Report

Theme 4: Rangelands Monitoring.

Project 3: **Developing an analytical framework for monitoring biodiversity in Australia's rangelands**.

Agency: **Cooperative Research Centre for the Sustainable Development of Tropical Savannas.**

For: **National Land and Water Resources Audit.**

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TROPICAL SAVANNAS CRC

National Land & Water Resources Audit

A program of the Natural Heritage Trust

Report

Developing an analytical framework for monitoring biodiversity in Australia's Rangelands.

Contents

The person nominated against the individual components took principal responsibility for that report, but all personnel contributed to each of the sections.

Acknowledgments

The complexity and diversity of the task of monitoring the spectrum of biodiversity in the majority of Australia's landmass is considerable, and not to be underestimated.

We were determined to develop a monitoring framework we believed in, one that was scientifically credible and able to be implemented. What we have produced in the time available is a sound basis on which to commence this vital task.

The principal authors are Dr John Woinarski, PWCNT; Dr Peter Whitehead, NTU; Alaric Fisher, PWCNT and Kerry Beggs, NTU & PWCNT. Don Franklin, NTU made a significant contribution to project development and data analysis. Carmen Verhagen assembled the data and undertook the major task of map and graphics presentation and report compilation.

Representatives from State/Territory and Commonwealth jurisdictions with responsibilities for rangeland monitoring contributed significantly to the development of the framework by assisting in data collection and making important technical suggestions during the development workshop.

The project benefited from the help and guidance of Ian Watson and Rochelle Lawson of the NLWRA.

We would welcome comments and advice regarding this framework.

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The Framework

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Summary

The National Land and Water Resources Audit (NLWRA) has sought proposals of "An adaptive framework for monitoring biodiversity in rangelands".

(1) Definitions of biological diversity endorsed by Australian Governments encompass an enormous range of phenomena. The rangelands occupy about 70% of a megadiverse nation. Any achievable monitoring scheme for biological diversity in rangelands therefore requires clear choices about targets for monitoring. There are strong incentives to nominate indicators or surrogates.

(2) However, design is dependent on clear understanding of the questions the monitoring system is designed to answer, and there has been little guidance from government or elsewhere on the biodiversity outcomes sought in rangelands.

(3) We therefore used an analysis of threatening processes in the rangelands to identify the questions that a rangeland monitoring framework might be expected to answer as well as providing guidance for relevant management responses. In very simplified form, the most significant seek to identify the particular impacts upon rangeland biodiversity of:

   (a) clearing of woody vegetation on rangelands

   (b) grazing impacts leading to vegetation change not necessarily involving gross structural simplification, including loss of perennial grasses and thickening of native woody plants

   (c) introduced unmanaged populations of herbivores and predators.

   (d) changed fire regimes

   (e) exotic grasses and other exotic plants

   (f) changed water regimes

(4) Existing pastoral monitoring programs operated by the States and Territories do not provide data with the content or environmental comprehensiveness to address these important issues.

(5) We conclude that a system capable of answering significant questions in regard to biological diversity over the long term, will need to include a number of components, including:

   (a) elements of the existing State and Territory pastoral monitoring programs;

   (b) increased application of remote sensing and improved linkage to both measures of landscape function and direct monitoring of biodiversity;

   (c) additional wildlife (flora and fauna diversity) surveys designed to repeat “landmark” surveys and validate surrogates or indicators;

(d) regular monitoring of populations of a range of selected species, emphasising those most sensitive to prevailing adverse processes or otherwise identified as good indicator species; and

(e) explicit linkage of monitoring programs for Parks and Reserves to their equivalents on lands used for primary production.

(6) Substantial effort is needed from the outset to validate often-proposed but poorly tested potential indicators of biodiversity status. A significant investment during the development phase may secure a robust and simpler framework over the long run.

(7) Studies of landscape function in particular require explicit and well-structured linkage to biodiversity monitoring, so that the use of Landscape Function Analysis as a surrogate for landscape health and biodiversity status can be tested rather than assumed. This should be accorded a high priority within the core of a national system, and will require increased sampling of biodiversity values over a number of sites at which LFA is also applied.

(8) Most threats to biological diversity in rangelands have been inferred from basic principles rather than validated by scientific study and analysis. The steps taken by the Audit to provide some standardisation and consistency in nationwide environmental descriptions will be important to explore links among biodiversity values, environmental attributes and socio-economic factors. The core system should include implementation of explicit short-term studies in selected trial areas (in conjunction with studies dealing with LFA) of the links between putative threatening processes and biodiversity values.

(9) A robust national framework for monitoring rangeland biodiversity is perhaps best developed in stages. However, ultimate failure is perhaps more likely if the starting point is excessively modest. We propose to begin with a core system comprising at least:

(a) a mandate to develop a system that satisfies the requirements of all relevant national strategies and policies and international commitments;

(b) staffing and support to design improved systems in conjunction with States and Territories, and perform integrated analysis of national scope;

(c) a workplan for a number of useful products to be produced early in its life; and

(d) support from Federal, State and Territory governments, through directions from relevant Ministerial Councils, to influence design of relevant resource mapping and inventory programs to optimise their contribution to monitoring and protection of biodiversity in the rangelands.

(10) We identify a minimum set of 9 indicators to provide a starting configuration for an ultimately useful scheme for monitoring biological diversity in rangelands. The indicators are:

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

(b) Extent of clearing of woody vegetation

(c) Landscape function metrics

(d) Native perennial ground cover (including grasses and shrubs palatable to stock)

(e) Exotic plant species cover

(f) Status of fire-sensitive plant species and communities

(g) Status of grazing-sensitive plant species

(h) Status of susceptible mammal species

(i) Status of susceptible bird species.

(11) We acknowledge that these indicators do not directly address all of the important issues in the rangelands and the utility of many of them for indexing adverse processes or status of biodiversity is unproven. However, together, they represent a consensus of opinion on those threads of biodiversity regarded as the most prone to change.

(12) Wherever possible, the indicators selected here build from or complement existing reporting requirements under State of the Environment and Montreal process reporting.

(13) Great emphasis must be placed on integrating existing work to realise the opportunities offered, through implementation of a national framework, to validate potential indicators to produce a robust and achievable system that meets the expectations of Government and the various stakeholders over the long term.

(14) We anticipate that implementing a framework based on these core indicators, validating them, and exploring possible enhancements to provide a comprehensive scheme will require at least 5 years and additional expenditure of approximately $5 million.

1. Background

The National Land and Water Resources Audit (Audit) is a major project established under the Natural Heritage Trust. The Audit is assessing the status of Australia's natural resources, primarily through the collation of existing and new natural resource data and the creation of related information products. The Audit aims to empower resource managers by making comprehensive information and methods for analysis more accessible.

The Audit's ambitious work program is organised under a number of themes, one of which is titled Rangelands Monitoring. A proposed output from that theme is an Australia-wide Rangelands Monitoring and Reporting System. A framework for monitoring the biological diversity of the rangelands is to be integrated with that larger monitoring and reporting system.

This report proposes and provides justification for a framework that meets the specifications of the Audit in regard to biodiversity monitoring in rangelands, satisfies relevant provisions in national strategies for the management of natural resources and conservation of biological diversity, and also meets international commitments. The report is supported by a number of more detailed background papers:

- **Background Paper 1**: Biodiversity in the Australian rangelands: a review of changes in status and threatening processes.
- **Background Paper 2**: Biodiversity in the Australian rangelands: a review of pastoral monitoring programs and their real and potential contribution to biodiversity monitoring.
- **Background Paper 3**: Biodiversity in the Australian rangelands: a review of information gathered from some existing biodiversity monitoring programs
- **Background Paper 4**: Biodiversity in the Australian rangelands: approaches to broad scale monitoring of biological diversity – a brief review of international experience

Prior to presenting the framework, we provide a brief re-statement of our understanding of the purpose of monitoring, an interpretation of the Audit's requirements, and relevant obligations accepted by Governments at various levels under agreements, policy statements or legislation.

1.1. What is monitoring?

At its most literal, monitoring is simply the observation (checking) of a phenomenon of interest. There are no simple rules that unequivocally define an acceptable monitoring program, because design will necessarily be matched to the objective to be met by observation. However, there are a few basic principles that any useful and informative system must incorporate.

(1) States of the phenomenon of interest should be readily classifiable or measurable;

(2) observations must be potentially repeatable;

(3) methods used to make and record observations should be consistent, to permit comparison of observations with each other or against a specified standard; and

(4) different states of the phenomenon under observation should be interpretable in terms of the observer's objective(s).

Beyond these few very simple "rules", there are no features of a monitoring system that might not be varied to meet specific objectives. The nature of the observation, the precision with which measurements are made, the detail that is recorded, the frequency of observation and the spatial distribution of observations cannot be settled unless there has been a clear prior decision about how the information will be used and analysed. This decision is in turn dependent on knowing just what it is that the user wants to be able to detect or demonstrate.

The need for monitoring to be informed by clear statements of purpose cannot be over-emphasised. A critical challenge in designing appropriate systems for monitoring biological diversity is to achieve that clarity, despite the enormous range of values embraced by the concept and the equally daunting range of objectives that different interests may bring to the task.

1.2. What is Biological Diversity?

A shared understanding of the meaning of biological diversity is a pre-requisite for understanding and acceptance of any scheme for monitoring and reporting on its status. We have assumed that the Audit, as a Federal initiative, will operate under definitions provided under the recently enacted Commonwealth *Environmental Protection and Biodiversity Conservation Act* 1999. The definition of biodiversity in the Act is:

> **…** *the variability among living organisms from all sources (including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part) and includes:*
>
> *(a) diversity within species and between species; and*
>
> *(b) diversity of ecosystems.*

Further, the Act specifies elsewhere that:

> **…** *components of biodiversity include species, habitats, ecological communities, genes, ecosystems and ecological processes.*

This definition is operationally equivalent to that contained in the *Convention on Biological Diversity* and the *Strategy for Conservation of Australia's Biological Diversity*. A particularly important element in the context of a monitoring framework is explicit extension of the meaning of biological diversity to encompass variation in assemblages of organisms, among ecological complexes and among ecological processes. Thus acceptance of an obligation to monitor biodiversity extends well beyond making tallies of recognised taxa, to include discrimination of some elements of the various interactions among organisms and their non-living environments.

Such a task is daunting enough when aimed at a single ecosystem or site, because even apparently simple systems often display a dazzling array of interactions among their components as well as complex temporal and spatial dynamics. The Australian rangelands encompass most of the land area of a mega-diverse island continent containing systems spanning all but unvegetated deserts to monsoon rain forests. The task of monitoring rangeland biodiversity therefore has the potential to approach in scope the regular description of fluxes in the life of a continent, in all its different permutations. To add to the challenge, an erratic climate drives major fluctuations in the abundance and distributions (and population structure) of many organisms, and there is a generally poor level of knowledge.

Considered from this perspective, an entirely comprehensive monitoring system is not a realistic option. We therefore begin this task with the recognition that we are seeking a compromise, probably based on descriptors that economically capture as much of this variation as possible in a number of well-considered measures very much smaller than there are elements of biological diversity.

2. Requirements for a Biodiversity Monitoring System

At this point we consider the directions, explicit or otherwise, that appear in a number of key documents that might further inform the objectives to be met by a national program for monitoring rangeland biodiversity.

2.1. Convention on Biological Diversity

Australia is one of 168 signatories to ratify the Convention. The Convention text commits parties to:

- *Monitor, through sampling and other techniques, the components of biological diversity … paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use*
- *Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects …*
- *Maintain and organize … data derived from identification and monitoring activities (Article 7)*

Annex 1 to the Convention provides an "indicative" list of those elements of biological diversity that should receive special attention for inventory and monitoring:

- *Ecosystems and habitats: containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social, economic, cultural or scientific importance; or,*
- *which are representative, unique or associated with key evolutionary or other biological processes;*

- *Species and communities which are: threatened; wild relatives of domesticated or cultivated species; of medicinal, agricultural or other economic value; or social, scientific or cultural importance; or importance for research into the conservation and sustainable use of biological diversity, such as indicator species; and*
- *Described genomes and genes of social, scientific or economic importance.*

The important implications of this language for Australia's national obligations are (i) a requirement to monitor the effects of adverse (threatening) processes as well as the elements of biological diversity; (ii) a wide range of biodiversity-related phenomena that should be subject to monitoring; and (iii) explicit mention of those species and communities that may be subject to sustainable use: requiring assessment that go beyond the rare and endangered.

2.2. National Strategy for Conservation of Australia's Biological Diversity (National Biodiversity Strategy)

The National Biodiversity Strategy has been endorsed by all State and Territory Governments and the Federal Government. It recognises long-term monitoring as an important process for improving understanding of biological diversity and the factors that threaten it. The Strategy promotes establishment of:

> *"… (A) national coordinated program of long-term ecological monitoring to document patterns of change or lack of change in order to establish a baseline for understanding the impact of such change or lack of it on natural communities, ecosystems and ecological processes, and to detect changes in biological diversity and their causes. The program will:*
>
> *(a) combine remote sensing with a national network of secure field-based monitoring sites in representative habitats;*
>
> *(b) develop and encourage the application of national monitoring protocols involving standardised sampling designs and techniques for testing management regimes and strategies, including rehabilitation and reintroductions;*
>
> *(c) use biological diversity indicator groups to reveal the impacts of environmental disturbance;*
>
> *(d) establish properly constituted and supported assessment panels or monitoring committees, or both, comprising representatives of industry, non-government conservation organisations, other appropriate community groups and governments;*
>
> *(e) accelerate research into new, cost-effective methods of monitoring;*
>
> *(f) integrate with an ecological research program aimed at improving our understanding of long-term and event-driven ecological processes."*

Importantly, the Strategy also includes provisions relating directly to rangelands. It calls explicitly for coordinated research into (i) the impact of total grazing pressure in rangelands on biological diversity and the resilience and regenerative capacity of palatable species, and

(ii) developing and implementing tools for adaptive management of rangelands. Taken in combination with the urging to integrate monitoring with ecological research, the Strategy provides the clearest available statement of the collective objectives of the different jurisdictions.

2.3. Environmental Protection and Biodiversity Conservation Act 1999

This recent legislation at least in part constitutes an attempt by the Federal Government to provide the statutory base to facilitate effective implementation of the Convention and the National Biodiversity Strategy. It also provides measures for meeting obligations under the World Heritage Convention and Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar).

> *Part 12 of the Act provides specifically for inventory and monitoring of biological diversity.* **Under Section 171:**
>
> *(1) The Minister may, on behalf of the Commonwealth, co-operate with, and give financial or other assistance to, any person for the purpose of identifying and monitoring components of biodiversity.*
>
> *(2) Without limiting subsection (1), the co-operation and assistance may include co-operation and assistance in relation to all or any of the following:*
>
> *(a) identifying and monitoring components of biodiversity that are important for its conservation and ecologically sustainable use;*
>
> *(b) identifying components of biodiversity that are inadequately understood;*
>
> *(c) collecting and analysing information about the conservation status of components of biodiversity;*
>
> *(d) collecting and analysing information about processes or activities that are likely to have a significant impact on the conservation and ecologically sustainable use of biodiversity;*
>
> *(e) assessing strategies and techniques for the conservation and ecologically sustainable use of biodiversity;*
>
> *(f) systematically determining biodiversity conservation needs and priorities.*

Clearly these laws signal the intent of the Federal Parliament to support monitoring work that not only tracks the status of elements of biological diversity and the processes that have impacts on it, but also to improve understanding of the way in which biodiversity can be conserved and sustainably used. In this emphasis, it is entirely congruent with the National Biodiversity.

2.4. National Strategy for Ecologically Sustainable Development

The key principles of ecologically sustainable development are (Anon. 1992):

(a) *decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations;*

(b) *if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation;*

(c) *the principle of inter-generational equity—that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;*

(d) *the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making; and*

(e) *improved valuation, pricing and incentive mechanisms should be promoted.*

These principles are incorporated in the Commonwealth *Environmental Protection and Biodiversity Conservation Act* 1999. Their particular relevance to a monitoring framework for rangeland biodiversity is the emphasis they place on long time frames and the recognition of biological diversity and ecological integrity as fundamental to sustainability.

2.5. Managing Australia's Rangelands: National Principles and Guidelines for Rangeland Management

This paper is the most recent incarnation of a series of draft statements dealing with management of rangelands. In this document, the relevant Ministerial Councils (ANZECC and ARMCANZ) set out their vision of a national framework for managing rangelands. The principles that appear particularly relevant to the present task are:

- *A wide range of values … need to be considered in making balanced decisions about the rangelands; financial analysis alone is an inadequate tool …*
- *Decisions … need to take account of inter-dependencies and inter-relationships between components of the ecosystem …*
- *Consideration should be given to the effects of episodic events, the spatial variability of processes and the generally long-term biophysical time frame of the rangelands.*
- *Prevention of any resource degradation is more effective than rehabilitation.*

The guidelines place a great deal of emphasis on regional planning processes, and refer to the need to incorporate "a stocktake of natural, human and other resources" and "a comparison with other rangeland regions to identify potential threats and opportunities". Taken together, these components of the Principles and Guidelines establish a requirement for information that is comprehensive in terms of its spatial and temporal coverage, contributes to understanding of interactions among components of the rangeland system, and provides early warning of adverse change.

The document also emphasises the obligation for Governments to work in partnership. It presents as essential processes for "*reviewing, monitoring and evaluating the environmental … conditions of the rangelands*" and promotes a role for the two Ministerial Councils (ANZECC and ARMCANZ) in these processes.

Several Guidelines are associated with actions of direct relevance to a national rangeland monitoring strategy:

Action 13.1 *Regional planning processes … should include transparent evaluation procedures.*

Action 13.2 *Governments should ensure that all programs, policies and services … are subject to regular, public evaluation …*

Action 16.1 *Governments, in consultation with rangeland users and managers, should develop agreed criteria and indicators for ecologically sustainable rangeland management …*

Action 16.2 *Develop comprehensive, cost effective monitoring programs to underpin implementation of criteria and ecologically sustainable rangeland management at a range of scales.*

Action 16.3 *The opportunity created by the National Land and Water Audit must be used to establish a national rangeland monitoring program to determine trends in the long term health of Australia's rangelands at a regional, land type and property scale*.

These proposed actions serve to reinforce other statements regarding spatial and phenomenological comprehensiveness, but also introduce the notion of cost-effectiveness. Recognition of the need for consultation with users and managers is important. The Audit's timeframe did not permit wide consultation and it is perhaps inevitable that the framework developed now will be biased towards the needs of Government. However, it is clearly important that flexibility to refine (adapt) the detail of monitoring arrangements be retained, if only to ensure that over the longer term the system is demonstrated to satisfy the land owning and managing groups in regard to relevance and credibility.

2.6. Managing Natural Resources in Rural Australia for a Sustainable Future

This discussion paper (Anon. 1999) was released by the Federal Minister for Agriculture, Fisheries and Forestry in early 2000. The aim of the paper was to stimulate public discussion and comment on the need for a national strategic policy framework for the long-term management of natural resources in rural Australia.

The paper places a great deal of emphasis on the significance of setting clear goals in all areas of natural resource management, including maintenance of biological diversity, and monitoring success in achieving those goals. Competent monitoring programs and ready access to their results are seen as essential for rural Australia to justify and be accountable for investments made in its future. Significant references include (emphasis added):

- *Natural resource management goals and objectives are to have clear and measurable outcomes, requiring **comprehensive monitoring** and assessment to evaluate progress and identify areas for refinement (Principles p 10)*
- *The strategic approach to extending knowledge and information involves*
  - *improving access to data and information and **increased monitoring** (p. 17)*
- *By 2005 there should be a 75 per cent increase in the number of landholders and regional communities actively monitoring resource condition—for example, by soil testing and water and **biodiversity monitoring**—to guide their management practices (Indicators of progress, capacity building for improved natural resource management, p. 20)*
- *Mechanisms for improving data and information—and for monitoring the effectiveness of actions—are an essential part of planning and implementing regional strategies (Regional strategies, p. 36).*
- *Development of sustainability indicators (p. 80)*
  - *… sustainability indicators should be capable of monitoring change in the condition of the natural resource base …*
- *The following features characterise a best-practice regional plan for natural resource management:*
  - *a regional profile of natural resources' condition and economic and social characteristics;*
  - *…indicators … to monitor progress towards sustainability and evaluate the impacts of particular management practices.*
  - *sustainability indicators that are useable at the regional scale*
- *…data need to be collected regularly and consistently (p 81).*
- *… robust and affordable systems for sharing data (are required) at the national, State and Territory, regional and farm levels.*
- *In meeting the data and information requirements, there is a need to (p. 82):*
  - *develop a system for data management, analysis and distribution, including guidelines and protocols to ensure national compatibility and comparability;*
  - *increase the use of topographic data and airborne geophysical remote sensing data for field surveying and mapping for monitoring at the regional scale.*

2.7. Audit Documentation

The Audit task has been divided into a number of themes. A statement of principles and a work plan for Theme 4 - Rangeland Monitoring – articulates a view of monitoring and its intent, which provides useful background to the present task. A number of significant elements is compiled in Box 1. Some bear emphasis here:

(1) reporting is expected to be regular, perhaps annual;

(2) the system will be primarily reliant on existing State and Territory agencies and research bodies;

(3) the information will be accessible to decision-makers and the wider public;

(4) an integrated set of measures, which can be related to the multiple values of the rangelands, is required;

(5) an emphasis on landscape function and an explicit expectation that biodiversity monitoring will link to measures of landscape function;

(6) coverage of grazed, occupied ungrazed lands, conservation lands and unassigned lands;

(7) emphasis on the regional scale, with an expectation that regional data can be aggregated to provide a national overview, as well as a "benchmark" against which property and paddock-level performance can be assessed;

(8) clients are government and land owners and land managers.

The specific objectives stated for this project (numbered 3.1 under the Rangeland Monitoring Work Plan and reproduced at Appendix 1) can be paraphrased as:

- develop a biodiversity monitoring framework comprising indicators that are closely linked to indicators of other rangeland values; and
- ensure that the system is sufficiently flexible to be adapted and improved through time.

Other documentation of the Audit's goals and processes throw additional light on the benefits expected from a monitoring scheme. A particularly significant statement (McDonald et al. 1999) is that the:

> … *Audit was designed to engage and work with Australian resource managers rather than to evaluate the activities and consequences of resource use* …

Thus it is important to recognise that in addition to generating information, the rangeland monitoring initiative must generate products that are accessible to and engage users in ongoing review of the implications of their management decisions. This demands that users perceive the monitoring framework to be relevant to them on introduction. To begin with a highly technical and abstract product would be to disenfranchise many potential users. This recognition should not be taken to suggest that technical standards should be compromised. Rather, issues widely accepted to be of high priority should be emphasised initially, and refinement and elaboration be built into the system as it proves itself useful to decision-makers.

Box 1: Key elements of the Audit's Rangeland Monitoring Work Plan

The **goal** of the rangeland monitoring component of the Audit is to:
Define the components of a national monitoring and reporting program that provides regular national reports and allows better decisions to be made affecting land use and management within Australia's rangeland.

Attributes

The rangeland monitoring component of the Audit will:

1. *recognise and depend on skills, information and interpretation, provided by the State and Northern Territory agencies and research institutions;*
2. *provide readily accessible, interpreted information to assist national and regional policy decision making, a framework for land management decisions and for the wider community (sic);*
3. *recommend and apply techniques to assess change in functional capacity of the landscape, primary production and biodiversity;*
4. *recommend and apply techniques to assess the history of extreme climatic events and fire, and trends in the intensity of use of the rangeland;*
5. *recommend and apply attributes to monitor and assess social, economic and institutional factors that influence land management decisions; and*
6. *provide a framework to specifically address the land management information needs of indigenous communities.*

Issues

The rangeland monitoring component of the Audit will address the following core issues:

- *productivity;*
- *ecosystem function;*
- *biodiversity;*
- *extreme climatic events and fire;*
- *economic and social factors affecting land management; and*
- *institutional arrangements affecting land management.*

Focus

The rangeland monitoring component of the Audit will primarily focus on an assessment of landscape or ecosystem function as the fundamental precursor for the two key biophysical components of rangeland management: biodiversity and productivity.
The rangeland monitoring component of the Audit will develop a framework to assess the regional management and conservation of biodiversity as an essential component of functioning ecosystems.

Coverage

… the rangeland monitoring component of the Audit will provide information on trends in the following pressures on ecosystems:

- *intensity of land use from grazing;*
- *change in land use; and*
- *history of extreme climatic events and fire.*

The rangeland monitoring component of the Audit will assess change on grazed, and ungrazed occupied land, conservation land and unassigned lands. It will not cover mined areas or irrigated lands.

Spatial Scale

The rangeland monitoring component of the Audit will primarily provide information at the national and regional spatial scales and provide a benchmark for the comparative assessment of trends at the property unit or paddock scale.

Clients

The rangeland monitoring component of the Audit is primarily concerned with meeting the information needs of two categories of clients:

- *policy advisers to Government, industry and community organisations; and*
- *land managers including pastoralists and Aboriginal communities through Government extension agencies, consultants, industry and community organisations.*

The general public will have access, through the Internet, to information provided to the above clients.

Projects

The component projects of the rangeland monitoring and reporting component of the Audit.

1. *Assessment of change in ecosystem function, trends in intensity of use, history of climate and fire, which impact on the ecosystem.*
2. *Determining trends in economic, social and institutional factors that influence land use and management in rangeland.*
3. *Developing an adaptive framework for monitoring biodiversity in rangeland.*
4. *Packaging and presentation of information and decision aids for value judgements by decision-makers.*

2.8. Synthesis of statements

In working through such a long-standing catalogue of discussion papers and formal commitments from Government, of which those mentioned above are a small part, it is difficult to avoid cynicism about the value of yet another statement of good intentions and reiteration of need for action. Nonetheless, we have chosen to treat these statements as though those writing them or putting their signatures to them did indeed intend that they might be acted upon at some time.

Key recurring themes in these documents are:

(1) Maintenance of biodiversity is a fundamental requirement for sustainability of rangeland use.

(2) Monitoring of biophysical attributes, including status of biodiversity, is an essential element of sustainable land management.

(3) Monitoring systems should be capable of providing information on processes affecting biodiversity, and improve understanding of causes of change as well as cataloguing that change.

(4) Monitoring systems require long-term commitment.

(5) Communities should, by one means or another, be actively involved in monitoring programs.

(6) The Commonwealth has a role in monitoring biodiversity, including funding relevant activity.

(7) Accountability requires regular public evaluation of standards of land management, informed by robust monitoring systems.

(8) Monitoring systems are required at a number of levels, ranging from the property to the national, and systems should be designed to be compatible across scales.

(9) Land management objectives and expected outcomes should be clearly stated so that they are capable of comprehensive monitoring and evaluation.

It is noteworthy that the various statements of goals, objectives and actions focus predominantly on features of monitoring systems and, to a lesser extent, the decisions and actions they are expected to inform. Nor do they indicate a clear pathway from unfavourable monitoring data to appropriate remedial change in land management practice. They do not specify the biodiversity outcomes that are sought in the rangelands. Do we wish to avoid the loss of any species of flora or fauna from any region? Is the loss of a unique assemblage of organisms acceptable if all of the component species persist elsewhere? Is loss of a number of vertebrate species from the entirety of a large pastoral property acceptable or not?

An obvious response to such a series of questions is that these value judgements are not what the Audit or this project are about. They are the province of policy makers. They are also very hard questions, which are, in consequence, mostly avoided by policy-makers. It is inherently difficult to present a decision that accepts any loss of biodiversity at any spatial

scale as other than an admission of failure, given the many statements of broad intent to avoid losses that are apparently embraced at the highest levels of Government. But it is more difficult to design a monitoring system to be capable of detecting any change that might at some time in the future be deemed important, while simultaneously requiring that it be tightly constrained in cost or depend on existing systems that have been acknowledged to be inadequate (Background Papers 2 and 3).

It is self-evidently true that the design of any system of information gathering and analysis will determine the range of questions it is capable of answering. Equally obviously, if the design is to be cost-effective, the questions must be framed before design can begin. Over-reliance on a capacity to adapt systems in the future as the questions become clearer may be a costly strategy. Wrong decisions about the fundamentals will see much time, money and effort squandered in the evolutionary process. ANZECC and ARMCANZ have acknowledged (Anon. 1999a) that the Audit presents a unique opportunity to honour the repeated commitments to develop competent monitoring capabilities. The critical need to clearly state objectives, before designing monitoring programs is repeatedly and strongly heard in all of the scientific and management treatments of this activity (above and Background Paper 4). It would be folly to ignore this advice.

Thus, in the absence of detailed guidance from Governments or other stakeholders, it falls to the designers of a framework to specify the questions they have constructed it to answer. Judgments about the quality and relevance of the framework can then be based on analysis of the importance of those questions to the various stakeholders.

3. Framing the Questions

We have shown that there has been a depressing history of decline of fauna and flora in the rangelands, and summarised evidence that indicates that declines are continuing and probably accelerating in large parts of the rangelands (Background Paper 1). A wide range of taxa is affected and the impacts extend over huge areas. Given the pervasiveness of change, it is reasonable to suggest that other, lesser known, taxa may also be experiencing difficulty. However, causes of decline and their full ramifications remain uncertain. Much must be learned about causal processes if the Australian public are to do more than act as spectators to a parade of extinctions and near extinctions. Options to halt loss of biological diversity must be reliably identified and decisions made about the most appropriate responses. Monitoring is then needed to evaluate the responses to conservation initiatives and measure the benefits of improved land management.

The three obligations to record diversity, measure processes and improve understanding have been endorsed in all the international and national instruments we have reviewed above. The ultimate goal of a system for monitoring biological diversity in Australia must be to equip the nation to recognise adverse change, understand the processes at work, and to respond to adverse processes with prompt and effective corrective action. A failure to inform users on any of these three fronts will limit their management options and promote attitudes of impotence rather than the empowerment sought by the Audit.

Accepting the obligation to go beyond observing change to draw inferences about cause and hence identify good options for response, has profound implications for design of a rangelands monitoring program. The most fundamental is that the systematic recording of a suite of measures of biological diversity, no matter how comprehensive, cannot in itself provide an adequate monitoring system. To explore causation requires that a suite of other variables be measured, including those that index variation in intensity and spatial distribution of potential influences on biodiversity values (the pressure and response indicators of State of the Environment reporting are examples).

So far as possible, identification of potential sources of change in biodiversity values should therefore precede design of monitoring systems, to allow those other variables to be incorporated in the framework's features. However, if significant and hence costlty action is to be based on the results of monitoring programs, correlating indices of change in biological diversity values with indices of the putative cause may not be sufficient. The risk of error and inappropriate focus may be regarded as too high. A more robust scientific process may be required, including experimental studies capable of providing strong inference. Incorporating such studies in the fabric of a monitoring program is likely to add substantially to its operational complexity and cost, and so limit the range of phenomena that can be considered.

Making choices for the starting configuration of Australia's national framework for monitoring biological diversity requires an informed decision about the most appropriate mix of a diverse range options. Parts of that task are addressed in Background Papers 2 and 3, which consider respectively the pasture monitoring systems that operate in Australia and the range of potentially useful data sources already reporting on biodiversity issues. There we consider the extent to which they have been or could be employed to analyse the nature and extent of change in natural values associated with use and management of the rangelands.

In addition, the States and Territories are likely to have primary responsibility for implementing a national monitoring program. Assuming that their actions are focused on the issues that cause them most local concern, their existing programs obviously require explicit and careful consideration. We have also summarised the outcomes from our review of the status of rangeland biodiversity and the causal processes invoked in the formal scientific literature (Background Paper 1), to identify recurring themes and concerns.

We use this range of perspectives to identify a minimum set of questions that a useful monitoring system must be capable of answering and, in particular, to inform the most appropriate initial balance among the many options. The process we apply to this task is to frame "pseudo-goals" for the maintenance of biological diversity in rangelands. We label these goals "pseudo-" in the sense that, while they are not specified explicitly in any widely endorsed government policy statement or other instruments, our analysis suggests they are implied by those statements and public expectations. We establish these goals within the context provided by a list of putative threatening processes.

4. Threatening Processes

The key threats to biological diversity in rangelands have been identified in the accompanying document "Biodiversity in the Australian rangelands: a review of changes in status and threatening processes" (Background Paper 1). A synopsis is provided in Table 1.

Clearly a monitoring framework that failed to address biodiversity questions relevant to the most significant of these processes could not satisfy any of the broader operational goals specified in a number of places. We frame questions around these processes below.

Table 1: A list of key processes affecting the biological diversity of the Australian rangelands, condensed from Background Paper 1. Bioregions are those most affected by that threat and are identified using the codes given in Thackway and Cresswell (1994).

Threatening process	***Category of threat***	***Bioregions***	***Quality of evidence for existing or potential impacts on biological diversity***
Tree clearing	*Habitat loss or degradation*	*DU, VB, TEC, DRP, CP*	*Good. Strong theoretical basis and good empirical support in many situations.*
Damage to key sites by grazing animals	*Habitat loss or degradation*	*All, but especially in arid zone*	*Weak: coherent theoretical argument but limited empirical support*
Changed water regimes	*Habitat loss or degradation*	*All, but especially in arid zone*	*Adequate: provision of artificial watering points has increased the proportion of the landscape subject to grazing, reducing biological diversity at some spatial scales. Changes in water flow – e.g. water extraction from Murray-Darling system – have also been shown to have substantial impacts.*
Introduced predators	*Direct impact on populations (Habitat degradation may increase vulnerability)*	*All*	*Good. Convincing experimental evidence for some species.*
Feral herbivores	*Habitat loss or degradation*	*All*	*Weak. Connection between density of ferals & declines in biodiversity not strongly made, but obviously add to total grazing pressure*
Climate change	*Habitat loss or degradation*	*All*	*Weak. Time scales unclear & management responses limited*
Displacement of native perennial grasses and palatable shrubs through grazing	*Habitat degradation*	*All*	*Strong in terms of direct effects on perennial grass diversity* *Weak in terms of roll-on effects on other biota*

Threatening process	***Category of threat***	***Bioregions***	***Quality of evidence for existing or potential impacts on biological diversity***
Invasion of exotic grasses	*Habitat loss or degradation*	*All*	*Strong in terms of capacity of introductions to invade sites & displace native species* *Weak in terms of demonstrated impacts at large spatial scales*
Unsuitable fire regimes	*Habitat loss or degradation* *Direct impact on populations*	*All, especially in northern Australia*	*Strong evidence of impacts on population viability in some woody species* *Emerging evidence of impacts on fauna at smaller spatial scales, but landscape level effects remain unclear*
Disease	*Direct impact on populations*	*Unknown*	*Limited evidence for role in wildlife or native plants declines*
Mining	*Habitat loss or degradation*	*PCA, BHC, COO,MII, TEC, PIL*	*Weak. Areas affected represent tiny proportion of rangeland area*
Hunting	*Direct impact on populations*	*All*	*Weak. Little evidence of adverse hunting impacts anywhere in rangelands*
Commercial harvest	*Direct impact on populations* *Habitat degradation for non-target species*	*Patchy*	*Limited. Examples of commercially-harvested items include kangaroos in all rangeland States and didjeridu stems in northern Australia, but impacts not measured*

4.1. Tree-clearing

Questions here relate to issues of habitat fragmentation and associated impacts on resource density. Theory is well-developed in regard to the impacts of fragmentation on the dynamics of resident populations, which are in varying degrees separated into smaller populations with less exchange of individuals and genetic material among them (Hanski 1991). Outcomes include the loss of non-viable populations from smaller and more isolated fragments, culminating in regional and wider-scale extinctions if the processes continue. Biodiversity questions that might be addressed by well-designed monitoring programs include:

(1) What configurations of woodland or forests in rangeland environments are required to avoid the loss of resident vertebrate species or vascular plant species at the property and bio-regional scale?

(2) What configurations of woodland or forest remnants in rangeland are required to sustain viable regional populations of endangered, threatened, vulnerable or otherwise especially valued species?

Threats posed by reduced density of resources for more mobile animals like nectarivores and insectivores are less well understood. For example, Woinarski et al. (2000) draw attention to the intense seasonal and spatial fluxes of nectar and pollen that occur in the Northern Territory. They identify the potential for loss of one or a few elements to break continuity of availability at particular sites or even at much larger (regional and above) scales. These tentative conclusions are consistent with what is known of the movements of some nectarivores, although the various implications of different patterns of woodland loss cannot presently be reliably predicted in sufficient detail to command management responses. However, it is reasonable to suggest that the loss of highly mobile vertebrates would greatly alter patterns of genetic exchange among populations of flowering plants. Questions that might be addressed by well-designed monitoring systems, especially if they are implemented before land clearing occurs, are:

(1) What configurations of woodland and forest ecosystems are necessary to sustain regional populations of mobile vertebrate nectarivores or insectivores?

(2) What populations of mobile nectarivores are needed to maintain current levels of genetic diversity among flowering plants, especially dominant trees and shrubs?

Both of these sets of questions are based on the pseudo-goals to (i) prevent loss of species dependent on woodlands or forests, or great reductions in their abundance over significant areas (ii) reduce loss of vertebrate animals and vascular plants at the property level and (iii) prevent loss of genetic diversity among flowering woody plants. We consider that ongoing losses of these sorts would be regarded as unacceptable by most stakeholders.

4.2. Damage to Key Sites

The progressive loss or degradation of resource rich patches that are particularly resilient to climatic variation and other forms of disturbance has been proposed as a key factor in the decline of many vertebrate species in the arid rangelands (Morton 1990). Plants dependent on refugia of various sorts are also at risk. Identifying these patches and managing them appropriately has been identified as a key goal for improved biodiversity management in the rangelands. These ideas and ways of implementing them (Morton et al. 1995) have been around for some years, but little or no progress has been made in fostering change. Based on the (pseudo-) goals) to (i) restore mainland populations of arid zone mammals like Bilby and Mala and (ii) prevent further regional extinctions of plants or animals, questions arising are:

(1) What components of the landscape are particularly important for vertebrate wildlife and vascular plants under adverse conditions and what features of these landscape components are most important?

(2) What effects are managed and feral herbivores and predators and exotic plants having on these sites?

(3) Are these features amenable to management action to prevent damage or restore their ecological function, and what are the most promising management options?

4.3. Introduced Predators

Australian rangelands have been invaded by a number of vertebrate predators, most notably the fox and the cat. There has been a number of experimental demonstrations of the positive effects of removing these predators (especially foxes: e.g. Kinnear et al. 1998), although there may be unfortunate side-effects such as increased populations of introduced rabbits (Banks et al. 1998). There is some suggestion that cats were introduced prior to European settlement and are perhaps now occupying the range of habitats they are capable of using under contemprary conditions. However, foxes may still be increasing their range in Australia and the impact of cats may vary with the condition of habitat (e.g. shelter available to native vertebrates). Impacts of feral predators on native wildlife may vary if alternative exotic prey (e.g. rabbits) are controlled. It would seem desirable to maintain some awareness of the distribution and relative abundance of these introduced animals so that risks can be assessed and the potential for management intervention maintained. If the (pseudo-) goal to minimise risks posed by predators is accepted then questions that might be addressed by well-designed monitoring programs include:

(1) Are the ranges and relative abundances of exotic predators changing in the rangelands, and are control programs influencing trends in distribution and abundance of exotic predators?

(2) Are changes in range and abundance correlated with changes in the conservation status of vulnerable vertebrate fauna, or with changes in land use patterns or management practice?

4.4. Grazing and the displacement of native perennial grasses (or other native perennial ground cover)

Perennial grasses and palatable shrubs are themselves important components of rangeland biodiversity. Changes in their relative abundance may also signal changes in floristics including displacement of less common plants. Perennial grasses and shrubs support native grazing animals and wildlife, including those dependent on seed (Garnett and Crowley 1995). Many of the seed-eating vertebrate taxa appearing to be in decline (Franklin 1999; Woinsarski, in press). Based on the (pseudo-) goal to prevent further loss of vertebrate animals and vascular plants from the arid zone and a spate of new losses of plants or animals from the tropical rangelands, the following questions are suggested:

(1) Which plant taxa are most at risk of displacement by grazing?

(2) Are long-term declines in relative abundance and diversity of native perennial grasses and palatable native shrubs associated with loss of floristic and vertebrate diversity at the property and regional scales?

(3) Which animal taxa are most susceptible to changes in native perennial grass and shrub diversity, abundance or seed production?

(4) What patterns of native grassland/shrubland diversity and disturbance regimes are necessary to sustain regional populations of fauna known to be at risk?

(5) What management options are available to ameliorate biodiversity effects of reduced native perennial grass and shrub diversity, declining relative abundance or reduced seed production?

It is obvious that these questions differ markedly in their detail and underlying assumptions about the ecological roles of perennial grasses from those framed under the landscape function paradigm. The particular mix of species may be all but irrelevant from the functional (e.g. nutrient trapping and cycling) view, but vital to maintain continuity of a supply of food for native animals under variable conditions. This is only one of the reasons why prevailing measures of landscape function cannot presently be substituted for measures of ecological function.

4.5. Invasion by exotic plants

A large array of weeds affect both production and biodiversity values (Anon. 1997) . Some species form monocultures that displace all native plants from substantial areas, and provide little suitable habitat for wildlife. However, these problems are not confined to plants that have been formally recognised as weeds.

Under the landscape function paradigm, one grass is as good as another, provided it is resilient to the prevailing disturbance regime. Thus a well-grassed landscape dominated by an exotic perennial that displaces most native species, produces few seeds that can be used by native wildlife or produces them at different times from native species, would be classed as highly functional, even though the landscape is able to support many fewer native animals and plants.

A number of introduced pastures are causing concern for the future of perennial grasslands in the rangeland environment (Whitehead and Dawson 2000; Fairfax and Fensham 2000). The continued spread of these species may have profound consequences for rangeland biodiversity. It is therefore desirable that their spread be monitored and, ideally, halted while the full implications are assessed. Questions raised by the (pseudo-) goals to (i) prevent loss of species dependent on grasslands and shrublands or great reductions in their abundance over significant areas (ii) prevent gross changes in the ecological character of ungrazed lands; and (iii) reduce loss of vertebrate animals and vascular plants at the property level and above, are :

(1) Are exotic pastures and other exotic plants (e.g. shrubs) continuing to spread in rangeland environments and to what extent are they invading sites outside the pastoral estate?

(2) What are the impacts of exotic pastures and other exotic plants on biodiversity on pastoral lands and how far do these impacts on pastoral lands extend beyond the property scale to regional and larger-scales?

4.6. Changed fire regimes

Changes in fire regimes associated with pastoralism and cessation of Aboriginal burning regimes are compromising both biodiversity (Russell-Smith et al. 1998) and production values in the rangelands (Dyer 1997). Declines in granivorous birds and mammals in the tropical savannas may be associated with altered fire regimes (Franklin 1999). It has been proposed (Bolton and Latz 1978; Lundie-Jenkins 1993) that declines in some arid zone mammals are due to the loss of small-scale patchiness resulting from repeated fine-scale

burning by Aboriginal people, although weak tests of this idea have not provided support (Short and Turner 1994). Progress against a pseudo-goal to prevent further loss of vertebrate animal and vascular plant diversity will require monitoring of prevailing fire regimes and their implications. Questions to be addressed by the monitoring framework therefore include:

(1) What are the prevailing fire patterns across Australia's rangelands?

(2) How are prevailing patterns of burning correlated with distribution and abundance of vertebrate animals and vacular plants in the rangelands at different spatial scales?

(3) What are the options to re-instate burning regimes favouring maintenance of rangeland biodiversity, and are those options compatible with the maintenance of production or other (e.g. aesthetic) values?

(4) How do fire regimes interact with other processes affecting biological diversity in rangelands?

4.7. Changed water regimes

Introduction of additional artificial watering points to the rangelands has had a number of impacts on biodiversity values. Some native species have been favoured by improved access to reliable water supplies (e.g. James et al. 1999). Others have been disadvantaged by extension of grazing into areas previously too isolated from water to be used by stock (Landsberg et al. 1997) . Extraction of groundwater and (in some cases) unregulated discharge may lead to broadscale changes in vegetation pattern. Impoundments and associated irrigation schemes have had extremely damaging effects on entire floodplain systems and downstream riverine systems (e.g. Kingsford 2000). Exotic semi-aquatic plants and use of ponded pastures threaten wetland systems in northern Australia (Clarkson 1995; Whitehead and Dawson 2000).

Subject to acceptance of a goal to minimise further detriment to rangeland systems through patterns of water management, we suggest that it is desirable that the following questions be addressed under the monitoring framework.

(1) Is the proportion of the rangeland subject to grazing increasing due to increased numbers and wider distribution of artificial watering points and what are the regional and wider-scale implications of these trends for biological diversity?

(2) Which endangered, threatened or vulnerable species are most likely to be adversely affected by increased use of artificial watering points?

(3) What impacts are water use having on important water-dependent environments, including mound springs and other permanent or ephemeral wetlands?

4.8. Feral Herbivores

Populations of feral herbivores increase the total grazing and browsing pressures on the rangelands. Impacts from rabbits (Williams et al. 1995), goats (Parkes et al. 1996) and pigs (Choquenot et al. 1996) are best documented, but effects of larger feral stock are also likely to be significant (Fogarty 1982; Bowman and Panton 1991; Dobbie et al. 1993). Whitehead

(1986) estimated that prior to the completion of the Brucellosis and Tuberculosis eradication campaign, the total number of large feral stock in the Northern Territory rangelands exceeded the managed herd by a considerable margin.

A reasonable pseudo-goal in regard to feral herbivores will be to reduce the total grazing and browsing pressure and hence impacts on biodiversity on rangelands, by controlling feral species and populations that do not contribute to economic production. Questions for a monitoring program derived from this goal are:

(1) What are the trends in distribution and abundance of feral herbivores and what ecosystems and regions are most affected by the dominant feral herbivores?

(2) To what extent are resources for control directed at sites and species that reduce impacts on biological diversity in the rangelands?

4.9. Animal Disease

Spread of animal disease (including parasitism) through domestic or feral animals has been suggested as a cause of declines in some native species (e.g. Braithwaite and Griffiths 1994; Tidemann et al. 1992), but the evidence remains equivocal. In part that uncertainty derives from a paucity of studies of wildlife disease in Australia. Given the limited effort currently devoted to this work in any jurisdiction, there seems little point at this time in seeking incorporation of disease surveillance in a national biodiversity monitoring framework. However, this situation should be reviewed early in the life of the framework.

4.10. Hunting

Aboriginal people harvest native plants and animals in significant numbers, at least in the rangelands of northern Australia (e.g. Vardon et al. 1997). Traditional controls have broken down in many areas, leading to concerns that some species may be over-exploited. Impacts are not well understood. Some Aboriginal groups report declines in some preferred species, but it is unclear whether these effects are due to over-hunting or environmental change associated with fire or other disturbances. Recreational hunting of native species is mostly limited to waterfowl and appears to have little impact on managed and monitored populations, even in the more densely populated parts of the nation (Briggs et al. 1985; Whitehead et al. 1988; Kingsford et al. 1999).

Systems for documenting harvests and their effects are not well developed in the mostly sparsely populated remoter parts of Australia where subsistence hunting continues to be significant. There are few sources from which a regional or national perspective could be built. We therefore propose no arrangements for monitoring hunting activity in the framework at this time. However, this may need to be reviewed when a larger number of Aboriginal groups actively exercise Native Title rights. There may be an associated increase in the number of people hunting, which will assume particular importance if diversification of commercial use of native species also occurs (see 4.12 below).

4.11. Mining

Impacts of mining are mostly localised, and cannot be related to observations of biodiversity change (widespread decline of birds and mammals) that give rise to most concern. However, the harsh and variable climate of much of the rangelands means that features like tailings dams may act as "traps" for large proportions of regional populations of mobile animals (especially birds) when they are already under stress from drought. Large kills are episodic (e.g. Sinclair et al. 1997), but frequencies of such incidents are likely to increase as the number of such features increases. Whilst we do not propose inclusion in the initial framework, the option should perhaps be retained to record the number and location of exposed toxic waste sites so they can be related to trends in biological diversity. In addition, cooperation should be sought from mining regulators to report kills to those agencies responsible for biodiversity conservation.

4.12. Commercial harvest of native species

A number of native plants and animals are currently harvested commercially from the rangelands. Grazing constitutes a form of plant harvest, but more direct uses include mallee for firewood, Eucalypt stems for didjeridus, sandalwood and *Melaleuca* species for products like oils. Large macropods are taken commercially under management regimes that also seek to reduce their numbers because they compete with domestic stock (Lunney and Grigg 1988). These harvests are regulated under permit systems that require submission of returns by permit-holders. Thus the potential exists to aggregate data to provide an overview of such activity and relate it to patterns of change in biodiversity. The existing kangaroo monitoring programs (see Background Paper 3) are particular suitable for incorporation in a rangelands monitoring framework, not so much because they directly reveal a great deal about biodiversity under prevailing conditions, but because they provide a long term view of change in the rangelands and their capacity to support native herbivores as use intensifies.

There are frequent calls for diversification of rangeland production (e.g. Senate Rural and Regional Affairs and Transport References Committee 1998; Anon. 1999) and it is likely that use of native species will increase. Proponents of the use of native species seek to reduce pressure on the rangelands by substituting alternatives to grazing. However, given the extreme economic pressures under which many rural communities presently operate, there is a risk that new resource uses might simply be added to already considerable demands on fragile environments. For example, timber harvest for a variety of purposes might add to the impacts of land clearing. It is therefore desirable that the growth of these industries be tracked and the implications for rangeland biodiversity carefully assessed. The pseudo-goal of ensuring that all commercial harvest of native species is sustainable and hence does not significantly reduce diversity at any spatial scale raises the following questions that might be addressed by a monitoring framework.

(1) What are the dominant trends in commercial use of native species and are changes in diversity, frequency and intensity of commercial use of native species associated with changes in regional biodiversity, affecting harvested or other species?

(2) Are changes in diversity, frequency and intensity of commercial use of native species associated with reductions in intensity of grazing?

4.13. Summary

This array of questions derives from what we consider to be some basic goals for the management of biodiversity in rangelands. In summary the key goals as we have constructed them from various statements of government and stakeholder intent, are to:

(1) maintain present levels of diversity of vertebrate animals and vascular plants at regional scales and above;

(2) restore viable populations and habitats of rangeland species lost or presently contracting in range; and

(3) are best achieved by:

(4) understanding effects of structural modification of forest and woodland habitats on plant and animal populations, and managing land clearing to minimise losses of species and genetic diversity;

(5) understanding and better managing effects of domestic stock on rangeland environments to minimise adverse impacts on ecologically significant native plants;

(6) understanding and minimising the impacts of feral herbivores on rangeland biodiversity and, in particular, reducing the contribution of herbivores to total grazing pressure;

(7) understanding and reducing effects of predators on dynamics of small vertebrate populations;

(8) improved understanding of invasion processes and their implications for minimising impacts of exotic plants on biological diversity at all scales; and

(9) improved understanding of effects of the distribution of stock watering points on biodiversity at a range of spatial scales, including the regional.

This statement of concerns and the associated questions are based on a detailed analysis of the dominant threats to rangeland biodiversity identified by a large number of workers over many decades. Although we have not attempted to address all goals nor frame all significant questions, the most casual examination of these questions highlights the complexity of the issues and the extensive work and careful design that will be necessary to address them. It is clear that a monitoring framework and associated activity capable of dealing with all of them would require a massive commitment of effort.

We have therefore also considered the monitoring the programs currently operated by the States and Territories in rangeland areas, what they indicate about their priorities and the extent to which existing activity can contribute to biodiversity monitoring.

5. Tightening the focus

5.1. Agency priorities

In Background Paper 3, we summarised programs identified by the State, Territory and Federal Governments as relatively large scale monitoring efforts to which they devote significant resources. This is by no means a complete list of Government and other activity,

but we consider that the sample is sufficiently large to serve as an indicator of the directions in which local concerns have pushed monitoring priorities relating to biodiversity (readers seeking additional information should consult Background Paper 3).

The salient features of the sample are:

(1) All States maintain substantial wildlife (flora and fauna) inventory programs, confirming in the most direct way the continued need for baseline information in the rangelands.

(2) Large-scale aerial surveys for kangaroos and feral ungulates dominate quantitative survey programs. They are not linked to assessment of range condition.

(3) Endangered species monitoring programs are common, but these schemes are mostly highly localised and not explicitly linked to range condition or other monitoring programs.

(4) Parks and Reserves monitoring programs are sparse and, where they exist, deal mainly with dominant processes (fire, grazing, invasive plants) rather than comprehensive monitoring of species or assemblages on conservation lands. They are rarely linked to programs outside reserves. Australian jurisdictions are cooperating to develop better monitoring systems for parks through the ANZECC Working Group on National Parks and Protected Area Management, and there is a good deal of international activity (e.g. Hosking et al. 2000) with which it would be timely to form links.

(5) A number of localised studies are designed specifically to provide information on effects of grazing on biodiversity, but lack the spatial coverage of pastoral monitoring schemes (Background Paper 2) and are rarely explicitly linked to those schemes.

(6) Schemes for monitoring impacts of feral animals focus strongly on rabbits and are not explicitly linked to monitoring of range condition.

The most striking features of this summary are (i) the scale of the commitment already made by State and Federal authorities to monitoring of aspects of rangeland biodiversity and (ii) the absence of linkages between the programs of conservation agencies and equally substantial commitments of primary production authorities who also monitor some aspects of biodiversity and landscape function.

Given the scale of the monitoring challenge, it is clear that the best possible use should be made of existing work, and the design of the framework should be capable of incorporating existing programs. There would appear to be a great deal being done under existing programs that could be better used if supplemented and integrated in a coherent way.

6. Criteria for a Monitoring Framework

The preceding discussion (Sections 2-5) positions us to derive a list of the criteria that the Audit's biodiversity monitoring framework must satisfy if it is to meet the stated expectations of the international community, the State, Territory and Federal Governments and other stakeholders, including a capacity to address the key questions identified in our analysis of threatening processes in the rangelands. We list them below in Tables 2 (operational criteria) and 3 (attributes necessary to address key questions).

We consider that these tables capture the minimum set of capabilities that a national monitoring framework must be capable of incorporating when it reaches its full operating capacity.

Table 2: Operational criteria to be satisfied by a framework for monitoring rangeland biodiversity if it is to meet the expectations of Government and stakeholders, as established in a range of widely endorsed policy and strategy statements.

	Criterion	**Source**
1.	Improves baseline knowledge of biodiversity components	CBD, NSCABD, NPGRM, EPBCA, BP1
2.	Tracks trends in biodiversity values at regional scales and above	NSCABD, MNRRA
3.	Provides information on significant adverse processes	CBD, NSCABD
4.	Tests links between adverse processes and biodiversity status	NSCABD
5.	Validates surrogates or indicators of biodiversity values	NSCABD, Audit work plan
6.	Identifies appropriate management responses to adverse trends	NSCABD, BP2, this analysis
7.	Designed to scale from sites to regions to national perspectives	MNRRA, Audit work plan
8.	Based on secure field sites	NSCABD
9.	Integrated with relevant ecological research	NSCABD, BP3
10.	Provides early warning of adverse change	NPGRM, MNRRA, this analysis
11.	Integrates with regional planning processes	NPGRM, MNRRA, NSCABD
12.	Provides base for inter-regional comparisons	NPGRM
13.	Derives principally from existing State and Territory programs	Audit work plan, this discussion
14.	Provides information on species suitable for sustainable use	CBD, MNRRA
15.	Incorporates standardised techniques	NSCABD, MNRRA
16.	Applies remote sensing technology to permit extension to large spatial scales	NSCABD, MNRRA, Audit work plan
17.	Contributes to regular public evaluation of rangeland condition	NPGRM, MNRRA, Audit work plan
18.	Accessible to and empowers land owners and resource managers (decisions makers)	MNRRA, Audit Integration Report
19.	Applies on grazed, ungrazed occupied, conservation and unassigned lands	Audit work plan, BP3
20.	Integrates with and fosters comparisons with indicators of other rangeland values, especially measures of landscape function	Audit work plan, this analysis, MNRRA, BP2
21.	Retains flexibility to incorporate new information as it becomes available or circumstances change	Audit work plan, this analysis

Notes: BPx=Background paper x; CBD=Convention on Biological Diversity; EPBCA=*Environmental Protection and Biodiversity Conservation Act* 1999; MNRRA=Anon. (1999b); NPGRAM=Anon (1999a); NSCABD=National Strategy for the Conservation of Australia's Biological Diversity.

Table 3: Attributes of a framework for monitoring rangeland biodiversity needed to meet the expectations of stakeholders, and to answer the key biodiversity questions and management challenges identified in this study.

	Criterion	**Questions addressed**
1.	Incorporates sampling designed to reveal landscape-scale responses to habitat fragmentation	1, 2, 3, 4
2.	Biodiversity sampling is matched to remote sensing or other measures of habitat fragmentation that provide large scale perspectives	1, 2, 3, 4, 5
3.	Measures of variation in habitat quality include attributes that do not necessarily involve obvious change in habitat structure	5, 6, 7
4.	Variation in habitat quality can be related to grazing pressure or other measure of land use intensity	5, 6
5.	Biodiversity measures include indices of feral predator distribution and relative abundance	6, 8, 9, 23, 24
6.	Provides for measures of change in diversity, identity and abundance of perennial grasses and palatable shrubs to be related to wider floristic and faunistic diversity (i.e. links aspects of landscape function directly to biodiversity values)	10, 11, 12, 13, 14, 5, 6, 7
7.	Sampling designs allow inference about causes of change in ecological function and hence identify appropriate management response for subsequent testing	all
8.	Provides information on rate of expansion and increase in relative abundance of exotic pastures and other weeds on all land tenures	6, 11,
9.	Relates biodiversity values to distribution and abundance of exotic pastures and other weeds	6, 11, 12, 13, 14, 15, 16
10.	Matches biodiversity sampling regimes to variation in fire patterns and histories	17, 18, 19, 20
11.	Provides capacity to measure or predict biodiversity change from change in water point availability and the hydrological change	21, 22, 23
13.	Tracks trends in commercial use of native species, and relates patterns of use to nature and intensity of other land use	26, 27
14.	Methods are applicable across all land tenures to ensure that sampling covers the widest possible range of land use intensity, including reserved lands, to provide for robust inference	All
15.	Designs and supporting administrative arrangements permit robust tests of inference	All

We have shown elsewhere (Background Papers 1 to 3) that the current systems of monitoring of biodiversity and production values in rangelands are deficient in a number of respects and are hence incapable of satisfying most of these criteria or addressing the most significant questions. The principal weaknesses relate to (i) failure to cover the full range of environment types, (ii) failure to sample sufficient proportion of the full range of disturbance types and intensities (especially of grazing), (iii) jurisdictional differences in approach and intent, and (iv) the absence of integration of biodiversity and production oriented measures, even within jurisdictions.

7. Existing and Proposed National Monitoring Frames

At the national level, a number of steps have been taken to establish systems for monitoring the condition of Australian environments, including the rangelands. We now relate our assessment of the necessary componenants of a rangelnd monitoring scheme to existing national monitoring programs (SOE reporting and the Montreal Process) and developments under the Audit.

7.1. State of the Environment

A broad biodiversity monitoring framework has been established as an element of the State of the Environment Reporting initiative (Australian and New Zealand Environment and Conservation Council State of the Environment Reporting Task Force 2000). That framework is built around identification of a group of core indicators for biological diversity that are reproduced in Table 4. A number of these indicators deal with the threatening processes we have discussed above and are consequently relevant to rangeland monitoring.

We have argued elsewhere that the SOE necessarily focuses on issues of general relevance and that can be reliably indexed across a huge range of environments and resource use issues. However, the rangelands are in part defined by their relatively higher levels of structural integrity and narrower range of land uses than other landscapes used for intensive production or habitation. It is reasonable to anticipate that usefully indexing the condition of biodiversity in the rangelands will require finer discrimination than currently provided under the SOE. We have shown that subtle variation in habitat condition, that is not captured in obvious changes such as land clearing, are having a major impact on some important fauna. Thus the SOE indicators are best viewed as providing elements of the upper level of a hierarchy within which more refined rangeland indicators may be nested.

7.2. Montreal Process – Biodiversity Indicators

The States, Territories and the Federal Government have reached agreement on a set of indicators for sustainable forestry. They based this framework on criteria and indicators established under the international Montreal Process. Details of biodiversity indicators are provided in Table 4.

Although of limited direct relevance to rangeland management, the indicators derived are of some interest because they represent a slight extension of the SOE indicators. They repeat the emphasis on fragmentation, which is obviously particularly relevant to forest management, but also introduce more detailed assessment of condition (age or successional stage of regrowth) that influence the capacity of forest fragments to support fauna. Measures of genetic diversity are also proposed. This attempt at more challenging and informative measures of forest condition is consistent with our view that subsets of the Australian environment (like the rangelands) would be expected to substantially add to and extend the coarse appraisal exemplified by the over-arching State of the Environment reporting.

7.3. Other Audit Initiatives

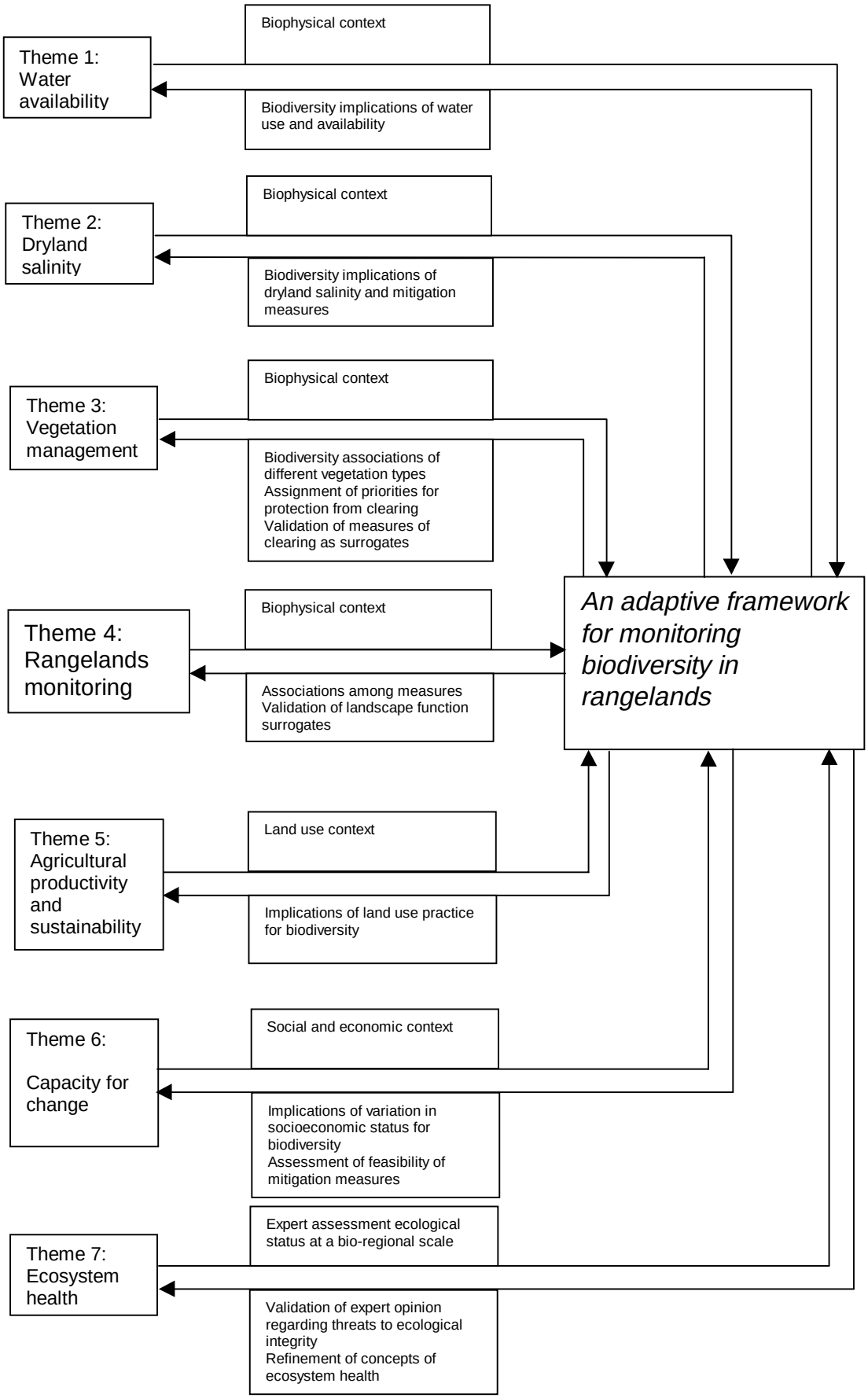
The National Land and Water Resources Audit is organised under 7 themes: Water Availability; Dryland Salinity; Vegetation Management; Rangeland Monitoring; Agricultural Productivity and Sustainability; Capacity for Change; and Ecosystem Health. All have relevance at some level to the monitoring of rangeland biodiversity because they consider factors influencing management practice and their links to sustainability. The most directly relevant are those that provide information or methods for monitoring putative threatening processes over the long term. The most important of these are:

- Projects 2.1 and 2.4 providing for assessments of future dryland salinity damage and methods for monitoring dryland salinity. These data will be useful for statistical analysis of land condition correlates of biodiversity status at a range of spatial scales, to validate indicators and assign regional priorities.
- Project 3.2 and 3.3 which compile existing digital vegetation data and identify gaps where more detailed mapping is required. Compatible vegetation data that seamlessly crosses jurisdictional boundaries at larger scales is necessary for comprehensive analysis of correlates of biodiversity status and proper tracking of land clearing.
- Project 4.1 provides measures of land condition from a variety of perspectives, none of which has yet been shown to be well correlated with direct measures of the status of biodiversity. Examining relationships between measures of land condition and independent measures of the status of biodiversity at large spatial scales will be important to:
  - assess the extent to which land condition measures might be used as surrogates for some elements of biodiversity
  - contribute to separation of environmental (e.g. climatic) noise influencing variation of direct measures of biodiversity status from underlying trends associated with land condition.
- A number of Theme 5 projects provides information which may be useful to predict directions likely to be taken in enterprise diversification and land use practice, which may in turn identify emerging problem areas for biodiversity and assist with the assignment of priorities for monitoring.
- Similarly, socioeconomic analysis under Theme 6 may be useful to assess likelihood of adoption of sympathetic or inimical land use practice and to monitor impacts of adoption.
- Outputs from Theme 7 provide useful contextual information for understanding of patterns of biodiversity in rangelands and likely sources of change. Project 7.4 in particular will provide an overview of the ecosystem health of bioregions that complements the analysis of biodiversity issues by rangeland bioregions provided in Background Paper 1 to this study.

The Rangeland Monitoring Theme is obviously the most directly relevant, as it includes a number of projects that provide broad scale measures of range condition and trends. The principal utility of all of these other projects for biodiversity monitoring is to improve understanding of the relationships between biodiversity status and land use/condition and socio-economic indicators. For example, use of remote sensing to monitor ecosystem response to rainfalls (Project 4.1.3) will strengthen capacity to interpret seasonal, annual and longer variation in measures of biodiversity status. Measures of land use intensity (grazing pressure) will contribute significantly to capacity to relate biodiversity status to management practice at a range of spatial scales. Integration is essential if monitoring schemes are to genuinely empower decision-makers by permitting exploration of causal relationships. As well as identifying problems, indicators must collectively point to solutions in the form of appropriate management responses.

In considering options for measures to be incorporated in a framework for biodiversity monitoring, we have explicitly considered relevant Audit initiatives (Section 9). We have not assumed that these initiatives will necessarily continue beyond the life of the Audit, but have identified those areas where we consider that continuation of work currently being done under the Audit or partially supported by it, will make an important contribution to an ongoing framework for monitoring and management of rangeland biodiversity, and the ongoing assessment of the quality of management for sustainability (Figure 1).

Figure 1: Some of the relationships among the various components of the Audit program. It may require some years for all of the potential linkages and benefits of integrated analysis to be



realised.

8. Options for an Adaptive National Framework for Monitoring Rangeland Biodiversity

A great many options are available to the Audit to design a monitoring framework that accommodates these various demands and satisfies the criteria we have outlined, or at least has the potential to do so over the long term. Many public statements of intent, like the National Biodiversity Strategy, indicate that there is support for considerable enhancement of existing arrangements for monitoring biological diversity in Australia. We have shown that existing arrangements in the rangelands and the level of support they currently receive are inadequate to address the most basic objectives in regard to biodiversity, despite the substantial investment in monitoring condition of leased lands from a production perspective. A substantial additional investment of public funds will be necessary to provide a genuine improvement capable of providing useful information.

However, we are mindful that others have made substantial investments but have yet to produce a robust national system for monitoring biodiversity (Background Paper 4). We are also acutely conscious of the difficulties that inevitably arise in achieving agreement among State and Territory jurisdictions in regard to national-scale initiatives in land management. The chequered history of the National Rangelands Strategy in its various guises is eloquent testament to the challenges involved. Difficulties will be exacerbated if proposals for change are radical, States and Territories may be seen to be deferring to the Commonwealth at some detriment to local influence or relevance, or costs are high. The notion of an "adaptive" system is particularly important here, because it offers the opportunity to introduce change in a stepwise fashion, demonstrate utility and gather support for further enhancement. This idea has strongly influenced our approach to the identification and consideration of different options. We turn now to a discussion of those options.

8.1. Operational Options

For the purposes of the present discussion, it is convenient to divide the operational options available to the Audit into four broad categories.

(1) Independent reporting within a common framework
   (a) data from existing State and Territory systems
   (b) agreement on a common reporting framework dependent on shared elements
   (c) each jurisdiction reports independently using common content and modes of presentation

(2) Integrated analysis within a common reporting framework as above, plus
   (a) integrated analysis carried out by a specialist group
   (b) specialist group may, based on experience of integrated reporting, suggest enhancements of State/ Territory systems to improve comparability
   (c) specialist group prepares integrated national report

(3) Integrated analysis based on enhanced data collection systems

   (a) State and Territory jurisdictions adopt enhanced data collection and collation methods (including some new surveys, variables and indicators subject to validation) to improve relevance and capacity to address recognised challenges

   (b) Integrated analysis by specialist group provides feedback for ongoing adjustment to system.

(4) Ideal biodiversity monitoring system

   (a) built from scratch to provide an optimal system, using existing data and systems only where compatible with an optimal output

   (b) large proportion of new (enhanced) systems

   (c) agreed by States, Territories and Commonwealth

   (d) all jurisdictions adopt standardised systems

   (e) specialised group designs, implements and analyses monitoring programs

These categories are of course somewhat arbitrary, and it is possible to conceive many variants and combinations of the features identified. Nonetheless, we consider that in this simplified form they provide a useful basis for further discussion.

8.2. A common reporting framework

The first of these options, based on a common reporting frame, is a component of all others. Under such a basic scheme, the States and Territories would use the information they presently have at their disposal to report individually to a relevant commonwealth agency, but under common agreed headings. Such schemes already exist in respect of the State of the Environment reporting and many other individual schemes (e.g. national reports to the Ramsar Convention, World Heritage Convention).

Because there exist such disparities among the States and Territories in the quality and coverage of rangeland data they can presently provide, a national framework for monitoring biological diversity that sought no more than a common reporting frame would necessarily follow a minimalist path. There would be neither incentive nor facility to capture the additional rather fragmented data from non-pastoral monitoring systems that we have identified in this paper as potentially useful. Therefore the system would mostly fall back on pastoral monitoring schemes that we have shown are inadequate for biodiversity monitoring, at least when considered in isolation. Such a system would not encourage advances in the quality of analysis of relevant data nor generate new insights and understanding. Individual jurisdictions may tend to skew their reports to their particular circumstances. A national perspective is unlikely to emerge from a series of idiosyncratically variable statements, even if the underlying data are to some extent comparable.

A common reporting frame for rangelands cannot in itself provide decision-makers with a clear view of the status of biological diversity in the rangelands, even if nested within other national reporting frames like the State of the Environment reporting. Links between large-scale processes and structural changes and biodiversity, on which schemes like the SOE

reporting mechanisms have tended to focus, have not often been explicitly made. Despite such frills as a special terminology (e.g. categorisation as pressure, condition, and response indicators), SOE core indicators for biological diversity rarely extend much beyond the recognition of some conditions or processes regarded as self-evidently bad and a number of responses as probably good. Yet we know that the intuitively bad processes are not responsible for some of the major biodiversity problems in the rangelands (Franklin 1999). Moreover, it is implicit in the definition of rangelands that they would be expected to have a better biodiversity status than lands used for more intensive production. A credible monitoring framework for the rangelands should be matched to that "better" status, rather than retreat to the limited vision of the SOE. Indeed, the limited scope, relevance and influence of the SOE indicators is a good illustration of the limitations of the "common reporting frame".

The common reporting frame could at best be regarded as a modest step towards a larger goal. Its only advantage is that it could be achieved at limited cost. It would not be a sufficient advance to be legitimately treated as meeting the Audit's brief.

8.3. Integrated analysis

A facility for taking existing information and providing integrated analysis and presentation across jurisdictions is the absolute minimum that could legitimately justify description as a national framework. It could make use of some of the non-pastoral monitoring information we have outlined above and in Background Paper 3. Even if it began with a somewhat disparate aggregation of information, the discipline of regular integrated analysis and reporting on implications and, importantly, constraints on quality of conclusions, could encourage review of current programs and movement towards a more coherent and somewhat standardised approach to data collection and management. A structured process of regular analysis, feedback and review, if actively encouraged by relevant Ministerial Councils, may provide the nucleus of an adaptive framework at modest cost.

We anticipate that full time staffing of 3 or 4 would be required to provide the level of activity and quality of products that would encourage the different jurisdictions and their representatives to take the issue seriously and so encourage growth and enhancement through time. In discussing the potential elements of a larger framework, we have repeatedly emphasised the need to bring a rangeland biodiversity perspective to bear on design of new or emerging initiatives in natural resource inventory, mapping or monitoring. A group with clear status and mandate will be required to assert that vision.

Possible structures for a specialist group briefed to undertake integrated analysis has been the subject of some discussion with State and Territory representatives. There was general agreement that a body established within a Commonwealth agency and formally answerable only to Commonwealth officials would encounter considerable resistance. Many of the reasons given for this view are cogent and relate chiefly to (i) the need for familiarity with State/Territory data and (ii) the obligation to encourage enhancements. Both of these issues would be best dealt with by bringing together a group comprising technically competent State and Territory representatives, who meet periodically to undertake the necessary analysis. Such an arrangement would provide State/Territory ownership of the process and,

importantly, a mechanism for problems and options for enhancement to be taken back to the individual jurisdictions. Although such an arrangement constitutes an apparently modest step, the challenge involved in assembling relevant data, understanding its limitations and designing systems that permit joint use will be far from modest. It will be sufficiently demanding that State and Territory jurisdictions may seek funding to allow diversion of key staff from their existing tasks.

However, the chief drawback of such a limited arrangement, unsupported by prior agreement about the nature of the enhancements to be pursued, is that it would be slow to produce results. The current commonalities in data content are so limited and variation in the quality and compatibility of databases so substantial that initial outputs would produce relatively modest insights and a great deal more in the way of justificationfor change in State and Territory processes. A slow process of growth may try the patience of politicians, bureaucrats and the public and ultimately discredit attempts to establish greater coherence. Rather than adaptation of an initially weak framework to ultimately greater fitness, there may be a greater likelihood of extinction in a challenging inter-jurisdictional environment.

8.4. Integrated analysis within an enhanced reporting system

The third option constitutes an extra step towards an informative system. It would add, to the common reporting and integrated analytical frames, a number of new data sources, improvements of existing sources and linkages among key components of the monitoring systems. The important additions will be new biodiversity surveys linked to monitoring of landscape function and programs to monitor particularly sensitive elements of the fauna and flora. The purpose of these additional data will be primarily to validate indicators and surrogates, so that a more streamlined but highly robust framework might be developed over the longer term. We consider it realistic to seek agreement for an enhanced framework that deals from the outset with some of the more fundamental problems with the existing arrangements. Although the process of achieving agreement about the particular form of that framework may not be simple, once introduced the resultant scheme is likely to more quickly produce useful results and so increase the prospects of its long-term survival and growth towards a genuinely informative system.

8.5. A technically ideal system

A number of attempts have been made to develop sophisticated environmental monitoring systems that emphasise technical quality (Background Paper 4). Perhaps the best known of these is the USA's National Environmental Monitoring Initiative. This comprises 3 tiers:

- spatially continuous monitoring and inventories (including remote sensing) that completely census specific attributes across a large region (>10,000 km^2)
- spatially subsampled surveys that are designed to evaluate the status of a complete region by sampling a subset of the region
- intensive research sites that are selected for their known ecological condition or suitability for experimental manipulation.

The Initiative brings together information from individual programs valued at several hundred million dollars, and is supported by research programs like the Environmental Monitoring and Assessment Program (EMAP) of the US Environmental Protection Agency (USEPA) (see Appendix 4). EMAP itself has had working budgets exceeding US$40 million p.a. Using these funds and links to other activity, EMAP seeks "to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources".

EMAP has provided funds for research on such related matters as Multi-Tier Monitoring Design and identification of robust indicators of environmental condition. The challenge facing a nation like Australia is equivalent in scale to that faced by the US, but must be confronted with a much less developed infrastructure and smaller resource base. Biodiversity loss has been greater and happened more quickly here, so the Australian challenges are in some ways actually larger.

The US experience confirms that biodiversity values present particularly intractable monitoring problems. There are neither convenient shortcuts nor simple rules that Australia can adapt from other places to simplify the task that Governments and other stakeholders have set. Given that one cannot measure everything of interest in the many ways that biological diversity presents, no matter how ambitious and expensive the monitoring program, any framework must be a compromise, initially based in part on guesswork.

In the Australian context, perhaps the most serious attempt to outline a system to provide a robust baseline and framework for ongoing monitoring of biological diversity is the report of Hopkins and McKenzie (1994). They proposed a series of permanently marked monitoring benchmarks placed to comprehensively sample the environments of the arid and semi-arid lands of Australia (much of the rangelands). They estimated that the initial cost of providing the baseline for 1400 to 2800 sites would be about $35 million (in 1994 dollars) and require recurrent expenditure of around $9 million pa for repeated sampling at intervals of 10-15 years and for data management. Their estimate did not include costs of remote sensing nor additional costs for linking biodiversity measures to other forms of environmental monitoring. Such figures are minor in terms of total Federal and State Government budgets for other purposes. However, recent history (including the failure of Governments to seriously consider the Hopkins and McKenzie proposal) suggests that such ambitious schemes are unlikely to receive serious consideration as a component of contracting environmental and resource management budgets.

It is equally obvious that both the US experience and the Hopkins and McKenzie (1994) proposal are based on simple and compelling logic. A national framework for monitoring biodiversity must bring together information from a range of sources. It should be based on good quality science and research to justify choice of indicators and other aspects of survey design. There must be some assurance that the program will be maintained over the long term (it is noteworthy than most of the monitoring initiatives outlined in our review above have no guaranteed funding and may soon cease to exist if the attrition observed in many other programs is repeated). A substantial baseline must be established in a reasonable time. Introduction cannot be so delayed nor the pace of data gathering so leisurely that the

processes of change the system is designed to measure become entrenched before they are detected. Under such circumstances monitoring reduces to no more than an elaborate way of cataloguing failure.

Monitoring systems that provide no early warning or are linked to no process for response are folly. The costs involved in competent monitoring can be easily justified if they are designed to stimulate early pre-emptive action that prevents degradation and hence avoids the huge future costs of rehabiliting damaged ecosystems. There is no way to produce a satisfactory national rangeland monitoring system for biodiversity without significant additional recurrent funding. Existing individual systems are demonstrably inadequate and even if better designed and matched across jurisdictions in ways that do not add significantly to State and Territory expenditure, integration and coordinated analysis will generate additional costs.

We have concluded that the best way forward in these circumstances is to identify the minimum investment necessary to provide a solid base (core) from which to encourage incremental enhancement leading to an optimal system. We are not arguing for abandonment of the ultimate goal of a high quality system, but rather laying out a path and specifying a minimum starting point on that path.

9. A core system and its components

Our preferred core system comprises facilities for *Integrated analysis within an enhanced reporting system*. Here we briefly outline (i) the way in which those existing State, Territory or other biodiversity monitoring schemes that we have rated as relevant and useful could be attached to the core system; and (ii) supplementary work that will greatly extend the value of the system.

We have concluded that a framework that strikes a balance between an optimal system and operational and financial feasibility will incorporate:

(1) elements of the existing State and Territory pastoral monitoring programs

(2) increased application of remote sensing and improved linkage to both landscape function and biodiversity monitoring

(3) additional wildlife (flora and fauna diversity) surveys designed to repeat “landmark” surveys or validate surrogates or indicators

(4) regular surveys of populations of a range of selected species, emphasising those that are thought most sensitive to prevailing adverse processes or that might otherwise be considered as good indicator species

(5) explicit linkage of monitoring programs for Parks and Reserves to their equivalents on lands used for primary production

9.1. Linking biodiversity and pastoral monitoring

We have indicated that the pastoral monitoring systems should form a part of the core of the framework for monitoring biological diversity, despite their present limited utility. We now consider how their value might be enhanced (see Background Paper 2 for a more comprehensive treatment) and to compare that contribution with other sources of information.

We have identified several generic problems with pastoral monitoring programs at a national scale. The most significant are:

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

But we have also noted a number of important features that demand that they be incorporated in any system for monitoring biological diversity:

- their large spatial coverage compared with any other single activity that is potentially compatible across jurisdictional boundaries;
- related activity to extend the scale and comprehensiveness of assessments through linkage to remotely sensed indices of land condition;
- relevance to a number of the major threatening processes (e.g. over-grazing, weed invasion, displacement of native perennial grasses); and
- apparent.willingness of managers of these programs to value-add to these sites, through the addition of some extra measures of biodiversity, especially if these can be done economically.

Programs vary substantially in the variables recorded (Background Paper 2). Useful commonalities do not presently extend much beyond the recording of the presence and absence of woody and herbaceous plants (excluding annuals). Comparisons of relative frequencies and densities are rendered difficult by differences in plot sizes.

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

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

9.1.1 Immediate/short term

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

(1) standardise plot sizes;

(2) record frequency (and/or cover) of all woody and herbaceous plant species within those plots;

(3) record standardised measures of soil condition, perhaps based on the simplified LFA of Tongway and Hindley (in preparation);

(4) standardise reporting protocols;

(5) incorporate ungrazed or little grazed sites as "controls";

(6) submit regular, standardised reports and data to a group charged to undertake a common analysis and report to each jurisdiction and Federal authorities.

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

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

- capacity to identify, track and interpret relevant change in (for example) temporal and spatial patterns of relative frequency of native perennial grasses and woody plants over a range of spatial scales, providing earlier warning of adverse change;

- patterns in the relative dominance of exotic pastures or other invasive species within individual sites as well as their invasion of new sites, again providing early warning of broad scale trends;
- greater potential to link pastoral monitoring data to biodiversity monitoring activity to reveal important associations; and
- greater potential to link pastoral monitoring data to remotely-sensed indicators of land condition.

9.1.2 Longer term enhancement

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

(1) additional sites to increase the comprehensiveness of sampling in terms of (a) rangeland bioregions (b) landscape/vegetation types and (c) grazing intensity;

(2) agreement on a suite of climatic variables to be incorporated in analyses of temporal variation;

(3) criteria for rating grazing intensity into a few broad classes (no managed grazing; lightly grazed; moderately grazed; heavily grazed) and their incorporation into reporting protocols; and

(4) explicit linkage to compatibly distributed and sampled biodiversity monitoring sites, maintained until links among various indices of land condition to biodiversity values are validated.

These improvements would permit:

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

We argue that pastoral monitoring systems enhanced along the lines we have suggested should form a core component of the national framework for monitoring rangeland biodiversity.

9.2. Increased application of remote sensing and improved linkage to both landscape function and biodiversity monitoring

Remote sensing is an ingredient of many current but disparate programs across the rangelands. It offers the main advantage of being able to provide information relatively consistently, objectively and economically across very broad scales. For biodiversity

monitoring, its main uses are in the mapping of environmental variation, vegetation clearance, fire, land condition (especially in relation to grazing), recent rainfall history, and (in some cases) distribution of environmental weeds.

Remote sensing should be a core component of a rangeland biodiversity monitoring program, but its utility will be greatly increased if it can be adapted in much the same way as that described for the integration, application and enhancement of pastoral monitoring programs discussed above. This enhancement should include:

- consistency between jurisdictions in practice, and regular national collation of information. At a minimum this should include regular reporting (at regional levels, and scaled up nationally) on
  - the proportion of every vegetation type cleared;
  - the fire history of every vegetation type;
  - land condition (at least in those regions where grazing is recognised as a major pressure); and
  - the extent of those weed species which can be detected reliably by remote sensing.
- carefully targetted link studies which aim to define the relationship between aspects of biodiversity and the expression of those environmental features reported on by remote sensing, such that there will be an increasing level of confidence that monitoring by remote sensing can provide a reliable descriptor and predictor of trends in (at least some aspects of) biodiversity;
  - such link studies should be based around on-ground monitoring at reasonably permanent sites, which (to aid integration with other components of the overall biodiversity monitoring program) should include a selection of pastoral monitoring sites and complementary sites on other land tenures.
- expansion of existing programs, to provide increased comprehensiveness and spatial coverage of monitoring across the rangelands.

9.3. Additional wildlife (flora and fauna diversity) surveys designed to repeat "landmark" surveys or validate surrogates or indicators

All rangeland jurisdictions have some archival databases that provide snapshots of (variably comprehensive components of) biodiversity for particular study areas. These all have some value for the assessment of change. The extent of that value is determined largely by:

- the repeatability and objectivity of the original sampling procedure;
- the reliability of the original sampling;
- the precision with which abundance (or other measure of status) and distribution was recorded;
- the comparability of procedure with that used elsewhere;
- the extent (of area, environmental range or duration) of the original sampling;
- the range and type of taxa sampled; and

- whether the expression of potentially threatening processes can be assessed and related to the period between re-samples.

We propose that the rangeland State and Territory conservation agencies should collaboratively nominate "landmark" historic surveys, based on the above criteria and on broad geographic and environmental representation across the rangelands. These "landmark" surveys should be upgraded to become a core component of the national rangeland biodiversity monitoring program, with regular (intervals of 5-10 years) re-survey and collated reporting of trends. In many cases, sampling protocols may need some enhancement to

- achieve greater consistency across the different landmark surveys;
- to increase focus on those groups of species most susceptible to change;
- to increase the statistical power of trend detection; and
- to improve recording of threatening processes.

Such enhancement will need to be advanced carefully, to avoid losing power in the comparability with the original sampling. In some cases, the archived set of landmark surveys may need to be complemented by newly established survey projects (especially in rangeland regions for which no adequate previous work has been undertaken).

9.4. Regular surveys of populations of a range of selected species, emphasising those that are thought most sensitive to prevailing adverse processes or that might otherwise be considered as good indicator species.

Some (types of) rangeland species have fared particularly badly in the face of environmental change over the last 200 years. Others have been largely unaffected. Notwithstanding the possibility of novel threats to the rangelands, or of some marked change in response of species to existing threatening processes, a monitoring scheme will be most efficient if it can concentrate on those species most likely to change in status or which provide a clear signal of response to particular threatening processes ("indicators").

Our Background Paper 1 suggests that the most susceptible animal species in the rangelands are groups of terrestrial mammals (small macropods, larger dasyurids and rodents, possums, and bandicoots) and a far less clearcut group of birds (generally including granivores, but also some insectivores and other species which forage or nest mainly on the ground), with less evidence suggesting that reptiles, ants and spiders may also be generally responsive to some rangeland pressures. Susceptibility is not so well etched for plants, but palatable herbs, perennial grasses, "fire-sensitive" species and vegetation communities, and some wetland communities (notably mound springs) appear to be most susceptible to change.

Information on trends in many of these species-groups will be collected routinely in the landmark survey program described above and (for some plant groups) in pastoral monitoring programs. But this source of data may need amplification, to provide finer-scale and more focussed reporting on the species for which rapid management responses may be

most needed to combat declining status. Hence we propose ongoing targeted monitoring programs for these identified indicators and susceptible taxa and environments.

We are not in a position to yet advocate a detailed protocol for monitoring for susceptible species. We note that efficiency and effectiveness may be best achieved if the program includes some component of landholder contribution. This may be especially so for Aboriginal communities and medium-sized mammals, but may also be appropriate more broadly for carefully-chosen indicator species which are conspicuous and unmistakeable (such as the flock bronzewing). Such community participation in rangeland biodiversity monitoring would also have many collateral benefits, most notably in helping foster some degree of community acceptance and ownership of biodiversity, monitoring and threat management.

9.5. Explicit linkage of monitoring programs for parks and reserves to their equivalents on lands used for production

The value of monitoring programs on both protected and production lands are reduced if there is no capacity for comparison between them. Parks and Reserves owe their existence to a belief that some biodiversity values cannot be adequately protected on pastoral lands, and it behoves managers of these public facilities to show that they are achieving high standards. Pastoral lands are currently monitored to assess the impacts of grazing on various functional and biodiversity values, but the capacity to draw conclusions is weakened by the absence of undisturbed "controls" which parks and reserves could provide.

In South Australia pastoral monitoring plots have recently been located in some parks (Lay *et al*. 1999) and in Queensland the Queensland Parks and Wildlife Service is extending a vegetation monitoring procedure similar to QGRAZE to some parks. Such initiatives should be strongly supported and instituted in all jurisdictions. Agencies should be encouraged to identify shared sites at which each will carry out its relevant monitoring programs. Not only will the quality of the conclusions from each program be enhanced, but this simple step will make an important, cost-effective contribution to the linkage of biodiversity issues to pastoral monitoring that we argue is essential (*1* and *2* above) if the pastoral monitoring system is to genuinely contribute to assessments of the status of rangeland biodiversity.

9.6. Summary

We acknowledge that this set of components omits many of the needs and opportunities we have identified elsewhere (eg Tables 4 & 5) as significant. The manner in which these additional requirements may ultimately be incorporated into a biodiversity monitoring framework is considered later in this discussion.

10. The core indicators

Many of the national strategies and other statements of intent, including the Audit's work program, seek collapse of the many attributes that make up rangeland biodiversity into a

(preferably small) number of indicators. We have already identified the risks associated with the use of unvalidated indicators and the significant logical and technical constraints on use of a few variables, no matter how carefully chosen, to describe phenomena that number among their valued attributes the differences in the ways they are expressed in nature. Over-exuberant use of indicators constitutes a denial of the significance of diversity.

Nonetheless, we have identified a small group of phenomena that if measured appropriately and, most significantly, linked to each other to provide multi-dimensional views of the impacts of rangeland use, provide a significant improvement over the existing capacity to understand the current status of life in the rangelands. We build that system around 9 indicators of the status of rangeland biodiversity and the processes that threaten biodiversity. However, we emphasise that these indicators do not address all of the options and opportunities we have identified as desirable in an adequate monitoring system. In our view they represent an absolutely minimal starting point from which to grow a satisfactory system. All require validation and will almost certainly require refinements and additions as we learn more from the development and implementation of the basic scheme.

Most of the following parameters can be assessed as part of coordinated and integrated monitoring at a selected set of existing pastoral monitoring sites, supplemented by new sites to round out representation of environments (e.g. including riparian areas), bioregions (e.g. including non-pastoral areas) and distances to water (e.g. including additional sites both close to and remote from water points). This set is termed PM+ below.

1. Progress to CAR reserve system

Measure of: conservation "security"

Threats addressed: All identified in Section 4.

Biodiversity Conservation (pseudo-) goals addressed: All. A CAR reserve system provides a necessary benchmark for assessing impacts of grazing and other disturbances and validating indicators.

Questions addressed: All.

How measured: Calculation of extent of reservation of all environments (translated to a single index).

Caveats: requires uniform environmental mapping at appropriate scale.

Bioregional scale: can be done with finer-scale environmental mapping.

Connections to other monitoring: part of existing SoE monitoring; also part of National Reserve System program.

Link studies: Reserves provide essential component of the range of land use intensities needed to infer grazing and other impacts on biodiversity. With incorporation of new reserves, questions involving the contribution of reserves to maintenance of regional biodiversity can be addressed. These would involve BACI (before-after-control-impact) type monitoring of biota with establishment of new reserves, based on PM+ sites and including the monitoring proposed in 8 and 9 below.

Cost. The cost of the core activity is essentially zero, assuming all jurisdictions report annually on their current reserve system and that a usable base vegetation map exists. Link studies could be done in 2 trial bioregions (those in which new reserves are likely to be located), with sampling every 2nd year for 10 years. Each sampling year would cost around $20,000/bioregion, so total cost over 10 years would be around $200,000.

The rationale for including this measure is to explicitly link ungrazed lands to the monitoring system. It will be difficult to make meaningful assessments of grazing impacts when the system fails in CAR, because areas of more productive lands are invariably grazed.

2. Extent of clearing

Measure of: rates and extent of tree clearing

Threats addressed: Land clearing and associated habitat fragmentation.

Biodiversity Conservation (pseudo-) goals addressed: Minimise losses of species and genetic diversity among taxa dependent on forest and woodland systems.

Questions addressed:

(1) What configurations of woodland or forests in rangeland environments are required to avoid the loss of resident vertebrate species or vascular plant species at the property and bio-regional scale?

(2) What configurations of woodland or forest remnants in rangeland are required to sustain viable regional populations of endangered, threatened, vulnerable or otherwise especially valued species?

(3) What configurations of woodland and forest ecosystems are necessary to sustain regional populations of mobile vertebrate nectarivores or insectivores?

(4) What populations of mobile nectarivores are needed to maintain current levels of genetic diversity among flowering plants, especially dominant trees and shrubs.

How measured: In those rangeland bioregions where clearing is an issue, annual (and cumulative) area cleared, measured through imagery (following SLATS protocol). Clearing rates subdivided by environmental class (e.g. vegetation type), reporting on the proportion of area remaining for each type.

Caveats: Imagery interpretation may be difficult in some bioregions, and there may be interpretative complications concerning re-clearing of regrowth. Comparisons may be confounded by variable descriptions of vegetation types.

Bioregional scale: The clearing extents should first be calculated on a bioregional scale, and then summed for the rangelands as a whole.

Connections to other monitoring: This indicator is already part of existing monitoring for SoE, Montreal and linked to initiatives under the Kyoto protocols.

Link studies: For at least two trial rangeland bioregions, examine the responses of rangeland biota to fragmentation. (Such studies are currently being conducted (in Darwin area, and in central Queensland)).

Costs. Assume no additional cost except link studies.

3. Landscape functionality

Approaches to measures of landscape function are dealt with in detail elsewhere in the Audit.

Threats addressed: Damage to key sites by grazing animals. Extreme deterioration of status of vegetation under grazing pressure.

Biodiversity Conservation (pseudo-) goals addressed:

Questions addressed:

(1) What components of the landscape are particularly important for vertebrate wildlife and vascular plants, especially under adverse climatic conditions and what features of these landscape components provide that significance?

(2) What effects are managed and feral herbivores and predators and exotic plants having on key sites?

(3) What features are amenable to management action to prevent further damage or restore function, and what are the most promising management options?

How measured: See other Audit documentation.

Link studies:

(a) Relationships with remote-sensed indices of condition (again, considered elsewhere in Audit).

(b) Relationship of LFA to trends in fauna assemblages. Would include:

   i. Vertebrate assemblages. Costs around $600/site, but this cost can be spread over 8 and 9 below, and optionally;

   ii. Invertebrate (ant) assemblages, examined by coordinated assessment of ant fauna and LFA at a selection of PM+ sites, undertaken as a monitoring exercise or as a one-off correlative study. Ant sampling would cost around $100/plot (A. Andersen pers. comm.: mostly for sorting), on top of (and assuming) collection on routine visits to plots to measure LFA and other variables. An adequate one-off correlative study would require samples from around 200 plots. Alternatively, ongoing monitoring would probably be based on a selection of 500 PM+ plots, sampled every 5 years (hence a total annual monitoring cost of $100,000).

4. Native perennial grass cover (or other perennial native understorey cover)

Measure of: ecosystem health; grazing pressure

Threats addressed: Loss of perennial grasses and palatable native shrubs

Biodiversity Conservation (pseudo-) goals addressed: To prevent further loss of vertebrate animals from the arid zone and a spate of new losses of plants or animals from the tropical rangelands.

Questions addressed:

(1) How are long-term declines in relative abundance and diversity of native perennial grasses and palatable native shrubs associated with loss of floristic and vertebrate diversity at the property and regional scales?

(2) Which taxa are most susceptible to changes in native perennial grass and shrub diversity, abundance or seed production?

(3) What patterns of native grassland/shrubland diversity and disturbance regimes are necessary to sustain regional populations of fauna known to be at risk?

(4) What management options are available to ameliorate biodiversity effects of reduced native perennial grass and shrub diversity, declining relative abundance or reduced seed production?

How measured: cover of native perennial grasses at PM+ sites

Caveats: may have some background seasonal noise; one perennial grass species is not necessarily equal to another in terms of information content. Existing pastoral monitoring systems vary substantially in methods of recording perennial grass abundance.

Bioregional scale: trends would be aggregated across different vegetation/land types and aggregated at bioregional level for comparisons and identification of commonalities/divergences.

Connections to other monitoring: already done at PM sites but may need inter-jurisdictional agreement for common approach.

Link studies: as with LFA (3 above), should be related to ant assemblages and vertebrates, to assess whether this measure informs trends for fauna. These link studies can be combined with 3 above, with no extra cost.

5. Exotic plant species cover

Measure of: ecosystem health/integrity

Threats addressed: Exotic species invasions and displacement of native perennial grasses and shrubs.

Biodiversity (pseudo-) goals addressed:

(1) To prevent loss of species dependent on grasslands and shrublands or great reductions in their abundance over significant areas

(2) To prevent gross changes in the ecological character of ungrazed lands

(3) To reduce loss of vertebrate animals and vascular plants at the property level.

Questions addressed:

(1) Are exotic pastures and other exotic plants (e.g. shrubs) continuing to spread in rangeland environments and to what extent are they invading sites outside the pastoral estate?

(2) What are the impacts of exotic pastures and other exotic plants on biodiversity on pastoral lands and how far do these impacts on pastoral lands extend beyond the property scale to regional and larger-scales?

How measured:

(a) (at PM+ sites) total (and relative to native) cover of exotic species; number of exotic species.

(b) mapping of subset of those exotics considered to have substantial biodiversity consequences (e.g. buffel grass; gamba grass; ponded pasture grasses).

Caveats: summing exotic species in (a) may be clumsy; mapping significant weeds may be difficult to achieve; some annual weeds may not be adequately sampled using existing PM techniques; there may be some definitional problem of "weed", which is best overcome by mapping exotics.

Bioregional scale:

Connections to other monitoring: SoE monitors 20 worst weeds, but does not include many invasive exotics that may have significant implications for biodiversity.

Link studies: Should be set up to demonstrate consequences/associations with native biota, again by synchronous sampling of ants and vertebrates at PM+ sites.

Costs:

(a) should already be included within pastoral monitoring programs (with the exception of annual weeds).

(b) regular (e.g. every 3 years) mapping to monitor selected set of environmentally significant weeds approximately $20,000 pa.

6. Fire-sensitive plant species and communities

Measure of: impacts of changed fire regimes

Threats addressed: Changed and inappropriate fire regimes.

Biodiversity (pseudo-) goals addressed: To prevent further loss of vertebrate animal and vascular plant diversity due to wildfire or inappropriate use of fire.

Questions addressed:

(1) What are the prevailing fire patterns across Australia's rangelands?

(2) How are prevailing patterns of burning correlated with distribution and abundance of vertebrate animals and vacular plants in the rangelands at different spatial scales?

(3) What are the options to re-instate burning regimes favouring maintenance of rangeland biodiversity, and are those options compatible with the maintenance of production or other (e.g. aesthetic) values?

(4) How do fire regimes interact with other processes affecting biological diversity in rangelands?

How measured:

(i) at PM+ sites, abundance and age structure of selected plant taxa (e.g. obligate re-seeders), and incidence of fire;

(ii) fire mapping;

(iii) where available, use historic and recent aerial photography to examine pre-baseline trends in tree cover (woodiness), and thence monitor tree and shrub cover at PM+ sites.

Caveats: interpretation may be difficult given interactions between fire and grazing

Bioregional scale: item (i) above needs focus on particular species or communities in different bioregions.

Connections to other monitoring: SoE monitors area of vegetation burned by frequency and intensity of burning and type of vegetation. However, view of burning patterns and their

implications grossly biased and inaccurate, especially in regard to implications for rangeland management.

Link studies: need to demonstrate consequences/associations with fauna. Because of the association of fire with grazing, orthogonal sampling designs will be difficult. Important that reserve sites subject to different burning regimes be incorporated in monitoring system.

7. Grazing-sensitive plants

Measure of: impacts of grazing

Threats addressed: Damage to key sites. Grazing and displacement of native perennial grasses and other native ground cover.

Biodiversity (pseudo-) goals addressed: To prevent further loss of vertebrate animals and vascular plants from the arid zone and a spate of new losses of plants or animals from the tropical rangelands.

Questions addressed: Which plant taxa are most at risk of displacement by grazing?

How measured:

(i) identify a class of highly palatable "decreaser" plant species

(ii) abundance measured at PM+ sites.

Caveats: Frequencies may be low in most long-established pastoral sites, and inference in regard to impacts of grazing intensity relatively weak. Utility will be strongly dependent on ability to reconstruct prior distributions from Herbarium records and inclusion of ungrazed sites for comparison of trends.

Bioregional scale: Trends would be aggregated across vegetation types for comparison across bioregions.

Connections to other monitoring: SoE monitoring includes species formally identified as at risk (endangered etc). For the rangelands, this indicator would differ in identifying those species that, while still present in the landscape (e.g. on road verges) have undergone changes in abundance severe enough to affect ecological function (e.g. in seed or fruit production that sustains fauna).

Link studies: to measures of land condition (LFA and remote sensing) and for potential to identify good "indicator" species for different pasture, vegetation or landscape types.

8. Susceptible vertebrates – 1. mammals

Measure of: ecological health/integrity

Threats addressed: Damage to key sites. Grazing displacement of native perennial grasses and shrubs. Invasions of exotic plants.

Biodiversity (pseudo-) goals addressed: To prevent further loss of vertebrate animals and to restore populations of displaced species.

Questions addressed:

(1) Are long-term declines in relative abundance and diversity of native perennial grasses and palatable native shrubs associated with loss of floristic and vertebrate diversity at the property and regional scales?

(2) Which animal taxa are most susceptible to changes in native perennial grass and shrub diversity, abundance or seed production?

(3) What patterns of native grassland/shrubland diversity and disturbance regimes are necessary to sustain regional populations of fauna known to be at risk?

(4) What management options are available to ameliorate biodiversity effects of reduced native perennial grass and shrub diversity, declining relative abundance or reduced seed production?

How measured: for the set of {bandicoots, large rodents, large dasyurids, possums, small macropods}

(i) sampling at a selection of PM+ sites;

(ii) landholder (e.g. Aboriginal) survey;

(iii) designation of a set of benchmark key wildlife surveys, and periodic re-sampling.

Caveats: System may be noisy in response to seasonal conditions; for many rangeland areas, the measure may never again be anything but 0.

Bioregional scale: particular focal spp.

Connections to other monitoring: SoE monitoring includes species formally identified as at risk (endangered etc). For the rangelands, this indicator would differ in identifying an additional suite of species that appear to be acutely sensitive to variation in grazing pressure and other land use practice.

Link studies: important component of studies linking fauna assemblages to measures of pasture condition (LFA and remote sensing) and other surrogates for biological diversity.

Costs: variable depending on range of sites. Minimum of $150,000 pa recurring over 5+ years or until surrogates/indicators validated. Irregular for repeat surveys, say $500,000 (5-10 sites) at 10 year intervals.

9. Susceptible vertebrates – 2. birds

Measure of: health

Threats addressed: Damage to key sites. Grazing displacement of native perennial grasses and shrubs. Invasions of exotic plants.

Biodiversity (pseudo-) goals addressed: To prevent further loss of vertebrate animals and to restore populations of displaced species.

Questions addressed:

(1) Are long-term declines in relative abundance and diversity of native perennial grasses and palatable native shrubs associated with loss of floristic and vertebrate diversity at the property and regional scales?

(2) Which animal taxa are most susceptible to changes in native perennial grass and shrub diversity, abundance or seed production?

(3) What patterns of native grassland/shrubland diversity and disturbance regimes are necessary to sustain regional populations of fauna known to be at risk?

(4) What management options are available to ameliorate biodiversity effects of reduced native perennial grass and shrub diversity, declining relative abundance or reduced seed production?

How measured: (i) sampling at PM+ sites; (ii) Birds Australia -type atlassing; (iii) designation of a set of benchmark key wildlife surveys, and periodic re-sampling of these. Scoring can be related to proportion of recognised increaser (e.g. crested pigeon): decreaser groups.

Caveats: System may be noisy in response to seasonal conditions;

Bioregional scale: particular focal species or groups of species for different bioregions

Connections to other monitoring: SoE monitoring includes species formally identified as at risk (endangered etc). For the rangelands, this indicator would differ in identifying an additional suite of species that appear to be acutely sensitive to variation in grazing pressure and other land use practice.

Link studies: important component of studies linking fauna assemblages to measures of pasture condition (LFA and remote sensing) and other surrogates for biological diversity.

Costs: incorporated in 8 above.

Unless States and the Territory choose to abandon some existing pastoral monitoring sites, achieving the PM+ network will generate substantial additional costs. Information available for costings are presently limited, but based on South Australian experience and a 50% increase in the number of sites in each jurisdiction, PM+ costs for monitoring pastoral condition alone will be in the order of $750,000 for establishment and $350,000 pa for maintenance.

These indicators represent a modest increment on the number of variables already incorporated in Australia's SoE report (ANZECC SoE Reporting Task Force 2000: Table 4). However, we consider that there are important differences in content and emphasis that warrant the additional cost and effort needed to aggregate them into a rangeland perspective. Chief among these differences are:

(1) Extension of indicators of landscape or habitat condition beyond the measures of structural change emphasised by the Audit to reflect more subtle effects on fauna and flora.

(2) Explicit spatial and conceptual linkage among different measures to permit validation of surrogates for or indicators of biodiversity values. Use of the monitoring framework as a mechanism for indicator validation is a critical element of the present proposal.

(3) Incorporation of data gathered under the extensive pastoral monitoring schemes operated by the State and Territory jurisdictions.

(4) Inclusion of measures useful at finer spatial scales (e.g. landscape function analysis) than SoE indicators.

(5) Focus on species subject to adverse change prior to their formal recognition as endangered or otherwise at severe risk. This is an important distinction as it provides opportunity for incorporation of warnings rather than belated sign-posting of wreckage.

(6) Focus on species that play important functional roles in rangeland environments.

The manner in which these various components link to each other is illustrated in Figure 2. Again we feel obliged to clearly acknowledge that the indicators fail to address some important issues or contribute to answering some important questions that we have taken a good deal of effort to identify. Most notable among these are:

(1) making better use of other ecological studies in rangelands;

(2) meta-analysis of surveys of exploited, pest and endangered species to enhance early detection of broad-scale adverse processes with a common cause;

(3) linking rangeland monitoring programs to large scale flora and fauna mapping or atlas schemes;

(4) targeted surveys of sites where there is already evidence of adverse change; and

(5) linking plans for enhanced or expanded environmental mapping to biodiversity monitoring for priority species, communities or sites.

These omissions should be among the first enhancements of the core scheme after its utility has been demonstrated. The choices summarised here are made not because the mix is optimal, but it provides a sufficient base for developing a fully functional system.

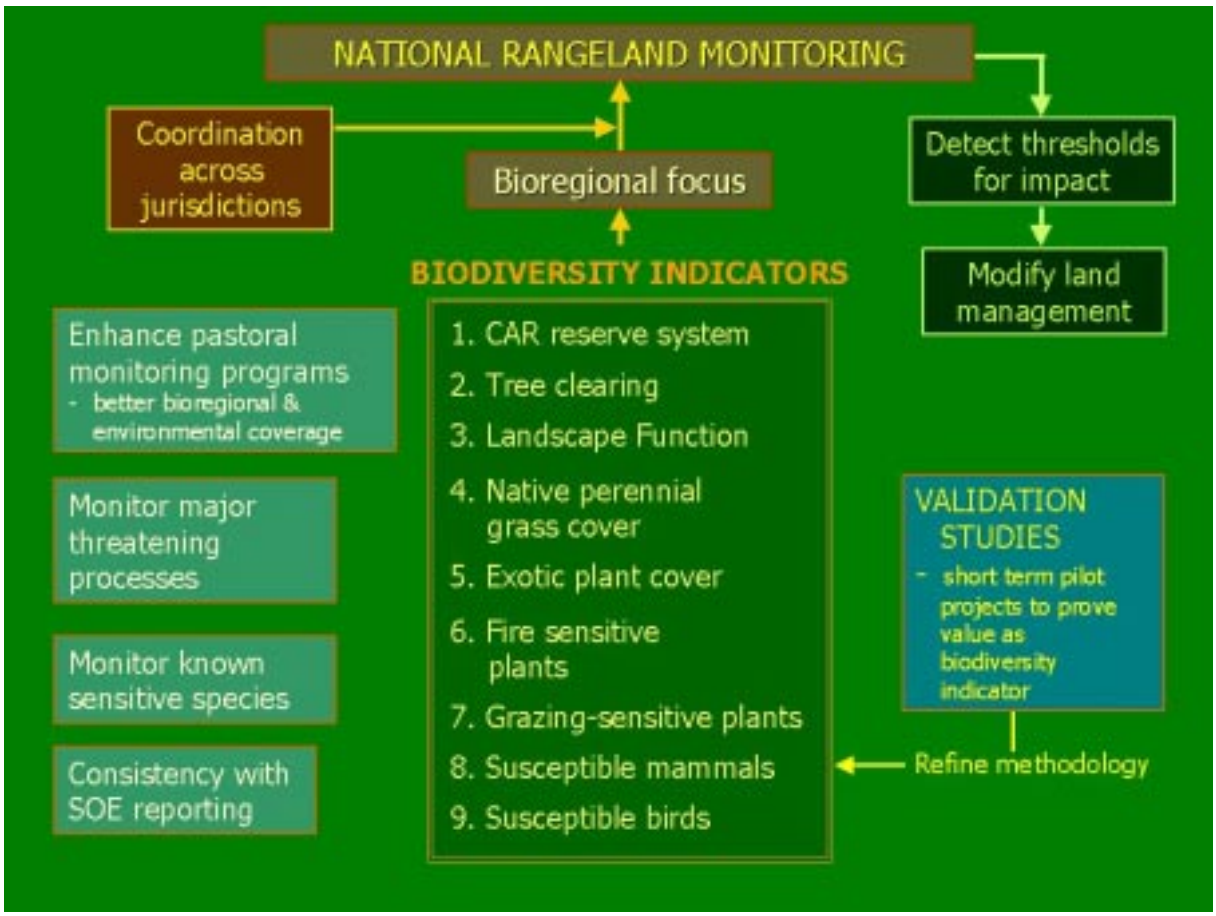
Table 4: Comparison of indicators proposed here for monitoring biodiversity in the rangelands, with those developed for national State of the Environmer reporting (ANZECC SoE Reporting Task Force 2000) and those developed for assessment of sustainable forest management (the Montreal Process: Santiago Declaration 1995).

Proposed indicators for monitoring rangeland biodiversity	**Core biodiversity indicators for State of Environment Reporting**	**Montreal protocol– national and regional indicators of sustainable forest management (criteria related to biological diversity, and ecosystem health and vitality)**
1. Progress to CAR reserve system Area by vegetation type in protected area categories as defined by IUCN, in hectares and as a percentage of the pre-1750 area, by IBRA region. Values converted to a single CAR index for IBRA region and rangelands *in toto*	**BD10. Terrestrial protected areas** Area by vegetation type in protected area categories as defined by IUCN, in hectares and as a percentage of the pre-1750 area, by IBRA region	**1.1.c. Extent of areas by forest type in protected area categories as defined by IUCN or other classification system** **1.1.d. Extent of areas by forest type in protected areas defined by age class or successional stage**
2. Extent of vegetation clearing Rate (and cumulative extent and percentage) of clearing, in hectares per annum, of terrestrial native vegetation types, for IBRA region and rangelands *in toto.*	**BD1. Native vegetation clearing** Rate of clearing, in hectares per annum, of terrestrial native vegetation types, by clearing activity	**1.1.e. Fragmentation of forest types**
3. Landscape functionality Extent of change in LFA scores measured in pastoral monitoring plots, collated by vegetation types and IBRA.	**BD7. Extent and condition of native vegetation** The area and condition of native vegetation by type. In the absence of other measures, vegetation assemblages are used as surrogates for ecological communities and ecosystem diversity	**3.1.c. Area and precentage of forest land with diminished biological components indicative of changes in fundamental ecological processes** (e.g. soil nutrient cycling, seed dispersion, pollination) **and/or ecological continuity** (monitoring of functionality important species such as fungi, arboreal epiphytes, nematodes, beetles, wasps, etc.)
4. Native perennial grass cover Extent of change in total cover of native perennial grass measured in pastoral monitoring plots, collated by vegetation types and IBRA.		
5. Exotic plant species cover Extent of change in total cover of exotic plant species measured in pastoral monitoring plots, collated by vegetation types and IBRA. Mapped distribution of nominated significant weed species.	**BD4. Introduced species** The distribution (and abundance where possible) of non-indigenous terrestrial, marine and freshwater species (plants, vertebrates, invertebrates, and pathogens) identified as pests. This indicator also includes displaced/translocated native species. The identified species will vary with place and time.	**3.1.a. Area and per cent of forest affected by processes or agents beyond the range of historic variation**

Proposed indicators for monitoring rangeland biodiversity	Core biodiversity indicators for State of Environment Reporting	Montreal protocol– national and regional indicators of sustainable forest management (criteria related to biological diversity, and ecosystem health and vitality)
6. Fire-sensitive plant species and communities Area of vegetation burnt, by frequency and intensity of burning and type of vegetation (for selected fire-senstive vegetation types only). Age structure and abundance of populations of selected fire-sensitive plant species measured in pastoral monitoring plots, collated by vegetation types and IBRA.. Change in woody cover, derived from pastoral monitoring plots and imagery.	**BD3. Fire regimes** Area of vegetation burnt, by frequency and intensity of burning and type of vegetation	**1.1.b. Extent of area of forest type and by age class or successional stage**
7. Susceptible species – plants Change in abundance/cover of selected set of highly palatable non-resilient ("decreaser") herbs and grasses, derived from pastoral monitoring plots	**BD6. Extinct, endangered and vulnerable species and ecological communities** Number of species and ecological communities presumed extinct, endangered or vulnerable. This indicator should be reported by major group, together with the estimated number of endemic species per major group. Applies to animals and plants, both terrestrial and aquatic. **BD9. Populations of selected species** Estimated populations of selected species, including declining species, are an important measure for assessing the conservation status of species. They are also potential surrogates for assessing changes in genetic diversity	**1.2.b. The status of forest dependent species at risk of not maintaining viable breeding populations, as determined by legislation or scientific assessment** **1.3.a. Number of forest dependent species that occupy a small portion of their former range** **1.3.b. Population levels of representative species from diverse habitats monitored across their range**
8. Susceptible species – mammals Change in abundance/presence of selected suite of species as detected by collation of repeat sampling of "landmark" surveys. Change in abundance/presence of selected suite of species as detected by set of landholders (especially Aboriginal communities)		
9. Susceptible species – birds Change in abundance/presence of selected suite of species as detected by collation of repeat sampling of "landmark" surveys. Change in abundance/presence of selected suite of species as detected by repeat Atlasses.		

Proposed indicators for monitoring rangeland biodiversity	Core biodiversity indicators for State of Environment Reporting	Montreal protocol– national and regional indicators of sustainable forest management (criteria related to biological diversity, and ecosystem health and vitality)
	BD5. Species outbreaks The number (and identity) of native species outbreaks and the location and area affected.	
	BD12. Recovery plans Recovery plans for threatened species and ecological communities as required under legislation	
	BD13. Area revegetated The area revegetated by species or genus, in hectares per annum, disaggregated into areas revegetated using loocal vegetation or other vegetation, and the purpose of the revegetation.	
		1.1.a. Extent of area by forest type relative to total forest area
		1.2.a. The number of forest dependent species

Figure 2: Summary of the links among the various components of the biodiversity indicators and monitoring protocols proposed in this study.



11. Reinforcing the Framework

We are conscious of the risk that statements of requirements as outlined above may be dismissed as shopping lists constructed by vested interests. However, we do not resile from the view that a useful framework must be robust enough from the outset to accommodate a range of inputs and to provide the means to integrate and refine the components through time.

The framework should not be static. Additional elements and enhancements of existing elements should be introduced progressively. Moreover, the emphasis placed on the various elements will vary through time, and for different components the level of input from the keepers of the framework will range from encouragement, through negotiation, to substantial original analysis.

It is particularly important to recognise that the core aim and, paradoxically, the source of much of initial complexity, is the desire to ultimately simplify a highly robust framework. Much early work is necessary because potential indicators and surrogates have not been validated, or links between processes and biodiversity outcomes have not been strongly made. The range of

phenomena monitored may be expected to reduce as the validation phase is completed, but this cannot be responsibly done until the behaviour of indicators and surrogates is well understood.

12. A Process for Implementation

Based on the assumption that our core group of indicators and the general approach to recording them is agreed by State, Territory and Federal jurisdictions, we also outline a path for implementation. It is based on a model of cooperation among jurisdictions implemented through relevant Ministerial Councils. We propose that:

(a) A Technical Working Group be formed answerable to both ANZECC and ARMCANZ and with membership of relevant personnel from conservation and primary production agencies with an interest in rangelands.

(b) Members nominated by the respective State/Territory jurisdictions should have expertise in monitoring of biodiversity and/or production values.

(c) The group would be chaired by a relevant Commonwealth employee, also with relevant expertise.

(d) Technical and administrative support would be provided by a small group of personnel funded by the Commonwealth but accountable to the working group. The leader of this group of staff would be a key member of the working group.

(e) The terms of reference for the group would include a requirement to provide annual reports to ANZECC and ARMCANZ on the status of rangeland biodiversity and any significant change, and also to promote reform of procedures within jurisdictions to improve comparability of existing monitoring data and the range of issues and phenomena for which a genuinely national perspective is achieved.

(f) Early tasks for the group would be to develop a timetable and process for modification and extension of the pastoral monitoring systems to accommodate biodiversity values and to bring into use the other data sources we identify in sections 9.1 to 9.5 above and eslewhere.

(g) The group would also be responsible for establishing links with other segments of the Audit, to build understanding of the relationships between biodiversity patterns and trends and other descriptions of the rangelands built or synthesised under the Audit program. The nature of the links and relationships to be explored are indicated in Figure 1.

(h) The continued need for the group would be reviewed after 5 years.

In making this proposal, we are conscious that the performance of working groups formed under Ministerial Councils has been patchy, with progress often being very slow. This variability is due in part to the limitations that arise from such duties being added to the work of existing positions. We consider that the role of this group will be sufficiently important for the Commonwealth to consider defraying part of the salary costs of key State and Territory personnel to ensure that they are able to devote a significant portion of their time to it. They will also need the assistance of 3 or 4 full-time staff to access data and convert disparate data sources into compatible forms. Depending on details of design, statistical analysis is likely to

present significant challenges. It should be recognised that many jurisdictions have yet to begin analysis of information collected over substantial periods, and substantial difficulties additional to those already identified (Background Paper 2) can reasonably be anticipated.

In addition to such direct contribution to the group's activities and capacity to operate effectively, the Commonwealth could take other steps to enhance commitment to the ongoing development of the framework. For example, effective implementation and enhancement of the framework could be made an important criterion for assessment of applications for grants to support State or Territory development of bioregional plans for rangelands. A more detailed statement of process and methodolgy is given in the manual, also prepared under this contract.

Our estimates suggest that the cost of implementing even this modest system will considerably exceed the Audit's estimate (Appendix 1) of post-audit expenditures. This difference is most likely due to our incorporation of the costs of integration and additional work needed to validate indicators. We consider it poor economy to base a monitoring system for much of the nation's biological heritage on guesswork and the associated use of untested and inadequate surrogates. The additional cost we have identified is modest given the detriment already suffered and the compelling evidence for ongoing and probably accelerating adverse change. The rangelands have already been the scene of the world's worst post-colonisation extinction event: we have no wish to contribute to the next one by understating the nature of the challenge facing Australia's rangeland managers.

13. Conclusion

Australian Governments have, through a variety of legal instruments and statements of intent, set high standards for monitoring of biological diversity. A framework for the rangelands congruent with those commitments will necessarily be complex and require significant operational support. In the short term, and incomplete but useful product is achievable with relatively modest initial expenditure, provided it is accepted that early products will have to be built from initially miscellaneous and ill-matched components. However, if the State and Territory jurisdictions are supportive, a base does exist for building a system that will ultimately have the potential to deliver information of the quality and coherence .

We consider that the shortest path to a robust and manageable system will be to provide significant operational capacity from the outset and maintain it for some years, so that a process of testing and validation of indicators will permit simplification over the longer term. Failure to provide adequate resources early in the life of the framework will be wasteful, because the most likely outcome from a token effort will be abandonment of a fragile and static national system by the State and Territory jurisdictions, which have already made major investments in developing schemes that meet their particular circumstances.

14. Acknowledgments

At a workshop held in Darwin in June 2000, a number of State, Territory and Federal rangeland scientists and managers gave generously of their time to examine and refine earlier proposals for the framework. Participants in the workshop were Alan Anderson, CSIRO, NT; Eric Anderson, Dept of Primary Industries, QLD; Rod Applegate, Dept Lands, Planning & Environment, NT; John Benson, Royal Botanic Gardens, Sydney; David Carter, Environment Australia, ACT; Andrew Craig, Agriculture WA; Gabriel Crowley, Queensland Parks & Wildlife Service; Leasie Felderhof, Queensland Parks & Wildlife Service; Rod Fensham, Qld Herbarium; Daryl Green, Dept of Land & Water Conservation, NSW; Alec Holme, University of WA; Angas Hopkins, CALM, WA; Craig James, CSIRO, NT; Bob Karfs, DLPE, NT; Rochelle Lawson, NLWRA, WA; Brendon Lay, Dept of Environment & Heritage, SA; David Robson, National Parks & Wildlife Service, NSW; Paul Sattler, Queensland Parks & Wildlife; Tony Start, Tropical Savannas CRC & CALMScience; Ian Watson, AgWA and John Childs, Tropical Savannas-CRC, for his advise and encouragement throughout the project. We thank them all for their efforts. Particularly useful input and comments on drafts of this and related reports were provided by Angus Hopkins and Ian Watson. Don Franklin played an important role in setting up the project and gathering background information.

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Appendix 1

Project 3. Developing an adaptive framework for monitoring biodiversity in rangeland

Project goal:

To embed biodiversity monitoring within the proposed national rangeland monitoring and reporting framework to improve decision making and management of the rangeland.

Project objectives:

1. To embed biodiversity monitoring within the proposed national rangeland monitoring and reporting framework
2. To identify additional indicators within the proposed national rangeland monitoring and reporting framework, that highlight major threats to biodiversity and the adequacy of management responses.
3. To recommend processes and identify agency support to incorporate additional indicators within the national rangeland monitoring and reporting framework.
4. To recommend research and development that will build upon and improve the proposed methods.

Project outputs:

- An improved framework for monitoring biodiversity
- Application of indicators and other tools to measure biodiversity
- A process to link with and recommend changes in management
- On –line access to baseline data
- Process to link the results of research and development with the national rangeland monitoring and reporting framework

Contract 3.1 Biodiversity monitoring in rangeland

Guidelines for Contract Activity

Using the national rangeland monitoring and reporting model as the broad framework for assessing trends in the capacity of the landscape to support biodiversity:

1. Review the proposed indicators and information products and their relationships to the specific requirements for biodiversity management in consultation with Commonwealth, State and Territory agencies.
2. Recommend additional indicators (or modifications) based on existing on-going programs such as SoE reporting, which when implemented, provide a mechanism for assessing major threats to biodiversity, trends in biodiversity and progress towards management goals and targets for the Australian rangeland, where these exist.
3. Recommend Commonwealth, State and Territory jurisdictional processes, seek agency support and assist these agencies to collate and provide on-line access to base line data of recommended additional indicators.
4. Propose an adaptive framework for biodiversity monitoring through the identification of R&D or critical monitoring procedures that will significantly improve the application of biodiversity policy and management or land use decision making and prepare a strategy to coordinate and focus future research.
   This may include :
   - the selection of appropriate indicator species for regional monitoring.
   - the development of long term reference sites for biodiversity monitoring.
   - Identification, and monitoring the management, of threatened ecosystems, communities or species
   - establishing targets for, and monitoring the progress towards, an adequate reserve system

Supporting tasks

State/Territory/Commonwealth: ***Post Audit Data Management***

1. Maintenance of ongoing biodiversity monitoring activities.
2. Develop on-line data-bases and information products to effectively portray the results stemming from the framework's implementation and relevant research results and update as necessary.
3. As research and monitoring progress, adjust monitoring framework as appropriate and implement changes (see also Project 5).

Indicative budget

Project 3 Contract	***Indicative funding required in the implementation phase***					***Post Audit Estimated $/year***	
	Audit	***Audit/ CRC***	***Common-wealth***	***State/ Territory***	***Total***	***State/ Territory***	***Common-wealth***
3.1	125,000				125,000	250,000	200,000

Linkages and connections to existing programs:

The need to develop practical approaches to monitoring bio-diversity within Australia's rangeland has been recognised and is being researched through several programs. These include work on identifying appropriate indicators by Environment Australia and in the Tropical Savannas CRC, grazing gradient and target taxa work in southern Australian rangeland by CSIRO (Landsberg *et al*., 1997), the IBRA program (Thackway and Cresswell, 1995) and work in the Great Australian Basin project. The audit work will seek to augment this work and to develop partnerships to facilitate the work plan objectives for a national rangeland monitoring program.

Data requirements and confidentiality issues:

To be determined as an output of this project