes, and may provide an inadequate assessment of the regional and smaller-scale dynamics of exotic plant invasions and impacts, and because exotic plants may often spread with a highly contagious dispersion. At least for the declared weeds of national significance, more comprehensive monitoring of distribution and abundance (where possible using interpretation of imagery) should be undertaken.

Link studies: relationship of biodiversity to exotic plant species

A series of link studies should be undertaken to assess biodiversity across sites of similar environment but varying in abundance of exotic plant species (and including some sites representing areas subject to weed control mechanisms). This series should include representation of those exotic plant species considered most likely to have substantial impacts upon rangeland biodiversity, most notably rubbervine *Cryptostegia grandiflora*, mimosa *Mimosa pigra*, buffel grass *Cenchrus ciliaris*, prickly acacia *Acacia nilotica*, gamba grass *Andropogon gayanus*, and para grass *Brachiaria mutica*. Some such studies are already being undertaken in northern Australia, and one study has been completed on the biodiversity impacts of athel pine (tamarisk) *Tamarix aphylla* (Griffin *et al*. 1989).

These link studies should consider not only the relationships between native biodiversity and the occurrence/abundance of these weed species, but also the consequences to biodiversity of control mechanisms applied to these weeds.

6. Fire-sensitive plant species and communities

Remote sensing (mostly using interpretation of NOAA-AVHRR and/or LANDSAT imagery, depending upon the scale of resolution demanded) is now being used routinely to monitor fire occurrence across the rangelands of northern Australia, and to report on the extent, timing and frequency of fire by bioregion and by vegetation types (e.g. Russell-Smith *et al*. 2000). The procedure is suitable for extension to include monitoring across the entire rangelands (Wallace and Campbell 1998), which would allow annual reporting (by environment, bioregion, and at jurisidction and national scales) of the proportion of lands burnt, of the proportion of lands of varying ages since last fire, and of varying fire frequencies.

It is evident that some species (such as northern cypress-pine *Callitris intratropica*: Bowman and Panton 1993), groups of species (such as those heathland plants which reproduce only as obligate re-seeders: Russell-Smith *et al*. 1998), or environments (such as rainforest patches, mulga woodlands and chenopod shrublands) are particularly intolerant of some fire regimes. While the fate of these can be inferred from remote-sensed monitoring of fire patterns generally, this inference may initially be weak. We suggest that for each main rangeland environment and/or bioregion, natural resource management agencies should nominate one or several species or species-groups which best represent these fire-sensitive plant species or groups, and that targetted monitoring programs then be established specifically for such taxa. Such programs should aim to relate fire regimes to the abundance and population structure of these plants, using sampling in plots established across their distribution and representing the range of land-uses or management regimes operating. Wherever possible, this sampling should include existing pastoral monitoring plots.

Such programs may need to be relatively species-specific, and hence general monitoring protocols cannot readily be defined.

Fire-sensitive plant species or communities represent only one extreme of responses to fire regimes. The decline of these is often counterpointed by increases in other species or communities. The most notable such examples are the increase in native “woody weeds” in generally grazed and infrequently burnt rangeland areas of eastern Australia (e.g. Noble 1997). It may be as important for biodiversity monitoring in the rangelands to keep track of such increases and environmental dynamism. Some measure of such change should be extractable from the existing pastoral monitoring plot network, although the sampling intensity may need to be increased in some environments or bioregions through supplementation with additional long-term plots (e.g. Burrows *et al*. 1998). The plot-based monitoring should be complemented by use of remote-sensing to detect landscape-scale changes in tree or shrub cover (Wallace and Campbell 1998).

7. Grazing-sensitive plants

Many rangeland plant species are known to decline under sustained grazing pressure (from livestock and/or feral animals), characteristically because they are highly palatable and nutritious (colloquially termed “ice-cream plants”), and have reproductive characteristics which provide little defence against ongoing grazing. Typically such species respond through marked decline in abundance or distribution, or by manifesting highly skewed age structure. Examples include western myall *Acacia papyrocarpa*, rosewood *Alectryon oleifolius,* some *Casuarina*, *Santalum* and *Myoporum* species, and many daisies.

The existing pastoral monitoring programs may provide some information on the status of such species, and especially so if the existing plots on pastoral lands are complemented by additional plots on ungrazed lands. However, this information will generally be diffuse and relatively shallow. To understand trends in these grazing-sensitive species, more targetted monitoring programs will be required. We suggest that, as for indicator 6 above, for each main rangeland environment and/or bioregion, natural resource management agencies should nominate one or several species or species-groups which best represent decliner plant species, and that targetted monitoring programs then be established specifically for such species. Such programs should sample the abundance and population structure of these plants, in plots established across their distribution and representing the range of land-uses or management regimes operating. Wherever possible, this sampling should include existing pastoral monitoring plots.

8. Susceptible mammals

Of all biodiversity components, native mammals have suffered the most substantial loss across the rangelands, and this decline is continuing in at least some rangeland areas. Losses have been most pronounced among bandicoots, larger rodents, larger dasyurids, and smaller macropods. No biodiversity monitoring program for the rangelands would be acceptable if it did not include a direct assessment of trends in the status of these mammal groups. We suggest two threads to this monitoring program.

For the more remote (generally non-pastoral) rangeland bioregions, the most informed assessment of mammal fauna is likely to be held by Aboriginal residents. Where appropriately used, this knowledge has proven generally to be a remarkably authoritative and perceptive tool for monitoring trends (e.g. Burbidge *et al*. 1988; Pearson and the Nagaanyatjarra Council 1997). We propose that appropriate Aboriginal agencies be contracted to provide, or contribute to, an assessment of the status of mammal fauna across the communities and outstations of (at least a selected subset of) the remote rangelands, at 5-10 year intervals, and that this monitoring follow the protocol outlined in Burbidge *et al*. (1988) and Pearson and the Nagaanyatjarra Council (1997).

More quantitative assessment of trends in the mammal fauna will be achievable through replication of a set of a small number of selected fauna surveys. These landmark surveys (no more than 2-5 per jurisdiction) should be chosen to represent a range of environments and regions, and to include the most precisely documented and most methodologically rigorous sampling from those available (note that survey procedure varies so much among jurisdictions that national consistency is unlikely to be possible). Such landmark surveys should be repeated at 10-year cycles.

9. Susceptible birds

Many bird species and groups have undergone substantial changes in distribution and abundance across the rangelands, although lack of systematic recording makes it difficult to accurately quantify this change.

The current second Atlas of Australian Birds (1998-2001) represents a major opportunity to evaluate changes across the nation since its predecessor (1977-1981), and (given its increased methodological rigour and locational precision) will provide a firmer benchmark for ongoing monitoring. These Atlases are the most substantial biodiversity monitoring programs in the Australian rangelands, and they should be maintained at about 20 year intervals. The current Atlas cost is around $1.5 million, spread over a 5-year period, but supported by a major contribution from volunteers. It should provide clear evaluation of change at a bioregional level, and an indication of the species whose abundance and/or distribution is undergoing most marked change.

The extensive Atlas coverage should be complemented by more targetted and frequent monitoring of species or species-groups which are known to be declining or susceptible to changes in rangeland conditions. There is now sufficient information generally on rangeland birds to list several such species for every main rangeland environment and/or bioregion. Examples include golden-shouldered parrot *Psephotus chrysopterygius* in savanna woodlands and grasslands of Cape York Peninsula; granivorous birds generally in the tropical savannas; hooded robin *Melanodryas cucullata* in *Acacia* and eucalypt woodlands across much of the rangelands; and white-winged fairy-wren *Malurus leucopterus*, thick-billed grass-wren *Amytornis textilis*, redthroat *Pyrrholaemus brunneus*, slender-billed thornbill *Acanthiza iredalei* and/or rufous fieldwren *Calamanthus campestris* in chenopod shrublands. Monitoring programs for these species or species-groups will need to be individually tailored, but should include quadrat-based annual or biennial estimates of abundance, with sampling stratified across a range of land-uses or management regimes.

Bird species composition and abundances should also be recorded in re-sampling of the landmark surveys described above for indicator (8). As noted above, birds should also be sampled in the link studies validating indicators (1) to (5).

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Table 2. Comparison of biodiversity indicators proposed here for monitoring biodiversity in the rangelands, with those developed for national State of the Environment reporting (Saunders *et al*. 1998) and those developed for assessment of sustainable forest management (the Montreal Process: Santiago Declaration 1995).

Proposed for rangeland biodiversity monitoring	**SoE – core biodiversity indicators**	**Montreal – national and regional indicators of sustainable forest management (criteria related to biological diversity, and ecosystem health and vitality)**
1. Progress to CAR reserve system Area by vegetation type in protected area categories as defined by IUCN, in hectares and as a percentage of the pre-1750 area, by IBRA region. Values converted to a single CAR index for IBRA region and rangelands in toto	**BD10. Terrestrial protected areas** Area by vegetation type in protected area categories as defined by IUCN, in hectares and as a percentage of the pre-1750 area, by IBRA region	**1.1.c. Extent of areas by forest type in protected area categories as defined by IUCN or other classification system** **1.1.d. Extent of areas by forest type in protected areas defined by age class or successional stage**
2. Extent of vegetation clearing Rate (and cumulative extent and percentage) of clearing, in hectares per annum, of terrestrial native vegetation types, for IBRA region and rangelands in toto.	**BD1. Native vegetation clearing** Rate of clearing, in hectares per annum, of terrestrial native vegetation types, by clearing activity	**1.1.e. Fragmentation of forest types**
3. Landscape functionality Extent of change in LFA scores measured in pastoral monitoring plots, collated by vegetation types and IBRA.	**BD7. Extent and condition of native vegetation** The area and condition of native vegetation by type. In the absence of other measures, vegetation assemblages are used as surrogates for ecological communities and ecosystem diversity	**3.1.c. Area and precentage of forest land with diminished biological components indicative of changes in fundamental ecological processes** (e.g. soil nutrient cycling, seed dispersion, pollination) **and/or ecological continuity** (monitoring of functionality important species such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.)
4. Native perennial understorey/ground cover Extent of change in total cover of native perennial grass measured in pastoral monitoring plots, collated by vegetation types and IBRA.		

5. Exotic plant species cover Extent of change in total cover of exotic plant species measured in pastoral monitoring plots, collated by vegetation types and IBRA. Mapped distribution of nominated significant weed species.	**BD4. Introduced species** The distribution (and abundance where possible) of non-indigenous terrestrial, marine and freshwater species (plants, vertebrates, invertebrates, and pathogens) identified as pests. This indicator also includes displaced/translocated native species. The identified species will vary with place and time.	**3.1.a. Area and per cent of forest affected by processes or agents beyond the range of historic variation**
6. Fire-sensitive plant species and communities Area of vegetation burnt, by frequency and intensity of burning and type of vegetation (for selected fire-senstive vegetation types only). Age structure and abundance of populations of selected fire-sensitive plant species measured in pastoral monitoring plots, collated by vegetation types and IBRA.. Change in woody cover, derived from pastoral monitoring plots and imagery.	**BD3. Fire regimes** Area of vegetation burnt, by frequency and intensity of burning and type of vegetation	**1.1.b. Extent of area of forest type and by age class or successional stage**
7. Susceptible species – grazing-sensitive plants Change in abundance/cover of selected set of highly palatable non-resilient ("decreaser") herbs and grasses, derived from pastoral monitoring plots **8. Susceptible species – mammals** Change in abundance/presence of selected suite of species as detected by collation of repeat sampling of "landmark" surveys. Change in abundance/presence of selected suite of species as detected by set of landholders (especially Aboriginal communities)	**BD6. Extinct, endangered and vulnerable species and ecological communities** Number of species and ecological communities presumed extinct, endangered or vulnerable. This indicator should be reported by major group, together with the estimated number of endemic species per major group. Applies to animals and plants, both terrestrial and aquatic. **BD9. Populations of selected species** Estimated populations of selected species, including declining species, are an important measure for assessing the conservation status of species. They are also potential surrogates for assessing changes in genetic diversity	**1.2.b. The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment** **1.3.a. Number of forest dependent species that occupy a small portion of their former range** **1.3.b. Population levels of representative species from diverse habitats monitored across their range**

9. Susceptible species – birds Change in abundance/presence of selected suite of species as detected by collation of repeat sampling of “landmark” surveys. Change in abundance/presence of selected suite of species as detected by repeat Atlasses.		
	BD5. Species outbreaks The number (and identity) of native species outbreaks and the location and area affected.	
	BD12. Recovery plans Recovery plans for threatened species and ecological communities as required under legislation	
	BD13. Area revegetated The area revegetated by species or genus, in hectares per annum, disaggregated into areas revegetated using loocal vegetation or other vegetation, and the purpose of the revegetation.	
		1.1.a. Extent of area by forest type relative to total forest area
		1.2.a. The number of forest dependent species

Table 3. Summary table showing inter-relationships of monitoring elements. Underlining signifies existing component of (at least some) pastoral monitoring (although note that additional sites would be needed to reduce locational biases = PM+ sites).

Element	**assessment based on PM+ sites?**		**other form of assessment**	
	direct measure	*link studies*	*direct measure*	*link studies*
1. progress to CAR	-	assessment of relationships of biodiversity to this indicator (for 1-2 trial bioregions)	GIS analysis	-
2. clearing	-	-	imagery, GIS analysis	assessment of relationships of biodiversity to this indicator (for 1-2 trial bioregions)
3. landscape functionality	yes (LFA analysis)	assessment of relationships of biodiversity to this indicator (for 1-2 trial bioregions)	-	relationship with remote-sensed indices of condition
4. native perennial understorey cover	yes	assessment of relationships of biodiversity to this indicator (for 1-2 trial bioregions)	-	-
5. exotic plant species cover	yes	-	mapping of significant environmental weeds	assessment of relationships of biodiversity to this indicator (for 1-2 trial bioregions)
6. fire-sensitive plant species and communities	(yes)	-	a) fire mapping b) targetted monitoring for selected fire-sensitive plant species or communities; c) monitoring of increased “woodiness” or other environmental change (remote-sensing and additional plots)	-

Table 3. Continued

element	**assessment based on PM+ sites?**		**other form of assessment**	
	direct measure	*link studies*	*direct measure*	*link studies*
7. grazing-sensitive plants	yes	-	targetted monitoring for selected grazing-sensitive plant species or communities.	-
8. mammals	yes	-	a) Aboriginal information in remote areas; b) re-sampling “benchmark” surveys	-
9. birds	yes	included in 1, 3 and 4 above	a) Atlassing b) re-sampling “benchmark” surveys; c) targetted monitoring for selected susceptible bird species.	-

Appendix A. Existing reporting framework for progress towards CAR reserve network.

NATIONAL RESERVE SYSTEM - REPORTING TABLES.

IBRA REGION:
Priority: Jurisdiction: Regional Conservation Strategies Available:

		1996		1998		2000	
		Area (ha)	%	Area (ha)	%	Area (ha)	%
Protected Area as % of region (IUCN I-IV)	Ia -						
	Ib -						
	II -						
	III -						
	IV -						
	Total						
Protected Area as % of region (IUCN V-VI)	V -						
	VI -						
	Total						

	IUCN Cat	Ia	1b	II	III	IV	V	VI
No. of management plans over number of protected areas by IUCN category (x/y)	**1996**							
	1998							
	2000							

Summary Data – Ecosystems within IBRA regions and Protected Areas (PA):

Percent of current areas within protected areas	Ecosystem	Current area and % across State/ Territory	Current area within bioregion (ha) & % of bioregion						Current area within protected areas (ha) & % in protected areas						Pre-European area (ha) & % in protected areas					
			1996		1998		2000		1996		1998		2000		1996		1998		2000	
			Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
0%																				
<5%																				
5 – 10%																				
>10%																				

Summary of All Vegetation Types					
Mapunit	**Total Area**	**Area protected in 1998**	**Percentage protected 1998**	**Area protected in 2000**	**Percentage protected 2000**