Rangelands Monitoring:

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

Background paper 3.
A review of information gathered from existing biodiversity monitoring programs.

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

National Land & Water Resources Audit
A program of the Natural Heritage Trust

This report is prepared as a resource document for Project 3 "*Developing an analytical framework for monitoring biodiversity in Australia's rangelands*" of the **National Land and Water Resources Audit** Theme 4 (*Rangelands monitoring*).

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Darwin,October 2000.

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Summary

As a complement to a companion paper on the potential use of existing pastoral monitoring programs for biodiversity monitoring, we summarise a range of biodiversity monitoring schemes currently operating within the rangelands, and consider their potential contribution to a national monitoring framework.

We conclude that potentially useful insights on the status of rangeland biodiversity, relevant to a national perspective, can be gleaned from past and current studies and smaller-scale monitoring schemes. Sources of information include:

- *museum, herbarium and other collections backed by voucher specimens*
- *biological surveys and associated databases*
- *various ecological studies*
- *State and Territory monitoring schemes for endangered, exploited and pest plant and animal species*
- *parks and reserves monitoring programs*
- *plant or animal atlas schemes*
- *landscape mapping*
- *study and monitoring of landscape processes, and*
- *biogeogeographic analysis.*

The most useful programs and the steps needed to realise the utility of these programs for tracking the changing status of rangeland biodiversity are:

(1) Studies of rangeland organisms or sites. Utility ranges from a single record of the occurrence of a particular organism at a specified place and time, to opportunities to repeat important quantitative surveys and so assess intervening change
  - a number of carefully chosen “landmark” surveys should be repeated to validate evidence of acute change in status of important elements of biological diversity
  - arrangements similar to the Australian Spatial Data Directory (ASDD) should be mimicked by Government agencies and other institutions engaged in (a) studies of elements of biological diversity in rangelands and (b) monitoring of pasture and land condition, and metadata for those studies held in a central repository available to all interested parties
  - the very miscellaneous nature of studies will require that metadata entries be actively filtered to provide focus on the most useful.

(2) Schemes for monitoring endangered, exploited native (and pest) organisms. These surveys contain much information important for a comprehensive monitoring system. Important underlying trends may become apparent earlier if regularly examined in an integrated way.
  - arrangements should be made to aggregate data to permit meta-analysis of trends. Environment Australia is already responsible for review of reports derived from related surveys and would be an appropriate body to conduct

integrated analysis for endangered and exploited species. The Bureau of Rural Sciences has previously performed this role in regard to exotic animals.

(3) Parks and reserves monitoring. Sites managed for conservation have the potential to provide "controls" or contrasts for biodiversity trends on pastoral or other sites used for production. However, there are few comprehensive and long terms programs in place in even the most significant and well-resourced parks and they are not matched to equivalent programs on production sites.
- steps should be taken to improve biodiversity monitoring on reserves within the rangelands and to establish symmetry of monitoring programs on neighbouring pastoral and reserved lands.

(4) Vegetation and other landscape mapping at national or large regional scales. Such data are mostly too coarse or too infrequently updated to permit effective use to monitor change in biodiversity values, except perhaps to broadly index important threatening processes.
- agencies active in environmental mapping should have access to advice on rangeland areas where improved (finer scale and/or better discrimination of different environmental classes) mapping is particularly needed to better understand threatening processes or change in biodiversity values.
- land clearing and other measures of land cover change already collected should form part of a rangeland biodiversity monitoring program

(5) Studies of landscape processes. Investigations of landscape processes at a range of scales require explicit and well-structured linkage to biodiversity monitoring so that the use of Landscape Function Analysis (LFA) as a surrogate for landscape health and biodiversity status can be validated.
- biodiversity values should be measured at sites used for landscape function analysis and other measures of landscape condition, including large-scale studies based on remote sensing

(6) Biogeographic analysis. Most threats to biological diversity in rangelands have been inferred from basic principles rather than validated by scientific study and analysis. Standardisation and consistency in nationwide environmental descriptions is important to explore the links between biodiversity values, environmental attributes and socio-economic factors at large spatial scales.
- a system for monitoring rangeland biodiversity should provide explicitly the capability for investigating the links between putative threatening processes and biodiversity values
- interpretation of such studies will be enhanced by access to other Audit products such as greening indices which may help to distinguish climate-driven from other, anthropogenically derived change
- improved access to socio-economic data held by the Australian Bureau of Statistics is necessary to provide insights to the associations among environmental features, socio-economic status and change in biodiversity values.

The most productive use can be made of existing work if the capacity exists to actively promote integration of the presently unconnected efforts of conservation and production agencies. Under-resourced State and Federal agencies are hard-pressed to maintain existing programs, let alone provide the quality of integrated analysis needed to usefully monitor decline in rangeland biodiversity at a national scale and infer causes of change with sufficient confidence to suggest appropriate management responses.

The history of rapid and irreversible decline of many elements of the rangeland fauna demand that systems provide early warning of further change so that corrective action can be taken. Although existing information can be rendered much more useful, it will also be necessary to supplement those data with information gathered explicitly to directly index the condition of fauna and flora thought most at risk under contemporary circumstances.

National obligations will not be easily met, but a useful start can be made by providing modest additional support to build a framework that, while initially skeletal, is sufficiently robust to support enhancements over the longer term as it evolves towards a credible national system.

Introduction and Approach

Elsewhere in this sequence of reports we have examined the purposes of monitoring and the extent to which programs established overseas and locally have been able to satisfy that range of purposes (Main Report and Background paper 4). We have emphasised the importance of objectives of monitoring being clearly stated, well understood and widely endorsed if effective and efficient programs are to be designed and implemented. However, we have also recognised that much of the evidence for change in biodiversity in the Australian rangelands and elsewhere has come from work that was not explicitly designed to reveal temporal trends nor intended to be repeated in the future. Striking examples of the use of records that were not designed to monitor change are the work of Franklin (1999) who brought together large numbers of individual bird observations from many sources, and that of Burbidge *et al*. (1988) who documented decline in arid-zone mammals from collation of records from Aboriginal informants.

Table 1: List of monitoring projects conducted by State, Territory and Federal Governments capable of returning information relevant to the status of rangeland biodiversity and considered for this report. Projects are loosely grouped to reflect the organisation of the discussion in the body of the report, but it should be noted that many projects cover a wide range of attributes, sites and processes that cross categories.

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
Wildlife Inventory												
Flora and fauna surveys of southern NT	regional survey	Species diversity	fl/fa	All	NT	TAN, SSD, MAC	100-500	Sth NT			1978	ongoing
Regional Flora & fauna surveys WA	regional survey	Species diversity	fl/fa	mammal, bird, herp, invert, grass, tree, shrub	WA	GAS, MUR, LSD, CAR, GS	500-1000	By bioregion	strat sys	250 properties (1/2 total past area)	1970	ongoing
Biological Survey of SA	regional survey	Species diversity	fl/fa	mammal, bird, herp, invert, all vascular plants	SA	All SA	>1000	Anangu Pitjanjatjara (AP) land	strat ran	2 sites	1970s	ongoing
Biological Survey of WA	regional survey	Species diversity	fl/fa	mammal, bird, herp, invert, all vascular plants	WA	WA Ibra's	>1000	1/3 of WA	start ran	1/3 WA	1972	ongoing
Wildlife surveys of the Top end of the NT	regional survey	Species diversity	fl/fa	mammal, bird, herp, all vascular plants	NT	NT ibra's	500-1000		strat sys	5 000 quadrats	1990	ongoing
Western Region biodiversity conservation project NSW	regional survey	Species diversity	fl/fa	mammal, bird, herp, vascular plants, lichen	NSW	BHC, MDD, ML, CP, DRP, RIV	500-1000	western NSW	strat ran	120 sites	1994	ongoing
Environmental Assessment monitoring SA	site-specific survey	Species diversity/ species at risk	fl/fa	mammal, bird, herp, invert, vascular plants	SA	STP	10-100	1 256 km2	ran	76 sites + 50 km transects	1989	ongoing
Barkly Wetlands surveys	Other F/F	spp assem	fl/fa	mammal, bird, herp, all vascular	NT	MGD	100-500	Barkly Wetlands	stratified random	36 sites aver 75m x 75m	1998	2000
Ecological studies												
Genetic diversity of Black speargrass, *Heteropogon contortus*.	genetic diversity	threat	fl	grasses	QLD	EIU	>1000	Dalyrimple Shire	Strat Sys & random	20 sites	1996	2000
Great Basalt Wall tree dynamics	repeated quantitative samples -plant dynamics	ecological processes	fl	tree	QLD	EIU	<10	interior Gt basalt wall	other	1 plot	1996	ongoing

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
Triancinia retroflexa research and monitoring	plant dynamics	ecological processes	fl	grasses, herbage, trees	QLD	BBN	<100	Bluegrass downs	systematic	2 sites, 60 plots in total	1997	2000
Boolathana grazing study	various	various	fl/fa	shrubs, herbs/forbs, invertebrates, reptiles	WA	CAR	2 x <10 km	1455 km^2	mostly plot-based	137 perm transects, many temp transects	1983	grazing trial 1994, veg. plots ongoing
Yeelirrie destocking study	plant dynamics	ecological processes	fl	woody plants (shrubs)	WA	MUR	<10 km	Yeerlirrie Station	plot based	4 permenat "flightlines"	1973	1982
Glenorn vegetation dynamics study	plant dynamics	ecological processes	fl	all vascular plants	WA	MUR	<100	Glenorn Station	plot based	9 permanent flightlines	1973	1975
Mileura Station	vegetation dynamics	ecological processes	fl	shrub/forbs	WA	MUR	100-500	2 820km2	other	60 x 30m diameter	1960	ongoing
<u>Exploited species</u>												
Kangaroo management programme	Broad-scale aerial survey	Polulation status	fa	mammal	NSW	BHC, MDD, ML, CP, DRP, RIV	500-1000	Western 3/4 NSW	systematic repeated annually	9 600 km transects	1985	ongoing
Annual aerial survey of kangaroos	Broad-scale aerial survey	Population status	fa	Mammal	WA	PIL, GAS, COO, ESP, MUR	500-1000	1 000 000km2	systematic repeated annually	333 000 km2	1981	ongoing
Annual monitoring of commercial macropod spp in Qld	Broad-scale aerial survey	Population status	fa	Mammal	QLD	MUL, BBS, MGD, GUP, CHC	>1000	49 600km2	systematic repeated annually	10 blocks 500km of transects	1980	ongoing
SA aerial survey for Kangaroos	Broad-scale aerial survey	Population status	fa	mammal, bird	SA	SA ibra's	500-1000	207 000 km2	systematic repeated annually	1.5% of the state	1978	ongoing
The Eastern Australia water bird survey	Broad-scale aerial survey	Species, populn & habitat status	fa	waterbirds	NSW, QLD, VIC	NSW, QLD, VIC	>1000	2 697 000km2	systematic repeated annually	1 500 X 10, 30km wide bands	1983	ongoing
Magpie Goose population monitoring	Broad-scale aerial survey	Population status	fa	bird	NT	TEC	100-500	N-W NT: Murgenella-Moyle rvr	systematic	16% of wetland area	1983	ongoing
Crocodile monitoring	Broad-scale survey	Population status	fa	herp	NT	TEC, PCA, DAB, VRD	100-500	Top end floodplains & waterways	systematic	7 rivier systems	1984	ongoing
Cycads	Site-based surveys	Population dynamics and status	fl	shrub	NT	TEC, PCA, VB, EUC, DAB	500-1000	Top end NT	other	32 sites	1995	1998
<u>Endangered Species</u>												
Black-footed Rock-wallaby monitoring in Cent Land Management Ass.	Ground-based qualititative survey	Species status regionally	fa	mammal	NT	SSD	100-500	Simpson-Stresleki Dunes	other	2 sites	1999	ongoing

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
Ptychosperma bleeseri monitoring	Ground-based quantitative survey	Species status and genetic diversity	fl	tree	NT	TEC	10-100	Top End	other	88 sites	1991	ongoing
Mulgara monitoring	Ground-based quantitative survey	Species and population status	fa	mammal, herp	NT	GSD	<10	transitional sand plains	systematic	10 sites	1997	ongoing
Great Desert Skink *Egernia kintorei*, Uluru	Ground-based quantitative survey	Species and population status	fa	herp	NT	GSD	10-100	Uluru-Kata Tjuta NP	systematic	12 x 400m trans	1997/8	ongoing
Mallee Fowl in the Anangu/Pitjantanjara land	Ground- based survey	Species and population status	fa	bird	SA	GVD, CR	100-500	1/5 of SA	other	8-10 sites	1995	ongoing
Marsupial moles in the Anangu/Pitjantanjara land	Ground-based survey	Species and population status	fa	mammal	SA	GVD, CR	10-100	NW corner SA	other	2 sites	1998	ongoing
Golden-shouldered parrot monitoring	Ground-based quantitative survey	Species and population status	fa	bird	QLD	CYP, GUP	>1000	240 km^2	systematic	several sites	1992	2002
Golden-shouldered parrot termite mound monitoring	Ground-based quantitative survey	Habitat condition	fa	bird	QLD	CYP, GUP	>1000	Dixie & Artemis stn	strat systematic	2 sites (150 mounds) + 300 on station	1993	ongoing
Ptilotis aristatus var. exilis monitoring	Ground-based quantitative survey	Species and population status	fl	annual (?)	NT	BRT	10-100	Mitchell grasslands	systematic	2km of transects, 20 quad x 200m2	1999	ongoing
Acacia latzii monitoring	Veg- con	spp	fl	tree	NT	FIN	10-100	Henbury station	other	2 exclosures, inside and out	1992	ongoing
<u>Parks and Reserves Monitoring</u>												
Uluru Fauna Surveys	repeated regional surveys	ecological processes	fl/fa	Mammal, bird, herp, invert, grass, all vascular	NT	GSD	100-500	uluru_kata-Tjuta NP	other	8 sites	1987	ongoing
Mimosa monitoring – Kakadu National Park	pest species	populn status and effects of control	fl	shrub	NT	TEC some PCA	100-500	Nth sectors Kakadu	Total inventory	160 sites	1989	ongoing

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
Mary River, grazing effects in seasonally-inundated vegetation	repeated local surveys	vegetation dynamics	fl	all vascular	NT	TEC	<10	Mary River	other - plot based	2 plots	1991	ongoing
Fire monitoring, Carnarvon Park	repeated local surveys	vegetation dynamics	fl	all vascular	QLD	BBS	10-100	Carnarvon NP	strat sys	20 sites	1995	ongoing
Indigenous protected Areas project	regional surveys	species status	fa	mammal, bird	WA	GD, GSD, CR, GVD	500-1000	250 000km2	other	2 sites (April 3-4 sites)	1994	ongoing
monitoring of vegetation changes on western Qld National Parks	repeated regional surveys	vegetation dynamics	fl	grasses, herbage, trees	QLD	ML, MGD	100-500	Currawinga, Maralay, Idalia & Welford NP	permanent plots		1994	ongoing
Fire monitoring Kakadu National Park	repeated regional surveys	vegetation dynamics – fire effects	fl	all vascular	NT	TEC, PCA	100-500	Kakadu NP	permanent plots stratified random placement	170 plots	1994	ongoing
SavMon Vegetation monitoring program for parks and reserves in north Queensland	repeated surveys of permanent sites	vegetation dynamics	fl	all vascular	Qld	north Queensland	1000	North Queensland Parks	permanent plots, stratified random placement	numerous and expanding	1999	ongoing
<u>Fire monitoring</u>												
Assessment of impact of fire regimes on fire-sensitive vegetation	repeated regionals surveys	vegetation dynamics	fl	Tree	WA	NK	10-100	Mt Hart - Kalumburu	other	270 sites	1999	2000
Fire Watch	description spatial and temporal distn of process	fire scar mapping	fl	all vascular	NT & WA	NT ibra's, PIL, GSD, DL, NK, CK, OVP	500-1000	NT & Nth WA	Total inventory	Remote sensing	1996	ongoing
Kimberley fire plots	repeated regional surveys	vegetation dynamics	fl	all vascular	WA	NK, CK, DL OVP, VBT	500-1000	The Kimberley	stratified systematic	100 quadrats	1995	ongoing
<u>Site-based studies</u>												
Fitzroy Valley Rangeland Management Initiative	broad-scale inventory	spp assembl, vegetation dynamics	fl/fa	All	WA	OVP, CK	500-100	0.0226km2	Total inventory	NA	2000	2003
Vegetation monitoring in the Mareeba vicinity	repeated local survey	vegetation dynamics	fl	tree, shrub, ground cover	QLD	EIU	10-100	Mareeba	other	4 x 500m2	1990	ongoing
The arid recovery project	repeated local survey	species assembl and grazing	fl/fa	mammal, herp, veg cover	SA	STP	10-100	60km2	stratified random	100 sites	1997	ongoing

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
Pilbara Mulga study	repeated regional survey	species responses to threat	fl/fa	all vascular plants, vertebrates, some invert	WA	PIL, GAS	500-1000	Mulga community	systematic	70 km of transects	1989	ongoing
Bradshaw field and training area biodiversity monitoring	repeated regional survey	spp assem	fl/fa	Mammal, bird, herp, invert, all vascular plants	NT	VBT	100-500	Bradshaw & adjacent stations	stratified random	80 plots	1998	ongoing
Aerial surveys of Anagu/Pitjantjantjara land	broad-scale aerial survey	spp assem	fa	large mammal	SA	CR, GVD	100-500	arid Nth-west SA	systematic	4 transects /degree block	1991	ongoing
Regeneration of Brigalow	repeated local survey	restoration – threat	fl	all vascular	QLD	BBS	<10	Brigalow research stn	stratified random	12 plots	1964	ongoing
Long-term change in brigalow country	repeated local survey	spp assem	fl	tree	QLD	BBS	100-500	Brigalow belt south	systematic	180 plots, 20 x 20m	late 1960's	ongoing
Bluebush monitoring, Barkly Tablelands	repeated local surveys	vegetation dynamics – grazing	fl	shrub	NT	MGD	10-100	Connell's lagoon, Miffiebah stn	other	2 paired plots	1989	ongoing
Barkly tableland vegetation monitoring	repeated regional surveys	vegetation dynamics – grazing	fl	all vascular	NT	MGD	100-500	Connell's lagoon, Lake Sylvester.	systematic	11 pairs of sites	1989	ongoing
Growth and survival of tea-tree (*Melaleuca viridiflora*)	repeated local surveys	plant dynamics and fire	fl	tree	QLD	CYP	>1000	Artemis Stn	stratified random	6 sites, 1000 trees	1993	ongoing
The Darling Riverine Plains Project	repeated regional surveys	spp assembl	fl/fa	mammal, bird, herp, all vascular plants	NSW	DRP	100-500	Darling Riverine floodplains	stratified systematic	100 sites (9 points/site)	2000	2001
Landscape Mapping												
Remote sensing of agricultural land cover change	repeated assessmt of RS imagery	land condition – vegetation cover	fl	all vascular	National	National	>1000	2 880 000 km2	Total inventory	Remote sensing	1990	1995
State-wide land cover and trees study (SLATS)	repeated assessmt of RS imagery	woody and other vegetation cover	fl	all vascular	QLD	QLD Ibra's	>1000	Queensland	Total inventory	Remote sensing	1991	ongoing
Resource assessment & monitoring system (RAMS)	repeated assessmt of RS imagery	woody and other vegetation cover	fl	all vascular	NSW	CHC, BHC, MUL, MDD, RIV, CP	500-1000	Western Div NSW	Total inventory	Remote sensing	1988	ongoing

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
<u>Management studies</u>												
Monitoring for management	repeated regional surveys	vegetation cover	fl	all vascular	QLD	Most Qld Ibra's	500-1000	Qld	systematic	30 plots	1999	ongoing
EPA vegetation monitoring	repeated regional surveys	vegetation cover in relation to fire	fl	tree	QLD	WT, EIU, DEU, BBN	500-1000	Hughenden-T'ville-Tully.	representative, random	50 sites + 90 trial sites	1996	ongoing
Ecological management of lake bed cropping	repeated local surveys	threat	fa	mammal, bird, herp, invert	NSW	MDD	500-1000	western divison	random	8 lake edges	1991	1997
Grazing exclosures	repeated local survey	vegetation dynamics – impacts of grazing	fl	grasses	QLD	EIU	100-500	Charters Towers area	random	7 exclosures	1986	ongoing
Aussie Grass	calibration of models	vegetation dynamics	fl	grass, tree, feral mammals	National (Qld)	Qld rangeland Ibra's	>1000	Qld pastoral areas	other	1998, 1619 obs/day	1991	ongoing
Coodardy grazing study	repeated regional surveys	perennial plant dynamics	fl	woody plants, perennial grasses	WA	MUR	<10	1655 km^2	plot based	61 permanent transects	variou s	ongoing
Exclosures and benchmarks	repeated local surveys	woody plant dynamics	fl	woody plants (shrubs)	WA	CAR, GAS, YAL, COO, MUR, NUL	<10	shrublands of WA	plot based	various	variou s	ongoing
<u>Ferals</u>												
Rabbits at Needlebush site	repeated quantitative surveys	population status and dynamics	fa	mammals	NT	FIN	10-100	calcareous grassland	systematic	40 km transects	1990	2000
Rabbit conrol in conservation reserves in western NSW	repeated quantitative surveys	population status and effect of control	fl/fa	Mammal, perennial plants, including woodies	NSW	MDD, DRP	100-500	Mungo, Kinchega, Nambinnie, Yachong	stratified random		2000	ongoing
Rabbit Calicivirus monitoring in Central Australia (RCV)	repeated quantitative surveys	population status and effects of control	fa	mammal, bird	NT, SA	NT, SA	100-500	Arid Cent Aust	other	8 sites	1997	1999
Large vertebrate surveys (chiefly ferals)	repeated broad-scale aerial surveys	population status and effect of control	fa	mammal	NT	NT Ibra's	>1000	NT	systematic	5 superblocks, bet100 000 to 400 000km2	1985	ongoing

Title	Type	Emphasis	Flora or fauna	Lifeform/Taxa	State	IBRA	Max extent (km)	Desc spatial scale	Sampling regime	Sample size	Start date	Finish date
Atlas Projects												
Atlas of Australian Birds	aggregation of systematic observns	spp assemb, bio-geography	fa	bird	National	All	>1000	National	other	100 000 bird lists	1977	1981
Bird of Prey Watch (BOP)	aggregation of range of observatns	spp assem and status	fa	bird	National	All	>1000	National	other	38 000 survey, 10 000 still to be entered	1996	2000
Australian Bird Count (ABC)	aggregation of systematic observatns	spp assemb, bio-geography	fa	bird	National	All	>1000	National	other	2 000 sites	1989	1995
Frog Watch	aggregation of range of observation	species status	fa	herp	National	All	>1000	Top End NT	other		1990	ongoing

In this paper we examine a sample of studies of different types performed and systematically recorded by different observers, but mostly funded by Government agencies. Details of some of the programs reviewed for this report are listed in Table 1. We use these projects to illustrate the uses to which this information has or might be put to reveal spatial or temporal patterns in the distribution and relative abundance of fauna and flora. Our purpose is to explore the feasibility of incorporating elements of these data sources in a national framework for monitoring biological diversity in rangelands.

We do not represent this analysis as comprehensive. There are undoubtedly many thousands of individual studies that could conceivably be used as part of a monitoring program if a framework and processes were established to locate and organise them. However, we regard the sample we have gathered as sufficiently representative to provide a reasonably comprehensive overview of the options available. Moreover, the sample comprises many studies to which ongoing access is most likely.

The classes of information we consider can be loosely grouped under a number of headings.

<u>Taxonomic and reference collections</u>

- Museums
- Herbaria
- Other collections backed with voucher specimens

<u>Wildlife inventory</u> (flora and fauna surveys)

- performed explicitly to fill gaps in survey coverage
- performed as elements of studies of particular organisms, communities or sites
- performed to meet statutory requirements (e.g. preparation of environmental impact statements)

<u>Ecological studies</u>

- studies of the ecology of particular organisms or communities that provide data on the distribution or abundance of one or more species or communities
- studies of processes influencing the capacity of rangelands to support biological diversity

<u>Exploited Species Monitoring</u>

- programs to regularly monitor the status of populations of exploited species

- observations of an exploited species, incidental observations of other species, or description of habitat features during such surveys

Pest Species Monitoring

- programs to monitor exotic plants and animals that are causing detriment to production and biodiversity values

Endangered Species Monitoring

- programs to monitor the status of species of conservation concern

Parks and Reserves Monitoring Schemes

- programs to monitor the status of biodiversity on protected lands
- programs to study the influence of threatening processes on lands subject to fewer forms of disturbance (benchmarks)

Atlas Schemes

- studies that aggregate information to provide periodic assessments of the distribution of a range of organisms
- national or other large-scale flora and fauna surveys explicitly designed to provide statements of distribution
- associated databases

Landscape Mapping

- studies undertaken to map landscape features, especially vegetation types that explicitly or incidentally incorporate information on elements of biological diversity
- land clearing
- land condition
- libraries of associated paper or digital images or drawings

Landscape Processes

- studies that measure indicators of landscape condition that could be used to index threatening processes (e.g. landscape function analysis, water quality)

Biogeographic studies

- identifying environmental and socio-economic correlates of geographical variation in biodiversity status and evidence of change.

Opportunites and Options

(1) Taxonomic or reference collections

All State and Territory Governments support institutions - museums and herbaria – that are charged with a responsibility to catalogue the diversity of animals and plants inhabiting their jurisdictions, and interpret biological variation and its significance for the public. Many of these institutions also collect specimens from other jurisdictions. The collections they maintain are of critical importance. Voucher specimens allow curators and others to check and update understanding of species distribution and geographical variation, as taxonomic understanding is improved and revisions occur. Many museums and herbaria now maintain tissue collections stored in ways that will permit their future use in molecular taxonomy and which may also contribute to better understanding of levels of genetic variation within and between populations. Efforts are sometimes made to ensure that these collections are spatially comprehensive. They are usually geo-referenced reasonably accurately, although there may be much ambiguity about the oldest records.

Thus the records of museums, herbaria and similar holdings in a few other institutions provide the most robust record of the past and present distribution of the nation's unique biological heritage. Indeed, they represent the fundamental underpinning for all monitoring schemes for biological diversity. They have been used to identify declining and threatened species (Burgmann et al. 1995; McCarthy 1998; Shaffer et al. 1998) and to provide biodiversity assessments of regions or sites, including analyses of invertebrate diversity (Ponder 1999; Stanisic 1999) which is often neglected.

It does not follow that there is much to be gained from active incorporation of museum or herbarium data in a formal structure for ongoing monitoring of rangeland biodiversity. They provide little or no information on relative abundance. But the most significant limitation is that collections are not comprehensively updated with a frequency that contributes usefully to regular monitoring. Taxonomic revisions and associated collection activity will often be idiosyncratically driven by individual interests in particular taxa, rather than having a geographic focus or temporal predictability. Many collections, especially of invertebrates, remain poorly catalogued. Inadequate funding means that many records of all types have yet to experience the digital revolution and remain in notebooks and on cards. The primary utility of these collections and their associated records is to firmly establish the historical distribution of species for comparison with more contemporary descriptions garnered from other sources.

However, it is desirable that those involved in one-off or regular surveys of plants or animals (including pastoral or biodiversity monitoring) establish good working relationships with these institutions so that voucher specimens can be lodged regularly and their original identifications verified or updated in the event of taxonomic change.

(2) Wildlife inventory (flora and fauna survey)

Many jurisdictions have established programs, conducted primarily by their conservation agencies, to inventory wildlife (plant and animal species) and describe biological communities and the environments that support them. Motivations vary, but an important driver of this activity is to provide the improved understanding of geographical patterns of biological diversity needed to design effective (comprehensive, adequate, and representative) reserve systems. An improved national reserve system is a key objective of the Intergovernmental Agreement on the Environment, endorsed by parties to the Convention on Biological Diversity, and incorporated in many of the national strategies endorsed by all State,Territory, and Federal Governments. In addition, State and Territory Governments most often require biological survey of sites as an element of their Environmental Impact Assessment processes. Because large numbers of these surveys are conducted and are formally reported, they constitute a potentially valuable source of information and some jurisdictions have made arrangements to capture these data systematically.

How might this large investment be harnessed to contribute to a national biodiversity monitoring program?

Predictive models

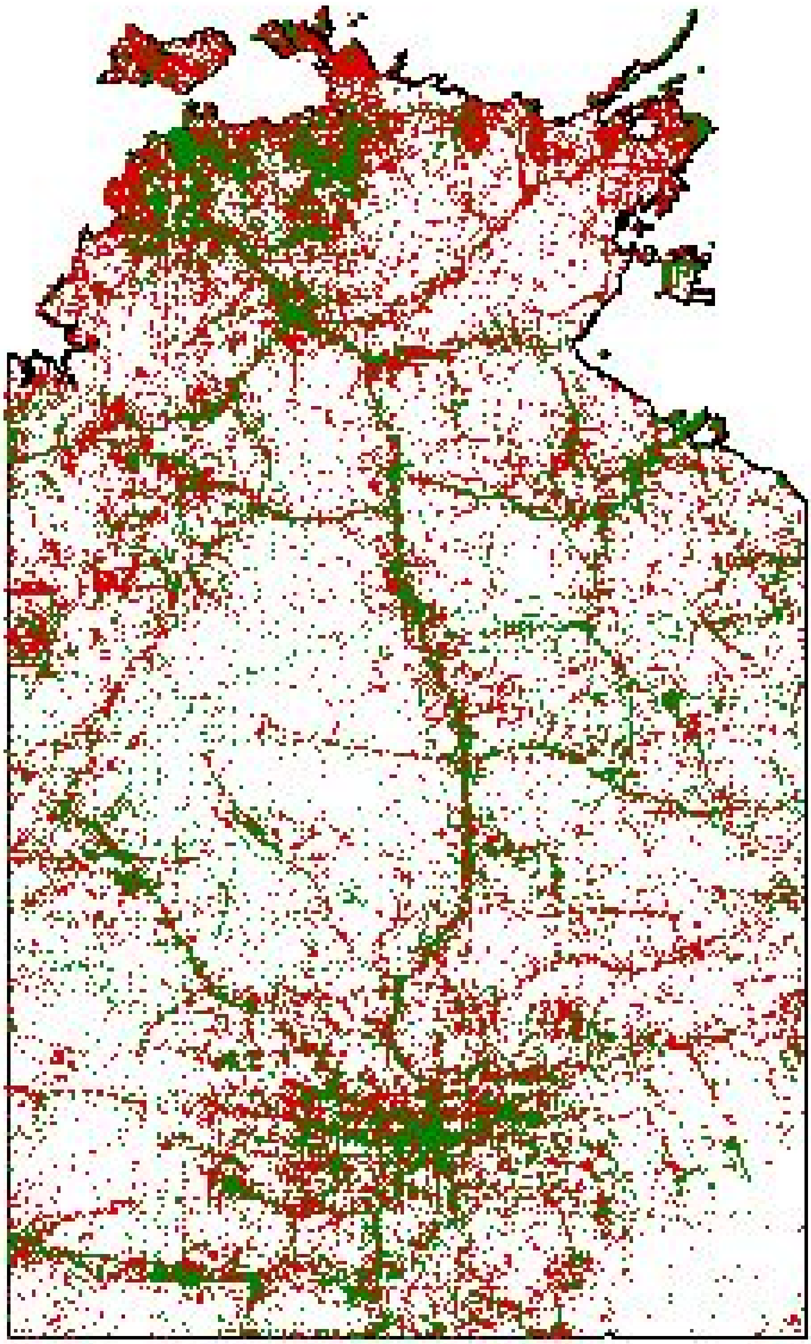
Tools for developing models to predict the distribution of species from features of the environments they inhabit are improving rapidly (e.g. Stoms et al. 1992; Buckland and Elston 1995; Tucker et al. 1997). The capacity of deductive or inductive models to provide predictions of the distribution and relative abundance of organisms is a potentially important option for the design of a framework for monitoring biological diversity. At least in theory, it should be possible to predict the geographical range of organisms from good knowledge of their physiology and ecology and so build up a catalogue of the taxa expected to be present in a given area of known environmental character. Comparison with what is actually present could identify “missing” species. Analysis of the details of the ecology of the absentees could in turn indicate those aspects of land use practice most likely to have caused their displacement and which therefore require a management response.

In practice, the physiology, habitat preferences, types of interactions with other species and many other relevant factors are rarely known in sufficient detail to derive robust “rules” to characterise the places that are capable of supporting specified taxa. Even were the biological knowledge good enough, most parts of the rangeland landscape and environment have not themselves been described (characterised and mapped) in sufficient detail to provide for comprehensive extrapolation for most species.

Similar basic problems confront the use of inferential statistics to derive empirical models relating observed distributions to features of habitats measured at sites of observation. At least in theory, such models could be used to explore relationships among faunal and floral assemblages and land use or land management practice, after other environmental variation had been accounted for. Problems could be inferred through statistical relationships between such practice and presence/absence of particular species, shifts in floristic or faunistic composition, or variation in relative densities. Alternatively, statistical models may be used to identify individual sites that would be predicted, on the basis of environmental features, to have a high probability of supporting a particular species or assemblage. Focusing further investigations on sites that show marked differences between predictions and measured biodiversity indices might provide pointers to environmental change that is particularly strongly associated with reduction in biodiversity values.

Whilst such empirical models can be derived without detailed knowledge of the biology of individual species, there are many practical problems. Useful inferential models are dependent on relatively comprehensive distributional data. Gaps in geographical or environmental coverage can produce spurious statistical models that generate unreliable predictions. We illustrate the geographical bias in observations of all vertebrate and vascular plants taxa for the Northern Territory in Figure 1. Despite considerable effort and expenditure, over the last decade or two, to fill gaps, plots of the density of observations still mimic road maps.

Figure 1: A plot of the sites at which the Parks and Wildlife Commission of the Northern Territory has recorded fauna (red) and flora (green). The linear arrangement of many observations reflects the bias of sampling to the vicinity of roads or tracks. Areas of greater density are focussed on the major centres of Darwin, Alice Springs, Katherine and East Arnhem Land and in parks and reserves.



Often the habitats used by the species of interest will have been described relatively crudely or, if the habitat information at observation points is more detailed, there will be no mapping at equivalent detail to permit extrapolation to the wider landscape. Even small scale (>1:1,000,000) vegetation maps vary in classification schemes across the rangeland's jurisdictional boundaries. The Audit is seeking to confront some of these difficulties in other elements of its program, but even newer products will be of relatively coarse resolution and obscure within broad classifications much of the environmental variation that is important to individual species of fauna or flora.

These core problems will not be overcome rapidly, because costs of filling gaps and providing fine scale environmental mapping are prohibitively high. Inadequacy of information and the associated risk of poor conservation decisions is well recognised (e.g. Conroy and Noon 1996), even in the world's richest nation (USA) with its highly developed infrastructure and relatively dense human populations. Moreover, even the most intensive surveys are unlikely to generate good models for rare or declining species that are sparsely distributed through apparently favourable landscapes. Commoner species whose distribution may have been influenced by historical events may also be difficult to model.

If the historical record is poor, as it is for many vertebrate animals and most invertebrate taxa, then resultant statistical models may be not be readily interpretable, because potential explanatory variables may be confounded. For example, the most fertile sites on good soils in areas of low topographic relief may have also been subject to the most intensive and long-standing agricultural use, so it will be difficult to statistically disentangle this suite of variables. Models derived from predominantly contemporary records may be so biased by anthropogenic artifacts as to do no more than predict that the species of interest should occur where we have recent records of their occurrence. It will be difficult to distinguish these trivial statistical outcomes from those having a more fundamental functional basis and hence having relevance to management responses. Caughley and Gunn (1996) draw attention to the risks of basing management actions on apparent habitat relations that represent the conditions under which fugitive populations hang on, rather than the conditions which would favour their strong and sustainable re-establishment.

Even where the data are at least in theory available and there are no insurmountable statistical problems, employing statistical models for national or sub-national analyses that incorporate potential surrogates for adverse processes (e.g. land use intensity) remains problematic. It is presently extremely difficult to get relevant integrated land use data from the States and Territory. Here the work of the Audit in generating new syntheses (Rangeland Monitoring Work Plan Projects 1 and 2) will open up some opportunities to demonstrate associations among land use variables and change in biodiversity status. Whilst these models may not have immediate management application, they may serve to direct the evolution of a robust biodiversity monitoring framework.

We conclude that in the short-to-mid-term, model-based approaches will be limited in application to the extremes of the options that the Audit may wish to consider for a national framework: either (i) crude assessments at very large spatial scales, based on coarse national-scale descriptions of environmental variation and crude descriptors of biological diversity; or (ii) finer-scale and more accessible but idiosyncratically focused assessments based on unusually well-known taxa living in unusually well-characterised landscapes.

Repeated biological surveys

A more direct approach may have greater potential, at least in the short term. Many recent inventories and a few extending back several decades have had a clear geographical focus and methodology has been clearly described, so that they are least potentially repeatable. An example of the power of repeated surveys to reveal important trends in the distribution of fauna has been given in other components of this report (Background Paper 1). There have been some particularly comprehensive "landmark" surveys that would be usefully included in a formal "Re-survey Program" to directly examine change at specific sites, or larger scale (regional) comparisons at (say) the catchment scale in which the location of individual sites is less well known but the survey boundaries, methodology, seasonal timing and total effort are well understood.

(3) Ecological Studies

Ecology is the study of the distribution and abundance of organisms and influences on those parameters (Krebs 1978). Monitoring as we have defined it is also about the distribution and relative abundance of organisms and, in particular, change in those parameters over time. Clearly there is considerable scope for ecological studies of individual species or assemblages of species to contribute information relevant to monitoring the status of biological diversity. The obvious difficulty is that such studies are most often constrained in both space and time and the range of taxa considered. One or a few sites may be studied over a period of several years, but it is rare for studies to be designed to continue indefinitely. Moreover, many studies are designed to answer specific questions: published accounts often provide a synthetic view that does not include the sort of detail that might contribute strongly to *post hoc* quantitative assessments of change. Methods of determining distribution and abundance may vary enormously, and it will often be difficult to compare outcomes from studies that report indices of abundance or probabilities of occurrence based on different methodologies.

However, the presence of the organisms that are the subject of the study at abundances sufficient to permit quantitative study will be the absolute minimum information extractable from any competently reported study. Thus records of such studies can complement point or other records of fauna or flora occurrence, and contribute to the elucidation of spatial and temporal patterns. To extract the minimum benefits for use in a monitoring framework, an accurate geo-reference and accurate and comprehensive description of methods are essential data. In some other cases involving reporting of local abundances, methods will have been specified in sufficient detail to permit repetition of the original survey in a manner analogous to the repetition of the landmarks surveys (above).

Moreover, whilst spatial and temporal constraints and variable methodologies limit the extent to which studies can be directly compared with each other across space or time, their sheer number may compensate to some degree, at least in some ecosystems or some taxonomic groups. Under prevailing circumstances, capturing those potential benefits and assembling disparate studies for some form of meta-analysis (e.g. Arnquist and Webster 1995; Bender et al. 1997) may involve a laborious collation of relevant studies, careful filtering to identify the type of information that can be robustly extracted, and perhaps contact with the original researchers to clarify ambiguities.

If such studies are to be meaningfully incorporated in a national framework in a better than *ad hoc* way, it will be necessary to simplify access and facilitate the filtering process. This is perhaps best achieved by seeking the cooperation of institutions and individuals involved in ecological studies to enter details of their study to a metadata facility maintained by a Federal resource management agency. Researchers will need incentives to use such a facility. Some of those incentives will flow directly from the existence of such a facility once established, and arise in the form of better recognition of individual expertise and improved options for collaboration to extend the reach of site-bound studies. Publishers of relevant scientific journals in Australia could require submissions to be accompanied by details of lodgment of metadata. Professional societies, especially those directly associated with conservation or other environmental or natural resource management could encourage their members to use such facilities. Universities and funding agencies (especially Federal and State Government bodies) could make it a condition of support that relevant metadata are lodged at a specified site.

A number of related steps have already been taken under the Australian Spatial Data Directory (ASDD) and Australian Spatial Data Infrastructure initiatives established under the direction of the Australian and New Zealand Land Information Council (ANZLIC). But the issues and utility of central data directories extend well beyond data relating to thematic or other mapping. Provided information can be placed in space and time at a specifiable resolution, then it is potentially relevant to the long term monitoring of biological and other phenomena, regardless of the software used for its storage. The States and Territories appear to have embraced the notion that much information about natural resources can and should be included in metadata directories and require that their staff enter their important datasets to such directories. So far as we are aware, the Universities and funding bodies such as the Australian Research Council have made no steps in this direction.

We interpret the current emphasis on the explicitly spatial as a byproduct of the recent rapid development of geographic information systems and an associated recognition of the extraordinary costs of generating, storing and interpreting maps that have been developed to different standards without proper concern for the capability to extrapolate and integrate across larger areas. In other disciplines, coherence of data collection, classification and collation mechanisms has been encouraged by the role of the Australian Bureau of Statistics (ABS) and the importance of the data they manage to bodies like the Grants Commission, which make recommendations about grants of Commonwealth funds to the States. Independent of the various coercive powers that the ABS may choose to exercise, jurisdictions that fail to comply and to position themselves to make their local perspectives and insights clear, may find themselves financially disadvantaged.

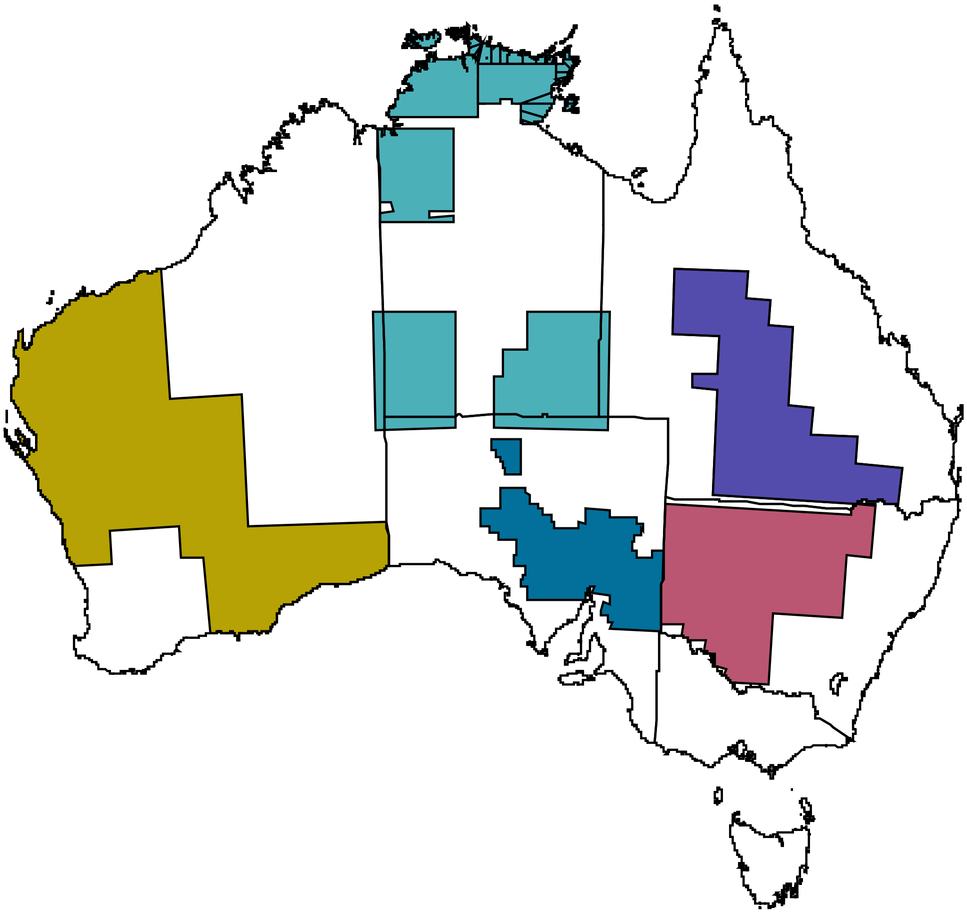
But a failure of coherence of statistics and standards of data collation regarding natural systems and their components currently carry no immediate financial or legal penalties (although the associated long term penalties for poor resource management and resource use planning may be severe). It will perhaps require an inclusion of environmental assets and values in the national accounts before systems of data management become sufficiently coherent to permit comprehensive inclusion of all relevant data in a monitoring framework for the rangelands, or other parts of the nation.

Nonetheless, we recommend that in the interim, the Audit explore options for establishment and ongoing maintenance of a metadata facility for biodiversity research in the rangelands. From the outset, those metadata will require some filtering facility to ensure that the system is not swamped by irrelevant detail.

(4) Exploited native species monitoring

All Australian jurisdictions require that native species subject to commercial use be monitored to determine the impact of that use or the capacity of populations to sustain ongoing harvest. The most significant examples in the rangelands involve the monitoring of large macropods (kangaroos and wallabies) (e.g. Caughley et al. 1977; Cairns et al. 1991; Southwell et al. 1997). Monitoring programs, mostly based on aerial survey, vary in their frequency and extent, but are common over large areas of South Australia, Western Australia, New South Wales and Queensland (Figure 2). It is ironic that the most coherent and scientifically robust programs for monitoring Australian fauna derive from perceptions of over-abundance and pest problems (below) rather than a desire to regularly review the conservation status of these Australian icons.

Figure 2: Areas in Australia surveyed from the air to monitor the distribution and abundance of large macropods (all sites except those falling mostly within the Northern Territory boundary) and feral ungulates (in grey-blue for Northern Territory).



However, they do demonstrate that with adequate incentives, impressive wildlife monitoring systems can be built and attract ongoing support from a range of interests. Similar examples involving different taxa include Magpie Goose *Anseranas semipalmata* monitoring programs in the Northern Territory and waterbird counts along the eastern seaboard (Braithwaite et al. 1985a, 1985b, 1986; Bayliss and Yeomans 1990; Kingsford et al. 1990, 1991, 1992, 1999).

These surveys share some important features that render them particularly suitable candidates for incorporation in a framework for monitoring biological diversity in rangelands:

- systematic placement of sampling units so that patterns of distribution and abundance can be related to spatial patterns of landscape change
- repetition of surveys at regular intervals to standardised methods so that long term trends can be systematically and powerfully explored
- well-developed processes for analysis and presentation of data in forms that are accessible to a wide audience
- actual (e.g. Caughley et al. 1980) or potential inclusion of additional (unexploited) species in counts, extending the relevance of the surveys to biodiversity monitoring.

Monitoring systems for other fauna, especially those that are not amenable to aerial counts, are mostly less compatible in terms of a capacity to make comparisons across taxa or landscapes. Nonetheless, they share another important attribute: most exploited species are the subject of formal management programs, often approved at the Ministerial level or above, that require monitoring of populations at specified intervals. They thus have considerable credibility and endurance within bureaucratic systems, increasing the prospect that they will continue over long periods.

All management programs for native species approved by the Federal Government require a monitoring program and regular reports to the Biodiversity Group of Environment Australia. Export of products from native species is conditional on Federally-endorsed management plans, so most State and Territory programs also have Federal approval. They are also important because they track trends in the condition of important components of the fauna (macropods) that are especially significant to the Australian public.

These surveys are already used to provide information on large and conspicuous native fauna such as emus (Caughley and Grice 1982) that are not the principal subject of the monitoring program, but can be recorded without compromising standards in regard to the target species. Much unpublished and unanalysed data that could be potentially useful for rangeland monitoring (e.g. of bustard, Brolga or Jabiru; or of sign like burrows of wombats and rabbit warrens) resides in aerial survey databases (P. Whitehead, unpublished data). The value of such “archival” material may be compromised by undocumented and idiosyncratically variable ways of recording these collateral variables, but their usefulness may be realised better in future surveys if the value was formally acknowledged.

Populations of large exotics like feral mammals (particularly horse, donkey, cattle, water buffalo, camel, goat; but less successfully, pigs) (Bayliss and Yeomans 1989) can also be sampled. Aerial surveys might provide independent data on density of domestic stock, though management related variations in spatial patterns of distribution may cause problems of interpretation.

Aggregation and meta-analysis is likely to increase the quality of interpretation of all of these data and their relevance to assessment of the status of biological diversity in the rangelands. For example, comparisons across geographically separated sites may provide insights to climatically driven change that may not be discernable at smaller spatial scales. It will also increase the prospects for making systematic use of observations of fauna additional to the main target species. Observations of spatial shifts in active rabbit warrens may pick up patterns in recovery from control measures (e.g. rabbit calicivirus) in isolated regions that would be difficult or expensive to monitor from the ground.

The Biodiversity Unit of Environment Australia already receives the outputs from these programs as an element of its responsibilities as the national authority for the Convention on International Trade in Endangered Species of Flora and Fauna (CITES). Lodging the data from which these reports are derived to permit integrated analysis would appear to represent a relatively simple step.

(5) Pest Species Monitoring

Pest species of plants or animals may constitute threats to both agricultural values and biological diversity. A number of jurisdictions carry out surveys of the distribution and abundance of these organisms to plan control and to assess the effectiveness of control. In other cases databases are maintained to aggregate *ad hoc* or systematic reports of their presence. These databases can provide evidence of expansion or contraction of range. However, they are rarely linked explicitly to information on biodiversity values, or even to pasture monitoring programs.

These data may also make an important contribution to an effective biodiversity monitoring framework not just because pests may present a particular threat to some elements of biological diversity, but because they may also provide an overview of those systems that are particularly susceptible to invasion. This knowledge in turn may be used to determine priorities and focus for better targeted monitoring systems and allocation of effort.

It is desirable that accessibility (and inter-jurisdictional collation) of these data is greatly improved, and that relevant observations also be routinely extracted from other surveys (e.g. those for kangaroos). This need is likely to best be met through a central metadata and meta-analysis capability, similar to that proposed for exploited species. The Bureau of Rural Sciences has performed a similar role in the past.

(6) Endangered species monitoring

Endangered species lie at the other end of the spectrum from the pests and most exploited species. They are so rare that there are concerns about their ultimate disappearance from large parts of the landscape, or total extinction. Substantial resources are often devoted to monitor those species that are the subject of recovery plans designed with the intent to restore populations to viability. Monitoring provides the means to assess the success of the recovery plans.

Monitoring programs for endangered species often differ markedly from those for more abundant species. They tend to be:

- spatially constrained, often to a few sites that continue to support viable or potentially viable populations and are the sites of intensive management activity
- very specifically structured to optimise probability of detecting rare organisms, and often very intensive in terms of effort (and hence cost) per unit area
- unlikely to be adaptable to increase the range of organisms included in counts.

But they do share the virtues of programs for exploited species in having strong institutional support and endurance. Moreover, they involve the very species that the general public might reasonably expect monitoring programs to inform them about: those already affected by prevailing management practice and requiring urgent management responses.

However, there is a conundrum here in strong institutional focus on either extreme of a spectrum of relative abundances. The highly abundant exploited or pest species clearly do not require ongoing management intervention to persist in the landscape because they are demonstrably coping well with prevailing rangeland management practice. Temporary reduction in levels of exploitation might be all that is needed to correct problems likely to emerge in the short to medium term. On the other hand, endangered species have usually been the subject of intense investigation and the management responses needed to support them are often clear and highly localised in their implementation and impacts on production. What of those species that have yet to be formally assigned the status of the maimed, but nonetheless show some evidence of decline over large areas or are at risk of becoming new victims unless processes affecting them are arrested?

Any national monitoring system for the rangelands or any other part of the nation must be capable of recognising the need for action and suggesting pre-emptive management responses in respect of this large (Franklin 1999) and growing (Reid and Fleming 1993; Woinarski 1999) segment of the nation’s biological diversity. No system could be considered credible that failed to reveal such trends and suggest responses before the processes leading to endangerment were entrenched. Providing effective warning signals is an important consideration in the design of an operationally plausible national framework.

Presently there are no explicit arrangements to bring details of Endangered Species plans and the monitoring outcomes together at large spatial scales. However, clearly some form of meta-analysis (e.g. Bender et al. 1998) has the potential to increase confidence in the interpretation of trends for individual species. For example, analyses by foraging guild (e.g. Franklin 1999) or other relevant groupings (Smith and Quin 1996) may more clearly establish links with putative threatening processes, so that the case for corrective action may be more strongly made. This is a potentially important capability for the rangelands in particular, because so many extinction events have occurred in the rangelands and a wave of further declines appears to be underway.

Arrangements should be made to facilitate meta-analysis of trends in status of endangered species in the rangelands and their responses to management, especially if these species are recognised as the "vanguard" of a large group of species follow the same paths. Subject to the nature of the framework ultimately adopted, this work could be performed by the Biodiversity Group of Environment Australia or a group specifically established to maintain the rangelands framework.

(7) Parks and Reserves Monitoring Programs

Monitoring programs on Parks and Reserves located within the rangelands provide a potentially useful complement to work done on grazed lands. They can provide some of the "controls" or contrasts needed for more robust interpretation of trends revealed by pastoral monitoring schemes (Background Paper 2). Sadly, the quality of monitoring on parks is often poor (http://www.biodiversity.environment.gov.au/protecte/anzecc/reports/bpprof-frame.htm), despite the formal recognition of the primary role of parks being maintenance of biological diversity. All State and Territory Conservation agencies have recognised the need for improved performance and are actively developing programs, in part through relevant working groups established under the ANZECC Ministerial Council.

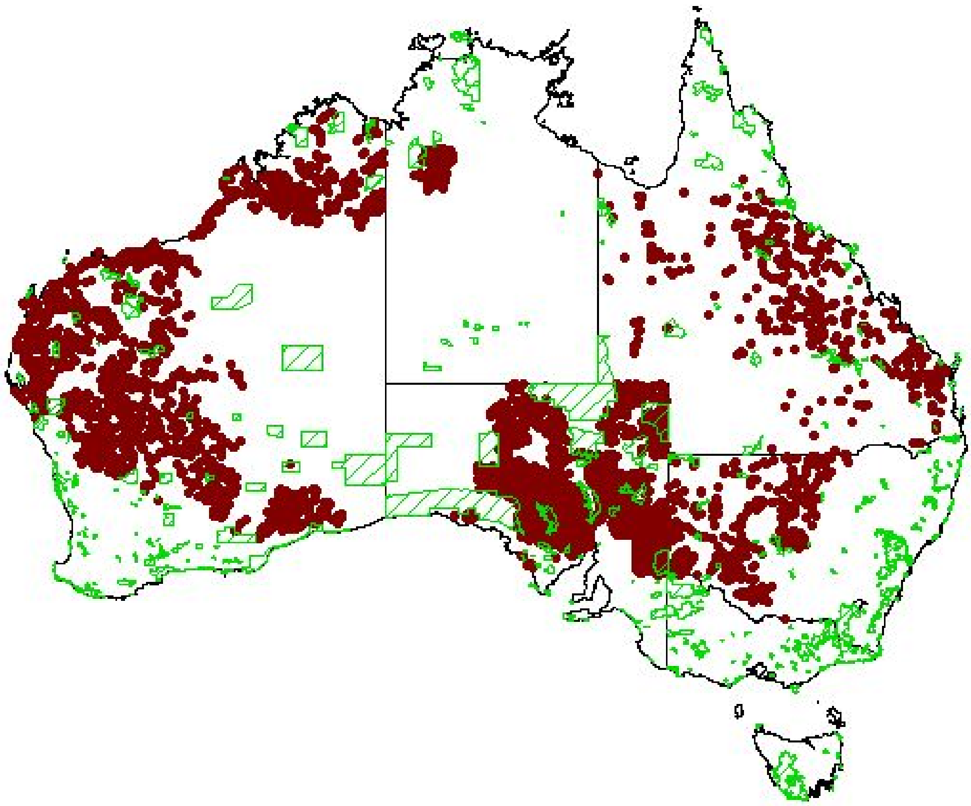
There are consequently few on-Park programs that provide the quality and continuity of sampling that could form a base for ongoing programs and contribute positively to a rangeland monitoring program. Some of the exceptions are:

- *Mimosa pigra* and fire monitoring in Kakadu National Park
- Magpie Goose monitoring in Kakadu National Park
- Extension of vegetation monitoring arrangements similar to TRAPS (see Background Paper 2) pastoral monitoring plots to a number of Queensland parks (G. Crowley, pers. comm.).

Aside from the South Australian pastoral monitoring plots in some reserve areas and the recent introduction of vegetation monitoring initiatives similar to TRAPS to some Queensland Parks (Table 1), there are few explicit links between methods used on Parks and Reserves and land used for grazing. These recent initiatives are unproven because the Queensland work has only recently begun, and the longer-established plots in South

Australia have never been revisited for re-assessment. The spatial segregation of pastoral monitoring sites and the reserve systems is illustrated in Figure 3.

Figure 3: Distribution of pastoral monitoring sites (red) in relation to parks and reserves (green hatching) in the rangelands of Australia. Both the biased geographic coverage of the monitoring sites and their scrupulous avoidance of parks and reserves are obvious. The distribution of parks and reserves is also shows strong geographic and environmental biases. Relying for maintenance of biodiversity on the contemporary protected lands system is clearly impracticable, emphasising the importance of extending monitoring of the impacts of pastoralism beyond production to include biodiversity values.



Failure to exploit variation in the nature and intensity of land use in the design of rangeland monitoring schemes is a fundamental flaw, whether the focus is on production or biodiversity and other amenity values. Clearly it is desirable that schemes for biodiversity monitoring established as feasible and robust on reserved lands should be repeated on pastoral lands. They can then provide a measure of the performance of reserves in meeting biodiversity objectives, especially those objectives that are thought difficult to achieve on grazed lands. Similarly, establishing schemes to monitor important biodiversity values on grazed lands without repeating them on reserves would appear to disable or drastically weaken interpretability. Pastoralists often see Parks and Reserves as the source of pest animals and plants: the value of linked pest monitoring programs for both interests is obvious. The Audit has recognised that its monitoring programs need to be applicable on grazed and ungrazed occupied lands, conservation land and unassigned lands (Rangelands Monitoring Work Plan).

It is especially important that steps be taken to achieve a greater symmetry in the design and implementation of monitoring programs so that they can be effectively applied on both production and reserved land. The best means of achieving this using existing infastructure would appear to be through relevant Ministerial Councils, but outcomes from such approaches have often been trivial and slow to emerge. It may be more effective for the Federal Government to invest in processes to bring the relevant agencies together to design integrated programs, as has been done successfully – albeit slowly - in a number of areas, including framing of the Interim Biogeographic Regionalisation of Australia (Thackway and Cresswell 1996).

(8) Atlas schemes

A number of institutions and individuals provide periodic statements of the distribution of individual species of plants and animals over large spatial scales. Examples include State-based or larger-scale atlases of mammals (e.g. Churchill 1998), birds (Blakers et al. 1984), reptiles (Longmore 1986; Horner 1992), frogs (Tyler and Davies 1986), vascular plants (Liddle et al. 1994), or wider slections of fauna (Ingram and Raven 1991). The way in which these collections source and package information varies: often they present points at which the species of interest has been reported, or synthetic representations of the limits of distribution at various resolutions. Sometimes they may be confined entirely to Museum or Herbarium records (see (1) above).

Perhaps the best example of this class of biodiversity synthesis is the Atlas of Australian Birds, produced in 1984 by the RAOU (now Birds Australia). The skills of 3000 volunteers were marshalled over 5 years to provide records of birds across the whole of the nation. Others collated historical records and added them to a large database. In addition to the printed output (Blakers et al. 1984), the atlas was supported by a well-organised computer database, which has provided opportunities for a number of workers to use the information for analyses relevant to conservation (e.g. Whitehead et al. 1992; Reid and Fleming 1993; Franklin 1999; Franklin and Woinarski 2000). Overseas, well-established atlas schemes for birds have permitted a number of innovative analyses for conservation planning at spatial scales so large that no other feasible survey methodology existed (Robbins et al. 1989; Osborne 1992; Harrison and Martinez 1995; Hogmander 1995; Robertson et al. 1995). Connors et al. (1996) used atlas data as well as other observations to undertake their analysis of the status of biodiversity in all of the Northern Territory's bioregions.

Burbidge et al. (1988) showed that other observations from skilled observers, of a type often dismissed as "anecdotal", can provide powerful insights if properly organised and cross-validated. Their experience suggests that a well-organised system of reporting by members of Aboriginal communities in remote Australia may provide better and more cost-effective warning of change in fauna distribution than many more elaborate and "rigorous" monitoring schemes based on infrequent visits. It is sobering to recognise that there is presently no monitoring program in place of a reach and quality that would be capable of revealing the slide to extinction of the arid zone mammals were those declines to be repeated today.

The Birds Australia Atlas is being re-activated now with support from Natural Heritage Trust funding. This support appears to have been conditional on a slightly different emphasis and methodology, to enable observations to be used in assessments of the local status of bird communities in restored landscapes. This change, emphasising relatively short fixed time observations, has been criticised on the grounds that it will tend to bias observations to more common, widespread or highly conspicuous species, and hence render comparisons with the earlier Atlas questionable. Franklin (1999b) argues that important assessments of the type he made (Franklin 1999a), based on reporting rates, will now be impossible. Because records will be biased to short censuses, apparent shifts in reporting rates may be attributable to variable detection rates based on behaviour or appearance, rather than underlying changes in distribution and abundance. The unlimited time search process adopted for the previous atlas are likely to have been less sensitive to this source of variation. Proponents of the new approach argue that comparisons between this second Atlas and all future versions will be more precise than had the original methodology been maintained.

Regardless of the merits of these arguments, the debate illustrates the caution needed in applying data gathered for specific purposes, to long-term monitoring the status of elements of biological diversity. If the robustness of reporting systems is questioned for conspicuous organisms like birds, which attract wide public interest and are reported through well-developed arrangements, then the difficulties facing other segments of the fauna are placed in stark relief. The difficulties inherent in any monitoring program are exaggerated in the Australian rangelands by the extreme variability of climate and hence environmental conditions and the (presently) unpredictable responses of a highly vagile biota. It is doubly important that all possible efforts be made to reduce or eliminate sampling noise originating in variable methodologies.

It will therefore be important that agencies and individuals concerned with the sustainability of rangeland use develop good networks with conservation agencies so that they are aware of Atlas or similar projects, position themselves to influence the manner in which they are conducted and to make best use of the resultant data and syntheses.

(9) Landscape mapping

The definition of biological diversity given in relevant legislation and adopted for this report encompasses assemblages, communities and ecosystems (Main Report). Different incarnations of these ill-defined entities are available in maps showing abiotic and biotic features of rangeland landscapes in various combinations.

Vegetation

Vegetation maps, being at least partly based on classification of mapping units derived from floristics (plant species), are perhaps most easily connected with the notion of biodiversity monitoring. However, all environmental mapping units – even at the largest scales - represent simplified abstractions of biological diversity, and the extent to which they can be used to index the status of individual species or aggregations of species remains an open and complex question (Kirkpatrick and Brown 1994; Conroy and Noon 1996). The effectiveness of such surrogates depends not only on the details of their derivation (Woinarski and Braithwaite 1993), but also on understanding of the influence of the size and configuration of the units, their individual condition, their relationship to other units and the landscape context more generally. Indeed, it is these features of landscape structure and condition that may be used to index processes (e.g. fragmentation of wildlife habitats) that affect their capacity to support biological diversity (Hansen et al. 1993; Fahrig and Merriam 1994).

There is currently no national vegetation map at a scale and resolution that could conceivably be used as a surrogate for biological diversity except at the crudest of scales. The Tropical Savannas CRC has supported preparation of a 1:1,000,000 scale vegetation map for northern Australia, which should become available during 2000. The Audit is seeking to develop other approaches to achieving consistent national coverage (notably through the National Vegetation Information System - NVIS), including assessments of landscape health, but these will become available too late to contribute to our analyses of their potential utility as an element of a monitoring framework.

Land Cover Change

All Australian jurisdictions are also engaged in mapping changes in coverage of woody vegetation, predominantly in an effort to determine rates of land clearing. This work is coordinated by the Bureau of Rural Sciences and employs remote sensing (Landsat Thematic Mapper satellite imagery). The extraordinary contemporary rate of land cover change, the acute change in conditions for living things associated with complete clearing, inadequate or ineffective controls and political posturing rather than action over the issue combine to demand that landcover change be explicitly monitored. Both its acute and less easily specifiable longer-term impacts must be well documented as part of any credible national framework for monitoring rangeland biodiversity.

We do not take seriously the sophistic argument that land clearing for more intensive land use is not relevant for monitoring rangeland biodiversity, because once so modified the area may cease to be described as rangeland. Accepting this peculiar line of reasoning would render the entire notion of monitoring rangeland biodiversity irrelevant, because removing woody plants is to remove biodiversity. Why should the use of bulldozers be considered irrelevant in these landscapes, but grazing, other forms of pasture improvement and weed invasion regarded as sources of loss that demand monitoring?

The work coordinated by the Bureau of Rural Sciences (BRS) covers parts of the rangelands but by no means all of the woodland or forest that is vulnerable to clearing. This is in part due to constraints on spatial coverage dictated by cost, but is also influenced by the restrictive forestry-based definition of woodland (>20% canopy cover) that restricts applicability to biodiversity monitoring in the rangelands. Moreover, remotely-sensed data of the resolution used in this study is not effective at measuring change in sparser woodlands.

Consequently, although the BRS study is useful for some areas, it does not capture much of the activity that may threaten biological diversity in the rangelands. Some of the State schemes (and in particular the Statewide Landcover and Trees Study (SLATS) in Queensland) provide wider coverage, but are not immune from the problems of resolution that confront use of all satellite data capable of being used over very large spatial scales. There are unavoidable tradeoffs between local resolution and hence the type of change, environment types and the total area over which relevant measurements can be made at acceptable cost.

To understand the full range of land clearing processes and their impacts in rangelands it may be useful to aggregate geo-referenced information provided by the States and Territories on permits issued under relevant legislation. Such data will be essential to interpret biodiversity effects at all spatial scales, especially if they are to be aggregated across jurisdictions. However, their utility will be constrained if they cannot be provided in digitised form that accesses the power of GIS to relate observations spatially. Such data are also likely to be incomplete: not all permits are enacted and some clearing is done illicitly.

Whatever the methodologies, we consider that monitoring of structural change at the scale of landscapes is highly relevant to the status of biological diversity and should be incorporated in a national framework for monitoring rangelands. The manner in which this option should be linked to work being done under other national initiatives is considered in our discussion of the framework (see Main Report).

Other Biophysical Mapping

All jurisdictions have mapped large areas of the rangelands in one way or another. Dominant methodologies include long established land system and land unit mapping protocols (e.g. Gunn et al. 1988). These protocols combine aspects of geomorphology, soils, and dominant vegetation to derive units described within mapped areas of various sizes. However, as a result of inconsistencies of description between mapped areas, these descriptions often fail to match across adjoining map boundaries so that they cannot be used for regional or larger scale analyses.

Many other methods are available to describe environmental variation at various spatial scales. Examples include the suite of climate and terrain models developed by the Centre for Resource and Environmental Studies at the Australian National University (e.g. Hutchinson and Dowling 1991)

If a function of the national framework for monitoring biodiversity of the rangelands is to provide a periodic overview of the status of the rangelands, then it will be important that those maintaining the framework have access to relevant mapping and tools for characterising rangelands over large spatial scales, and are in a position to influence the development of new tools or other initiatives.

(10) Landscape processes

Causes of acute change in biodiversity values in rangelands, as exemplified by arid zone mammals and tropical granivorous birds, remain uncertain. Substantial change in structure of woody vegetation is not considered to be a plausible general explanation (Morton 1990; Franklin 1999), although increase in woody stems may have been a factor in declines of some grassland species (Garnett and Crowley 1995). Recent research has focussed on change in understorey vegetation (Anon. 1999), often at spatial scales too fine to be informed by the remote sensing studies used to assess woody vegetation cover.

Grazing gradient studies, employing distance from water as a surrogate for grazing intensity, have revealed patterns of floristic and faunistic change that are significantly correlated with relative grazing pressure. These studies and the concepts developed by Morton and co-workers emphasise patchiness of understorey features at a number of scales, and the importance of this patchiness in the ground layer, including refugia from grazing, for maintaining rangeland biodiversity (Landsberg 1997; Morton et al. 1995). They also emphasise the significance of even sparsely dispersed woody plants in these processes. Such features will not be usefully monitored using imagery of the spatial resolution that has been applied to assessing land cover change in other environments.

The manner in which landscape patchiness influences ecosystem function – and in particular the movement and utilisation of water and nutrients and its mediation by the biotic and abiotic components of ecosystems – has developed as a fruitful area of study (Ludwig et al. 1997; Shakak and Pickett 1997) described in Australia as Landscape Function Analysis. These studies in arid lands and more recent extensions to tropical rangelands (Tongway and Hindley 1995; Ludwig et al. 1999a,b) have the potential to reveal a good deal about the interaction between such function, grazing and other disturbance, and the status of biological diversity and its role in maintaining function.

Whilst that potential may take some time to be realised, we regard it as important that the range of institutions currently engaged in studies of biological diversity and landscape function continue to foster links among these activities in the rangelands. The Audit and the proposed framework for monitoring rangeland biodiversity have an important role to play here. Many of the pastoral monitoring systems reviewed elsewhere (Background Paper 2) incorporate important components of the LFA protocol. With some adjustment it would appear possible to link those monitoring activities to improved systems of biodiversity monitoring to provide the equivalent of a structured long-term research program. That research would be designed to ultimately determine the extent to which existing, well-established monitoring systems focussing on attributes of landscape function of particular interest to the pastoral industry can contribute to understanding of the status of biological diversity.

Remote sensing of land condition by satellite imagery is also relevant here. Although unsuitable for monitoring condition of woody vegetation, application to other measures of land condition (e.g. Karfs 1999) has produced some encouraging results. In addition, a number of agencies are engaged in monitoring fire patterns in rangelands (e.g. Russell-Smith et al. 1997; Jacklyn and Russell-Smith 1998). Studies based on remote sensing have been used to track variation in frequency and extent of wildfires and control burns over large areas, and in some cases these patterns have been linked to biodiversity outcomes (Russell-Smith et al. 1998). Large numbers of fire monitoring plots are being established in northern Australia to ground-truth remote sensing, assess vegetation responses, and, at some sites, link to surveys of vertebrate and invertebrate animals. Fire is regarded as a valuable pastoral management tool in parts of northern Australia, so both production and conservation managers share an interest in fire monitoring tools.

In regard to changes in the status of woody vegetation, numerical analysis of recent and historical images from aerial photography (Fensham et al. in preparation; B. Sharp, unpublished data) has revealed dramatic change in the density of woody stems over large areas. These methods allow contemporary observations of the status of woody vegetation to be placed in their temporal context and related to larger issues such as global warming, carbon budgeting, and floristic and faunal change.

Other remote sensing tools may also contribute to interpretation of outputs from biodiversity monitoring programs. We have already noted the extreme variation in distribution and abundance of many fauna associated with responses to shifting resource availability (Woinarski 1999). Environmental responses to rainfall patchiness may be derived from greenness indices taken from NOAA or other imagery (e.g. Gallo and Daughty 1987), and these may help separate natural variation in abundance and distribution from underlying change associated with anthropogenic factors. The Audit's work in this area will provide important background to the interpretation of biodiversity monitoring data.

It is well understood that determinants of biological diversity at all scales are multi-dimensional and interact in complex ways. That complexity can never be understood and effective management action based on separate and conceptually disparate studies, no matter how competent individually. The need for integrated study is repeatedly heard, but rarely achieved. It is essential that a credible framework for monitoring the biological diversity of the rangelands describe the manner in which the information needs of pastoral industry regulators and those responsible for biodiversity protection might be met simultaneously.

(11) Biogeographic studies

We have previously highlighted the use of national or other large scale Atlases for analysis of the environmental correlates (and, by inference, determinants) of patterns in the distribution and abundance of flora and fauna. These efforts have been compromised by the lack of nationally consistent environmental descriptions. The Audit and other Federal institutions are addressing some of these concerns so that some mapping at relevant scales will shortly be available. These datasets should assist researchers to look in more detail at large scale biogeographic patterns and relate them to key environmental variables. Incorporation of land use type and intensity in statistical and spatial models could provide important insights to the sources of change in distribution and relative abundance of native flora and fauna and thereby assist with priority setting for future monitoring investments.

However, details of human population, agricultural production, infrastructure and the like are mostly aggregated to boundaries that bear little relation to the biogeographic regionalisations under which descriptions of many environmental phenomena are organised. Thus the ability to relate biodiversity issues to trends in the human use of the rangelands is substantially constrained. Obviously such capability would be most useful not just to better identify possible problem regions and so better focus monitoring effort, but also to validate potential socio-economic surrogates or correlates of biodiversity status. For example, it is likely that a large number of species are relatively insensitive to prevailing patterns of land use in the rangelands. Separating the faunal and floristic “decreasers” from other species will allow (for example) reserve systems to be explicitly designed to meet the needs of those sensitive species rather than be determined by potentially misleading measures of total diversity (Woinarski et al. 1997).

Re-aggregation of socio-economic data available from the Australian Bureau of Statistics (ABS) to improve matching is limited by unwillingness to provide information at collection unit level, as this may compromise individual privacy in sparsely populated regions like the rangelands. ABS charges for access to data are an important constraint and may need adjustment if genuine integration of socio-economic and environmental data is to occur. It is patently absurd for State, Territory or Federal agencies to be asked to engage in circular transactions requiring them to redirect large parts of small budgets to purchase information from other public servants so that they can apply it for the public good. Moreover, if the ABS is to seriously attempt the incorporation of environmental values in national accounts or other forms of national data collection and presentation, then improvements in the options available to re-aggregate data at different scales and to different boundaries will be essential.

Linkage among Activities

In its statement of principles for the Rangeland Monitoring Theme, the Audit described landscape function as a "fundamental precursor" to biodiversity. The implication was that active consideration should be given using indices of landscape function as surrogates for actual measures of biodiversity. The failure of this idea (above) illustrates an important difficulty with the management of natural resource data and the design of natural resource management programs. There has been a high degree of segregation of activity and information, and little incentive to integrate. As a result, measures of landscape function have rarely been carried out in conjunction with systematic matched description of biodiversity values.

There is currently no evidence that Landscape Function Analysis generates metrics that can in any way predict biodiversity values. To build a comprehensive and convincing biodiversity monitoring program from a base in landscape function would therefore require a considerable act of faith. Similarly, the effects of many putative threatening processes are only broadly understood, so it is not presently possible to specify when a process has progressed or will progress to a point at which biodiversity change becomes unacceptable. It is clearly inappropriate to build a monitoring system for the rangelands based on measurement of crude indicators of process (like many State of the Environment indicators), if we expect that the monitoring system will ultimately provide justification for management action.

We argue that it is possible to undertake some useful analysis from the various fragments currently available to us, but acknowledge that presentation of such jigsaws to land managers and users is not likely to achieve the empowerment of decision-makers that the Audit seeks. It is the desire to avoid this sort of "untidiness" that motivates much of the effort to identify indicators or surrogates, despite a lack of underpinning scientific knowledge.

Rather than take the high-risk route represented by a retreat to unproven indicators or surrogates, we propose that the framework for the rangelands be sufficiently robust from the outset to quickly generate integrated products and demonstrate their utility to those who need to be convinced about the value of integration and data-sharing. This may mean that the initial focus of analysis is on the most readily achievable rather than the most desirable.

However, the Audit has also emphasised that the national framework should be "adaptive". We strongly support this notion as indispensible in an information management environment that currently lacks organisation of a relatively poor knowledge base. Imperfections and gaps in the early content of the framework are inevitable, but can be overcome provided there exists:

- a commitment to produce useful products early to demonstrate both utility and constraints to decision-makers
- access to relatively modest additional resources and, most importantly,
- a mandate to build a comprehensive and competent system through time.

Within such a favourable policy environment, an evolutionary approach will ultimately produce a cheaper and more effective system than will a premature decision to invest heavily either intellectually or by redirection of resources in a gaggle of unproven surrogates, indicators or related theoretical constructs.

Making enduring linkages among information providers and their products should be the core aim of a framework for monitoring rangeland biodiversity, just as it should for other elements of the Auidt. Together with a well-considered and supportive framework for organising analysis, effective linkages will permit the validation of a range of indicators. In the absence of these linkages we will continue to hear repeated and increasingly pathetic calls for the identification of indicators or surrogates for difficult to measure biodiversity attributes, but make no progress towards them.

Conclusion

The existing information bases and monitoring schemes for rangeland biodiversity are too disjunct and idiosyncratic to simply be aggregated to form a national monitoring framework. However, we argue that technical capability exists to apply some of these disparate and currently disconnected threads to the challenge of monitoring some aspects of biological diversity in the Australian rangelands, and partly meeting the goals we have identified for such a system (see Main Report). This conclusion raises some fundamental questions. In particular, given that the nation's leaders have repeatedly committed us to develop a national biodiversity monitoring program, why has so little progress been made in that direction? Even our premier national parks are unable to demonstrate that they are achieving their conservation objectives.

In our view, the primary constraint is the polar positions taken up by environmental scientists and policy makers. Within scientific ranks, there has been a tendency to over-emphasise technical difficulties for establishing initially useful (as distinct from comprehensive and conceptually attractive) monitoring systems and under-rate what is achievable if the will and resources exist to make the best use of available information and expertise. Policy-makers have, at the other extreme, indulged themselves in the fatuous notion that the status of a huge array of complex biological entities and ecological, economic and social processes interacting across an entire continent subject to an erratic climate, as well as an understanding of those interactions sufficient to inform effective management response to adverse change, can be collapsed into a few simple measures that will cost little or nothing to collect. This yawning gulf is sufficient to deter all but the most determined, because those building a precarious crossing are aware that both sides can and will mount cogent criticisms to undermine the initially frail supports on which a more robust base might ultimately be built.

But we have shown in other papers (Background Paper 1) that there is some urgency about the task of attempting that crossing. Many elements of the rangeland biota that give the Australian outback its unique character are in decline. It is incumbent on those with knowledge of past and pending conservation catastrophes to realise the commitments made by Government to establish useful monitoring systems. Once it is acknowledged that analysis of trends in biodiversity values has been repeatedly determined and comprehensively documented to be a socially-relevant goal (Main Report), then there can be no excuse for failing to make the modest but highly strategic additional investment required for immediate and useful progress. We propose what we believe to be a useful beginning for the rangelands in the framework set out in our Main Report. Elements of existing programs summarised here form part of that starting configuration. The ongoing challenge will be to promote the political and bureaucratic will to reinforce early steps by also committing to the longer-term investments in design, data quality, and management and sharing of information that are basic pre-requisites for any coherent national monitoring framework.

Acknowledgments

A large number of people gave generously of their time to provide information summarised in this report. Informants include Peter Alexander (SA), Ross Anderson (NSW), Geoff Barrett (Birds Australia), Piers Barrow (CW), Joe Benshemesh (SA), Sue Briggs (NSW), Chris Brock (NT), Michael Clarke (Birds Australia), Jeff Cole (NT), Harvey Collerton (NSW), Michelle Cooper (NSW), Peter Copley (SA), Andrew Craig (Qld), Gabriel Crowley (Qld), Tim Danaher (Qld), Stephen Davies (WA), Will Dobbie (NT), Angus Duiguid (NT), Glen Edwards (NT), Murray Ellis (NSW), Nicki Fitzgerald (CW), Stephen Garnett (Qld), Joshua Gilroy (NSW), Gordon Graham (WA), Stuart Gunning (WA), Wayne Hall (Qld), Chris Hill (Qld), Angus Hopkins (WA), Bob Johnson (Qld), Kelli-Jo Lamb (SA), Richard Kingsford (NSW), David Liddle (NT), Geoff Lundie-Jenkins (Qld), Peter Mawson (WA), Steve McAlpine (NT), Ian Morris (NT), Katherine Moseby (SA), John Neldner (Qld), Keith Noble (WA), Colleen O'Malley (NT), Peter O'Reagain (Qld), Neil Phillips (NT), Julian Reid (CW), Jeremy Russell-Smith (NT), Keith Saalfeld (NT), Tony Start (WA), William Steel (Birds Australia), Simon Stirrat (NT), Lloyd Tucker (WA), and Paul Williams (Qld). In addition, several representatives of State and Federal agencies spent a few days discussing the issues canvassed in this report at a workshop held in Darwin in June 2000. Workshop participants were: Alan Anderson (NT), Eric Anderson (Qld), Rod Applegate (NT), John Benson (NSW), David Carter (ACT), Andrew Craig (WA), Gabriel Crowley (Qld), Leasie Felderhof (Qld), Rod Fensham (Qld), Daryl Green (NSW), Alec Holme (WA), Angas Hopkins (WA), Craig James (NT), Bob Karfs (NT), Rochelle Lawson (ACT), Brendon Lay (SA), David Robson (NSW), Paul Sattler (Qld), Tony Start (WA) and Ian Watson (WA). With thanks to John Childs, Tropical Savannas-CRC, for advise and encouragement throughout the project.

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