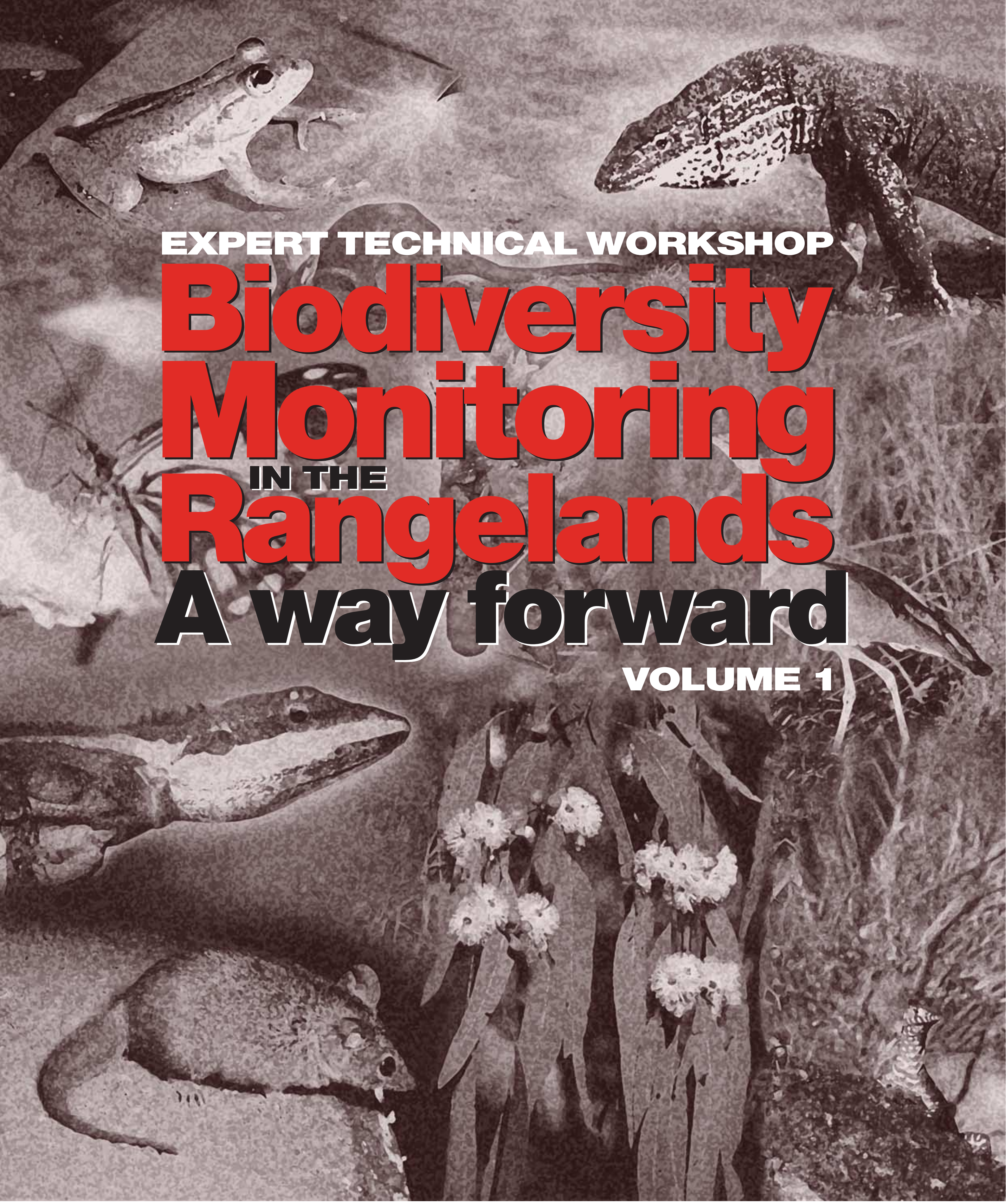

EXPERT TECHNICAL WORKSHOP

Biodiversity Monitoring in the Rangelands

A way forward

VOLUME 1

Final report to Environment Australia on an expert technical workshop held from 29 October to 1 November 2002 in Alice Springs by the Centre for Arid Zone Research, CSIRO Sustainable Ecosystems, Alice Springs, Northern Territory

Natural Heritage Trust
Helping Communities Helping Australia
An Australian Government Initiative

CSIRO
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Biodiversity Monitoring IN THE Rangelands
A way forward

VOLUME 1 *including a CD-ROM of commissioned papers*

Anita Smyth, Craig James, Grant Whiteman

Final report to Environment Australia on an expert technical workshop held from 29 October to 1 November 2002 in Alice Springs by the Centre for Arid Zone Research, CSIRO Sustainable Ecosystems, Alice Springs, Northern Territory

August 2003

Executive summary

This report describes the outcomes of an expert technical workshop on the monitoring of biodiversity in Australia's rangelands that was held from 29 October to 1 November 2002 in Alice Springs, Northern Territory.

The need for this expert technical workshop was identified by the National Rangeland Monitoring Coordinating Committee (NRMCC) at their final meeting to review the progress of implementing an Australian Collaborative Rangeland Information System (ACRIS) of which biodiversity monitoring was to be an important component.

At the final meeting of this committee it was argued by many—including some of the authors of the review on biodiversity monitoring in the rangelands for the National Land, Water and Resources Audit report (Tropical Savannas CRC 2001)—that there was poor understanding of the applicability of the report's proposed indicators, the techniques for monitoring them and other new tools. In recognition of this, the NRMCC agreed that a national biodiversity monitoring program could not be implemented without a better understanding of the:

- reasons for monitoring biodiversity in the rangelands
- most appropriate indicators for different clients
- best techniques for measuring these indicators
- guiding principles for monitoring programs
- knowledge gaps and research needs.

The objectives of the expert technical workshop were to produce:

- a brief review of recent (often unpublished) research relevant to biodiversity monitoring in Australian rangelands to establish current understanding, gaps in knowledge and ways to move forward
- a review of techniques and tools that do and don't work so that we can assess the capacity to value-add using existing approaches and build on lessons learnt from the past
- a 'manual' for operation of well-tested, existing approaches as a set of technical guidelines to support planning of biodiversity monitoring systems
- an outline of a framework for monitoring change using expert knowledge to support adaptive management and indicate environmental performance
- a toolbox that has the capacity for, or can fully support, 'measurable and meaningful' benchmarking by demonstrating the degree of effectiveness of natural resource management (NRM) programs and whether funds are targeted effectively nationally under the NRM 'matters for targets' initiative for Environment Australia.

Outcomes of the workshop included:

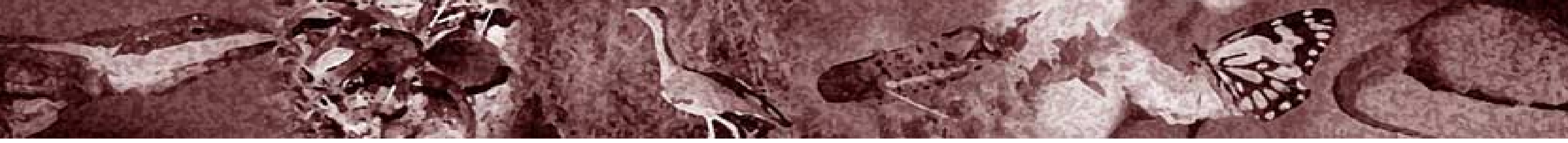
- the bringing together of experts from all rangeland states and the Territory
- consideration and review of recent, and most importantly, often unpublished research relevant to biodiversity monitoring in the rangelands
- development of a common 'state-of-the-art' view and an understanding of the complexity of biodiversity monitoring in the rangelands
- development of a shared view on the most appropriate 'sufficient and necessary' set of attributes and techniques for use now by different clients to monitor changes in biodiversity
- highlighting of the limitations of particular sets of attributes and techniques
- identification of interim guiding principles for rangeland biodiversity monitoring
- identification of knowledge gaps and research needs.

Products of the workshop included:

- proceedings of the workshop as described by this report
- a CD-ROM of near-final commissioned papers on recent and new research pertaining to rangeland biodiversity monitoring
- publication of key papers in a thematic issue of *Austral Ecology*, the journal of the Australian Ecological Society.

Subsequent to the workshop there are three key initiatives:

- A ‘how-to’ manual (Volume II) will be produced to describe the guiding principles and a delivery framework for biodiversity monitoring in the rangelands.
- An e-network will be set up for input into planning of biodiversity monitoring in the rangelands by workshop participants and others with similar interests.
- The outputs of the workshop and the new initiatives will be used to develop biodiversity information products for the ACRIS.



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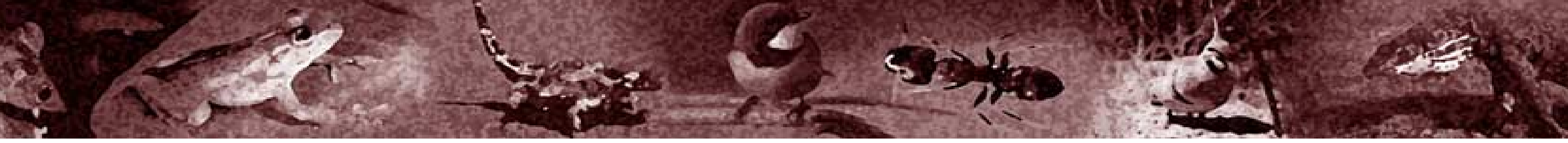

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CHAPTER ONE

Introduction

1.1 Background

Whole-of-the-nation biodiversity monitoring and reporting will underpin and justify future policy and funding directions at a national scale so it is important that these monitoring and reporting systems are as accurate and robust as possible.

Currently there is little biodiversity monitoring undertaken at large scales and so governments have little foundation on which to base forward planning and budgeting of scarce dollars for biodiversity conservation programs. A real opportunity now exists to incorporate such monitoring within the broader Australian Collaborative Rangelands Information System (ACRIS) program. The ACRIS is an initiative in its early stages of development sponsored by the Department of Agriculture, Fisheries and Forestry—Australia and Environment Australia.

Biodiversity monitoring within the rangelands may encompass many aspects and is clearly a very complex task. Aspects of biodiversity monitoring were considered in a recent review for the National Land and Water Resources Audit (NLWRA) and a set of potential biodiversity indicators were proposed by researchers at the Tropical Savannas CRC (TS-CRC 2001). This report:

- identified the key threatening processes or pressures affecting the conservation status of biodiversity in the rangelands nationally and bioregionally
- evaluated the value of existing pastoral monitoring programs in the states and the Territory, and other biodiversity monitoring programs nationally and internationally
- identified a minimum set of 11 indicators (see Table 1.1) and highlighted important analytical issues with their uses
- presented an analytical framework to support biodiversity monitoring in the rangelands.

Table 1.1 TS-CRC minimum set of indicators for biodiversity (TS-CRC 2001)

TS-CRC minimum set of indicators
Progress towards a comprehensive, adequate and representative (CAR) reserve system
Trends in the extent of clearing native vegetation
Landscape function metrics
Trends in the cover of native perennial grass/native perennial ground layer vegetation
Trends in the distribution and abundance of exotic plant species
Trends in the distribution, abundance and condition of fire-sensitive plant species and communities
Trends in the distribution and abundance of grazing-sensitive plants
Trends in the distribution and abundance of susceptible mammals
Trends in the distribution and abundance of susceptible birds
Trends in the distribution and abundance of listed threatened species and the distribution and condition of listed threatened communities
Trends in the intensity of land use

The TS-CRC report also highlighted that the general applicability of these indicators, details of techniques, and other potential tools for monitoring are still poorly known. Much expert knowledge in this field has not yet been documented or is not readily available.

At its final meeting in May 2002, members of the National Rangeland Monitoring Coordinating Committee reviewed progress and issues with implementing the ACRIS. In recognition of the work still needed to implement a national-scale biodiversity monitoring program, Commonwealth, state and the Territory representatives agreed to:

- support an expert technical workshop to build on the TS-CRC outcomes
- identify a set of integrated strategies which can be implemented immediately and those which will require further study.

Environment Australia (EA) contracted CSIRO Sustainable Ecosystems in Alice Springs to organise the workshop through a steering committee (see Appendix A).

This report represents the deliberations of that workshop and describes the:

- objectives (see Chapter 1, Section 1.2)
- structure (see Chapter 1, Section 1.3)
- expected outcomes (see Chapter 1, Section 1.4)
- outcomes and associated activities undertaken before and during the workshop (see chapters 2, 3, 4 and 5)
- next steps (see Chapter 7).

1.2 Objectives

The main objectives of the workshop were to produce:

- a brief review of recent (often unpublished) research relevant to biodiversity monitoring in Australian rangelands to establish current knowledge, knowledge gaps and ways to move forward
- a review of those techniques and tools that do and don't work in order to assess the capacity to value-add using existing approaches and build on lessons learnt from the past
- a 'manual' for operation of well-tested, existing approaches as a set of technical guidelines to support planning of biodiversity monitoring systems
- an outline of a framework for monitoring change using expert knowledge to support adaptive management and indicate environmental performance.

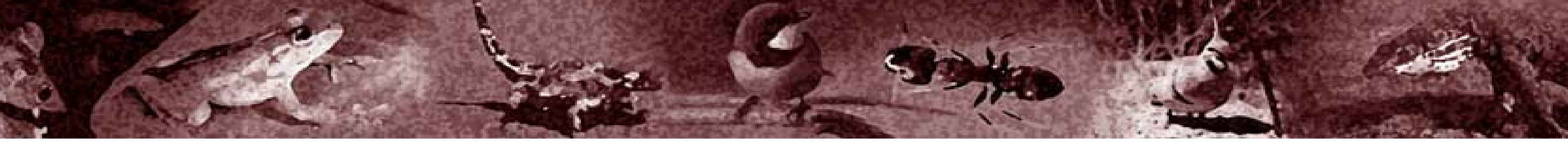
While planning for the workshop was under way, a national natural resource management (NRM) framework for monitoring and evaluation was being finalised. The framework sets out principles for monitoring, evaluation and reporting on natural resource condition. The framework also provides a set of matters for target for assessing change in natural resource condition and program performance. The indicators developed for reporting on the matters for target cover a range of geophysical, hydrological and biological issues, principally in relation to salinity, water, vegetation and species. The framework can be accessed through the following Internet address <http://www.ea.gov.au/nrm/monitoring/standards/index.html>.

The natural resource condition matters for target will, where relevant, be applied at the regional level as part of the reporting and feedback loop for implementing integrated NRM plans. The coincident timing of this workshop and the development and testing of indicators for regional reporting provides an excellent and timely opportunity to develop a robust suite of rangeland indictors for the biodiversity-related matters for target; as presented by Annemarie Watt (EA), these include:

- native vegetation communities' integrity
- significant native species and ecological communities
- inland aquatic ecosystems integrity (rivers and other wetlands)
- ecologically significant invasive species.

This new national monitoring and evaluation approach has an immediate impact on planning of biodiversity monitoring systems in the rangelands, so the additional objective of the workshop was to:

- produce a toolbox that also has the capacity for, or can fully support, 'measurable and meaningful' benchmarking by showing how well regional programs are working and whether funds are targeted effectively nationally.



1.3 Structure

1.3.1 Invitations

Many agencies and groups are engaged in biodiversity inventory but few are tackling the problem of how to monitor cost-effectively over large areas and how to detect trends against substantial background variability. Specifically, this process sought knowledge, experience and skills that could help to resolve key planning issues for biodiversity monitoring systems (see Table 1.2).

Table 1.2 Key issues for planning biodiversity monitoring systems tackled in the workshop

Issue	Context
Management applications	Is the technique useful to government agencies, pastoral companies, etc?
Scale (reporting, inference)	Can the tool/technique be used to report at different scales with confidence?
Cost-effectiveness and efficiency	Is it cost-effective and efficient to apply at appropriate scales?
Surrogacy and usefulness	How broadly does the tool/technique represent biodiversity?
Power of message	Is the message from the tool/technique going to be appreciated by policy/decision makers and the public?
Stage or readiness	Is the tool/technique ready to go or does it need a lot more research and refinement?
Applicability to different tenures and environments	What land uses, tenures and landscape types is the tool/technique useful for?
Sensitivity (time and thresholds)	Is the tool/technique robust for detecting trends through time? Is the time scale appropriate for political arenas? Is the tool/technique able to detect declining trends before an irreversible undesirable state change?

Hence, this workshop brought together experts who were involved in:

- sampling biodiversity to understand land-use effects and other threatening processes
- examining broad-scale surrogates for characterising landscape pattern and function
- statistical analyses to advise on sampling designs capable of detecting changes.

The steering committee tried to be very inclusive when inviting delegates to the workshop. They compiled a list of 48 experts with research or planning experience in the rangelands covering:

- the pressures of human activities (grazing, altered fire patterns, introduced predators and grazers, weeds and mining) on landscape patterns and function and aquatic and terrestrial biodiversity of the rangelands
- predictive and spatial modelling of biodiversity and pressures using satellite and GIS data
- statistical competence to advise on sampling designs capable of signalling change
- long-term monitoring programs and their evaluation
- policy making in biodiversity conservation, natural resource management and rural industries.

A total of 34 experts mainly from government agencies and research organisations attended the workshop (see Appendix B).

1.3.2 Pre-workshop activities

Questionnaire

To broadly understand the purpose of monitoring biodiversity in the rangelands, we informally distributed a questionnaire about a month before the workshop. We needed to know as a basis for designing the structure of the workshop:

- Who wants to use the information from biodiversity monitoring programs?
- At what spatial scale and resolution it is required?
- Over what time frame is it required?
- Would agencies or enterprise managers contribute funds to the program?

The questionnaire went to all delegates who attended the workshop and to others in government agencies particularly planners with interests in biodiversity monitoring, and to a small number of pastoralists. The results are summarised in Appendix C.

Commissioned papers

Seventeen papers were commissioned to bring together the knowledge of people working on the problems of sampling and interpreting change in different components of rangeland biodiversity. The process involved:

- soliciting papers to cover a broad range of topics: the context and background of biodiversity monitoring, pressures (or threats) to future biodiversity, potential indicators and designing monitoring programs (see Appendix D)
- distributing each paper to all delegates for their comments before the workshop
- distributing comments by delegates to each lead author to follow-up as part of the post-workshop activities.

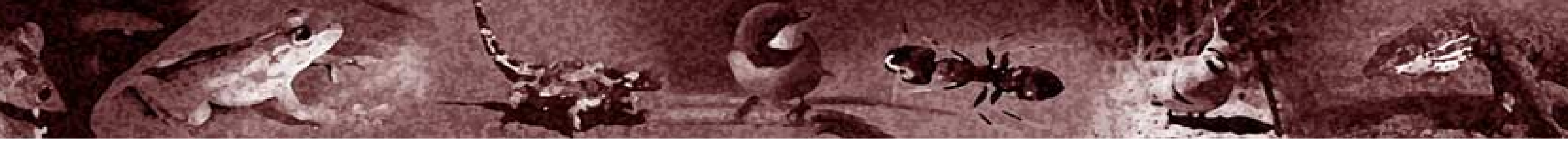
1.3.3 Workshop activities

On the first afternoon the proceedings, facilitated by Mark Stafford-Smith (CSIRO), began with a series of presentations:

- Annemarie Watt (EA) set the scene with the Commonwealth's policy and planning for biodiversity monitoring programs in the rangelands.
- John Read (Western Mining Corporation Resources Ltd) gave his perspective on what biodiversity monitoring means to a mining company that has interests in pastoralism too.
- Grant Whiteman (CSIRO) presented the results of the pre-workshop questionnaire.
- Members of the steering committee summarised the key issues highlighted in the 17 papers commissioned for the workshop.
- Ian Watson (WA Department of Agriculture) spoke about lessons learnt from Western Australian Rangeland Monitoring System pastoral monitoring systems.
- Simon Ferrier (NSW National Parks and Wildlife Service) challenged participants to think about how biodiversity could be in 200 years from now and what that meant for setting targets and designing a biodiversity monitoring system (BMS).
- Anita Smyth closed the presentations by describing and seeking input on a draft framework of the processes that needed to be undertaken when designing a BMS.

For the rest of afternoon and the next two days, delegates worked in four workshops seeking to identify:

- the purposes for biodiversity monitoring
- current techniques available for monitoring land-use pressures and biotic responses to those pressures
- the best indicators for different clients having specific purposes



- the principles that should underpin a framework to guide development of regional monitoring programs
- gaps in our knowledge and future R & D
- linkages with the TS-CRC biodiversity report, NRM matters of targets and the ACRIS.

These activities were interspersed with a field trip to Kuyunba Conservation Reserve during which people gave presentations, including:

- Andrew Bridges (Regional Manager—South, NT Parks and Wildlife Management, Department of Infrastructure, Planning and Environment (DIPE)) spoke on monitoring issues on parks. This was followed by a visit to the old enclosures on Owen Springs Station.
- Rudy Lennartz (Resource Assessment, DIPE) spoke on resource mapping of the Owen Springs Station.
- Glen Edwards (Parks andWildlife Management, DIPE) spoke on native fauna.
- Dave Kennedy (Pastoral Land, DIPE) spoke on pastoral monitoring.
- Will Dobbie (Centralian Land Management Association Incorporated) outlined what pastoral monitoring means to Central Australian landholders.
- Gary Bastin (CSIRO) discussed changes in the enclosures over time.

1.3.4 Post-workshop activities

After the workshop, some delegates and members of the steering committee undertook three main activities:

- Lead authors of draft commissioned papers were required to revise their manuscripts in the light of the workshop discussions and the comments from delegates for inclusion as attachments to this report.
- Lead authors were also requested to nominate whether they wished to submit their manuscripts for review in the thematic issue of *Austral Ecology*.
- Members of the steering committee discussed and planned (via teleconference and in person) the next steps following the workshop.

1.4 Anticipated workshop outcomes

The outcomes anticipated from the workshop included:

- the bringing together of experts from all rangeland states and the Territory
- consideration and review of recent, and most importantly, often unpublished research relevant to biodiversity monitoring in the rangelands
- development of a common 'state-of-the-art' view and an understanding of the complexity of biodiversity monitoring in the rangelands
- development of a shared view on the most appropriate 'sufficient and necessary' set of attributes and techniques for use now by different clients to monitor changes in biodiversity
- highlighting of the limitations of particular sets of attributes and techniques
- identification of interim guiding principles for rangeland biodiversity monitoring
- identification of knowledge gaps and research needs
- development of a set of practical, integrated strategies for biodiversity monitoring that can be incorporated into the ACRIS framework, combining the expertise of both researchers and natural resource managers.

CHAPTER TWO

Purpose, utility and attitudes towards monitoring

2.1 Pre-workshop questionnaire

Prior to the workshop, a questionnaire on biodiversity monitoring in the rangelands was distributed to 64 people. The recipients included workshop participants as well as government and private sector individuals with roles in rangeland management, administration or research. Twenty-eight responses were received (43%). The questionnaire investigated issues associated with the needs of particular organisations or enterprises for biodiversity monitoring in rangelands. The questionnaire was not intended to support a rigorous statistical analysis, but rather to provide an indication of the range and diversity of approaches to the issues canvassed.

Respondents were not constrained in the way they answered questions (e.g. by requiring them to select from a list of possible responses) and different interpretations and emphases were apparent in the answers. Therefore the following required an element of interpretation in order to identify and focus on common themes in the responses, rather than necessarily presenting an exhaustive inventory of responses. A summary of the key survey findings is presented below, and Appendix C contains a more quantitative summary of the responses.

2.1.1 Functional roles

The functional roles of the respondents included government agency research for natural resource management (NRM) (16 respondents), government planning, policy and/or administration of rangelands (6 respondents), private management of pastoral enterprises (5 respondents) and management of Indigenous lands (1 respondent).

2.1.2 Key issues

Respondents identified between one and seven key issues each, and these were grouped into eight broad types:

- incorporation of biodiversity management into natural resource management
- biologically sustainable enterprise management practices
- landscape monitoring and assessment
- species monitoring and conservation
- enterprise economics
- development of biodiversity indicators
- development of government standards and policy for rangeland use
- invasive/pest species management.

The incorporation of biodiversity data into planning and management was the frequently identified issue type, with 54% of respondents nominating a key issue in this class. The next most frequently nominated issue types were the identification, development and/or demonstration of biologically sustainable management practices (46% of respondents), and species monitoring and conservation (32%). All respondents with responsibility for the management of pastoral enterprises nominated at least one key issue concerned with the identification, development and/or demonstration of biologically sustainable management practices at the enterprise level.

2.1.3 Monitoring purposes

Nearly all respondents expressed multiple purposes for monitoring, but the single most frequent underlying purpose (75% of respondents) was to meet explicit or implicit legislative obligations. There were also strong emphases on improving enterprise-level decision making (64%), capacity building through enhancing awareness and understanding or by the provision of material resources (54%), and assessing the efficacy of government legislation, policy and administration (50%).

2.1.4 Information requirements

The respondents identified a total of 81 particular information requirements that could be classified into seven types of information. The most frequently required information types were distributions of particular species or areas of species richness (68% of respondents), biodiversity indicators (50%), and measures of landscape condition and function (46%).

2.1.5 Spatial and temporal aspects of monitoring

Monitoring information was most frequently required at enterprise or regional scale and resolution, although such information might subsequently be amalgamated to support reporting at broader (state or national) levels. The most appropriate time frames for monitoring varied according to the functional roles of respondents. Enterprise managers required monitoring on a seasonal or annual basis, with an additional capacity for event-driven monitoring. A five-year time frame was strongly preferred by those concerned with government planning and policy, and five years was also the typical time frame for NRM researchers, although their preferences were more diverse and ranged from three months to 20 years.

2.1.6 Budgeting for monitoring

Current and future funding intentions were highly variable. Six respondents (22%) had no monitoring expenditure, although three of these considered that expenditure was possible in the future. Nine respondents (32%) could not quantify resources devoted to monitoring. Among the remainder, annual expenditures ranged from \$20 000 to \$1 000 000, and from 5% to 65% of total budgets.

2.2 Workshop outcomes

2.2.1 Monitoring purposes

At the start of the workshop a distinction was drawn between monitoring and research. For the purposes of the workshop, monitoring was defined as 'detecting change through time', whereas identifying the cause(s) of change was regarded as a distinct research activity. It was generally agreed that meeting legislative or administrative requirements did not constitute a 'purpose' for monitoring, although the reasons underlying such requirements, whether or not they are explicitly stated, can be regarded as 'purposes'.

On these bases, nine types of purpose were identified:

- invoke management action
- assess whether management actions work
- improve ecosystem management
- evaluate investment intended to improve biodiversity outcomes
- increase formal and informal understanding of biodiversity-related processes
- determine whether biodiversity targets have been achieved
- involve communities
- inform the public about biodiversity and its management
- demonstrate achievement of compliance or accreditation standards.

It was considered that these nine purposes could be further reduced to two summary purposes:

- management/decision making
- environmental performance.

In essence, monitoring for management/decision making supports the internal goals and standards of an entity, which may include biodiversity conservation for its own sake or as an element in the production chain, whereas monitoring for environmental performance provides a basis for comparison of outcomes against external standards, whether formalised (e.g. NRM resource condition targets) or not (e.g. public expectations of 'stewardship').

2.2.2 Sustaining monitoring systems

It was generally agreed that, as well as being technically adequate, any biodiversity monitoring program must foster long-term administrative and public support, since the value of monitoring increases through time. Therefore, monitoring programs which require continual renewal of short-term projects, or which do not communicate results thus demonstrating their utility to a wide audience, were thought unlikely to achieve their purposes, regardless of technical merit.

Given that research was not considered a fundamental purpose of monitoring, doubts were expressed about the desirability of assigning monitoring functions to research-oriented organisations where long-term commitment to monitoring may be difficult to achieve. It was thought that management of monitoring functions may best be devolved to regional NRM bodies with appropriate government agency support, access to technical expertise, and inter-regional coordination. It was considered that the greatest effectiveness in identifying and meeting monitoring needs and in communicating outcomes would be achieved by focusing at the regional scale.

In setting priorities towards a necessary and sufficient system given limited resources, it was agreed it was necessary to:

- ensure techniques are in use or near this state
- encompass appropriate biodiversity values
- consider if we need to be spatially selective about monitoring
- consider 'social credibility'
- consider analysis, biological and statistical power, data management, storage and reporting as well as sampling method.

2.2.3 Necessary and sufficient set of biodiversity values

The biodiversity values discussed and agreed at the workshop to support a necessary and sufficient monitoring system fell into four broad categories:

- *Composition*
  - species and populations
  - community composition
  - genetics
- *Structure*
  - habitat
  - structure
  - landscape patterns
- *Function*
  - functional processes
  - resilience, integrity, sensitivity to threat
- *Social perception*

CHAPTER THREE

Assessment of attributes and monitoring techniques

3.1 Process

This workshop assessed attributes and monitoring techniques that were adequate for monitoring rangeland biodiversity. The workshop was divided into two sequential sessions:

- Session 1: Pressures
- Session 2: Biotic responses

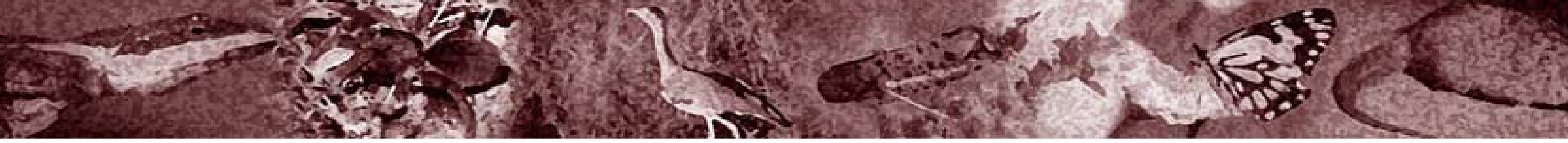
3.1.1 Summary of attributes and a glossary of assessment criteria for monitoring techniques

The types of monitoring attributes and the criteria used to assess the adequacy of monitoring techniques to measure them were presented in plenary at the beginning of each session to allow comment by participants.

The understanding of terms used by participants for this workshop and subsequent workshops is given in Table 3.1.

Table 3.1 Summary of attributes and a glossary of assessment criteria for monitoring techniques

Monitoring attribute	Type	Assessment criterion	Description
Pressure	Introduced predators Wild harvesting Grazing – domestic livestock – feral animals Weeds Landsurface changes – altered fire regimes – clearing – mining – vegetation change – hydrological changes (water quality, salinisation) – climate change – air and soil pollution	'Good' monitoring technique	Involved considering affordability and the other eight criteria identified here for assessment
		Minimum spatial resolution of measurement	The smallest area at which data for the attribute can be collected or derived using the specified monitoring technique, e.g. m^2, ha, km^2, region
		Minimum temporal resolution of measurement	The highest frequency for which data for the attribute must be collected or derived using the specified monitoring technique, e.g. weekly, monthly, annually
Biotic responses	Plants Invertebrates Vertebrates Ecosystem attributes	Reporting scale of measurement	The range of scales at which data for the attribute must be summarised for reporting
		Measurement quality	The accuracy and precision of the specified monitoring technique to measure the attribute
		Detecting change ability	The ability of a specified monitoring technique to detect change in a specified biotic response
		Indicator value	The ability of the pressure to indicate the specific biotic response(s) or the ability of the biotic response to indicate the specified pressure
		Limitations of monitoring technique and indicator	The shortcomings of the specified monitoring technique for measurement or the shortcoming of the specified attribute as an indicator
		Targeted attribute	Pressure (or biotic response) attribute to which the biotic response (or pressure) monitoring protocol specifically refers



3.1.2 Pressures

The purpose of the first session was to identify the land-use pressures that do or are likely to affect biodiversity and also 'good' monitoring techniques that currently exist to measure specified pressures.

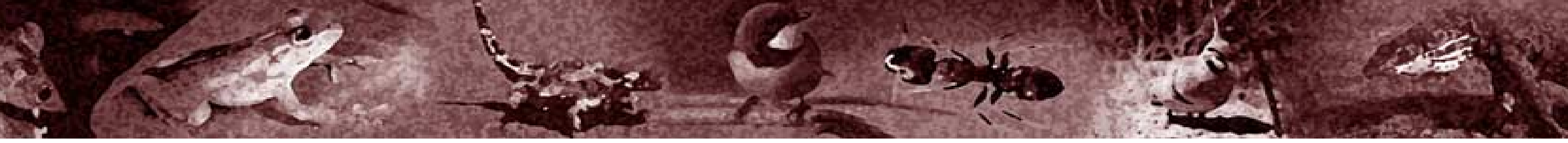
In small groups, delegates discussed five broad types of land-use pressures in the rangelands:

- feral predators
- wild harvesting
- grazing—domestic livestock and feral animals (total grazing pressure)
- weeds
- changed landscape patterns (later renamed 'landsurface changes') that included pressures associated with changed fire regimes, hydrological changes (salinisation, water quality), tree clearing, mining, vegetation change, climate change, and air and soil pollution.

Each group completed a template of questions to assess each 'good' monitoring technique for each major pressure that fell within their group's pressure type (see Table 3.2).

Table 3.2 Questions used to identify and assess adequate attributes and techniques for monitoring land-use pressures

Work group and pressure	Monitoring technique	Assessment criteria for each monitoring technique listed
1 Who are the members of the group? 2 Who is the recorder? 3 What is the pressure? 4 Who is the contact for follow-up information on monitoring techniques?	5 Identify the 'good' monitoring techniques that we have for the pressure. *Explain what is done and why it is a better technique than others. (Consider cost, ability to detect change over time, mismatches between scales of pressure and measurement, examples of use.)*	6 What is the spatial and temporal resolution of measurement? *I.e. is the spatial resolution in m^2, ha, km^2, bioregions? Is the temporal resolution in days, weeks, years or decades?* 7 What reporting scale(s) does each technique support? *E.g. is it from m^2 to a ha? Or ha to a paddock? Or paddocks to regions?* 8 Data quality—How effectively or reliably can the pressure be measured? *Rank L/M/H and explain.* 9 What are the target elements of biodiversity to which the monitoring protocol for this pressure refers? *E.g. do they impact on small mammals and/or a subset of plants?* 10 How well does the measurement of the pressure indicate status of the target elements of biodiversity? *Rank L/M/H and explain. If you were asked to recommend the monitoring technique as a basis for management of some aspect of biodiversity, how confident would you be that the result you got really indicated status?* 11 What are the limitations of the technique/indicator?



3.1.3 Biotic responses

Session 2 also involved delegates dispersing into work groups with expertise in four broad groups of biodiversity:

- plants
- invertebrates
- vertebrates
- ecosystem attributes.

The purposes of this session was to identify the biotic response group or taxon that does, or is most likely to, respond to land-use pressures and also to identify 'good' monitoring techniques that exist now for measuring the specified biotic response group or taxon.

Each group was asked to complete virtually the same 'pressure' template of questions for each major biotic response group or taxon that fell within their group's biodiversity type. The difference between the templates was a shuffling of 'pressure' with 'response group or taxon'. An additional question on detection quality also discussed is listed in Table 3.3.

Table 3.3 Modified 'pressure' questions from Table 3.2 and an additional question used to identify and assess adequate biotic response attributes and techniques for monitoring biodiversity

Work group and pressure	Monitoring technique	Assessment criteria for each monitoring technique specified
3 What is the response group/taxon?	5 Identify the 'good' monitoring techniques that we have for the groups and taxa. *Explain what is done and why it is a better technique than others. (Consider cost, ability to detect change over time, mismatches between scales of pressure and measurement, examples of use.)*	8 Data quality—How effectively or reliably can the taxon/group be measured? *Rank L/M/H and explain.* 9 What are the pressures to which the monitoring protocol for this taxon/group refers? *E.g. do they impact on small mammals and/or a subset of plants?* 10 How broadly applicable is the indicator value of this taxon/group? *Rank L/M/H and explain. If you were asked to recommend the monitoring technique as a basis for management of some aspect of biodiversity, how confident would you be that the result you got really indicated status?* 12 Detecting change—How good is each technique at detecting change? *Rank L/M/H and explain.*

3.2 Workshop outcomes

3.2.1 Participant effort

Expertise was well represented across both pressure and biotic response work groups as shown in Table 3.4. Key features of the effort of participants were:

- Each attribute was assessed by a number of experts.
- Eighty-nine techniques were identified for a total of 56 monitoring attributes of land-use pressures and biota that respond to those pressures.
- Most of the 'good' techniques were assessed against all of the criteria as adequate measurements of the monitoring attributes.
- Only 38 items (4%) of information were missing.

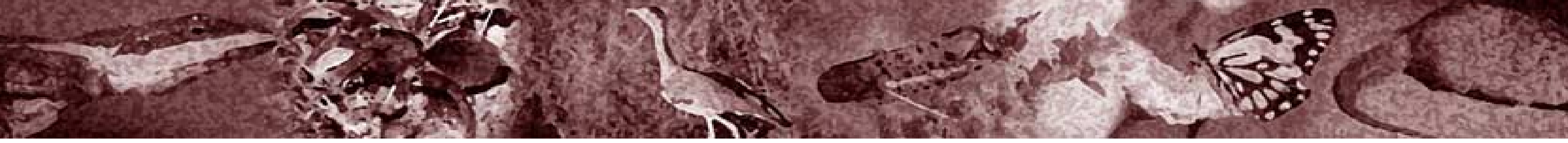


Table 3.4 A summary of effort by workshop participants in identifying monitoring attributes and techniques, and assessing their quality

Attribute type	No. experts in group	No. attributes identified	No. techniques identified	No. techniques assessed	Comments
Pressures					
Introduced predators	7	5	13	8[a]	Only 'good' techniques were assessed
Wild harvesting	7	4	3	2[a]	Fixed-wing aerial surveys were not assessed for kangaroos (see Lundie-Jenkins et al. in Appendix 4)
Grazing	10	4	8	8	
Weeds	5	3	4	3	
Landsurface changes					
– climate change, hydrological change (water quality, salinisation), air and soil pollution	8	7	16	10	Only 'good' techniques were assessed
– vegetation and landscape function changes (clearing, mining, erosion, land succession)	8	4	3	3	
– altered fire regimes	8	1	3	3	
Biotic responses					
Plants	10	c.14	5	3	Three similar techniques were assessed as one
Invertebrates					
– ants	5	1	1	1	
– aquatic	5	2	2	2	
Vertebrates					
– frogs	4	1	5	5	
– reptiles	8	1	2	2	
– fish	7	1	2	1	Two similar techniques were assessed as one
– birds	7	1	4	3	Two similar techniques were assessed as one
– mammals	8	1	10	10	
Ecosystem attributes					
– wetlands and riparian habitats	8	4	6	4	Three similar techniques were assessed as one
– habitat structure complexity and patchiness		2	2	2	

[a] Similar techniques for different pressures were repeated counts.

3.2.2 Adequate monitoring attributes and techniques

The adequate pressure and biotic response attributes, and good techniques for their monitoring are summarised in the following tables:

Attribute	Type	Table
Pressure	Introduced predators Wild harvesting Grazing Weeds Landsurface changes	3.5 3.6 3.7 3.8 3.9
Biotic responses	Plants Fauna Ecosystem attributes	3.10 3.11 3.12

Key information about the tables:

- They present the raw information provided by participants in the workshop as closely as possible.
- Where an interpretation of incomplete information was necessary, the text is printed in quotes.
- Lighter areas indicate that no information was provided.
- The richness of the information is given so that the reader can assess the adequacy of the monitoring techniques for particular monitoring attributes.

Table 3.5 Assessment of the monitoring techniques for measuring attributes of introduced predators using measurement criteria and the biota they target

Pressure	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Ability of pressure attribute to indicate biotic response	Limitations of monitoring technique	Targeted biota
		Spatial	Temporal					
Wild dog	Track counts	Hectares	Months	Paddock to land systems	Medium to high	Non-linear at high dog densities; may only approximate activity and not measure densities; substrate dependent	Highly variable depending on links with lower order predators	Endangered mammals
Red fox	Track counts	Hectares	Months	Paddock to land systems	Medium to high	Same as for wild dogs	Medium to high	Critical weight range mammals, some birds and reptiles
House cat	Track counts	Hectares	Months	Paddock to land systems	Medium to high	Same as for wild dogs	Medium to high	Same as fox
Pig	Helicopter aerial survey	km^2	Months	Paddock to land systems	High	Needs trained observers; difficult to sustain over time; limited data analysis and storage	Highly variable, medium in wetland areas but low elsewhere	Ground-nesting birds, ground and understorey damage, disease and parasite reservoir
	Direct counts, ground survey	Hectares	Months	Paddock to land systems	Low to medium		Highly variable, medium in wetland areas but low elsewhere	
	Indirect counts (tracks, rips)	Hectares	Months	Paddock to land systems	High		Highly variable, medium in wetland areas but low elsewhere	
Introduced fish	Netting	m^2	Weeks	m^2 to hectares	Medium	Can kill or injure as it is not a species-specific technique	Medium to high	Native fish and amphibians
	Electrofishing	m^2	Weeks	m^2 to hectares	Unknown	Same as for netting	Unknown	Same as for netting

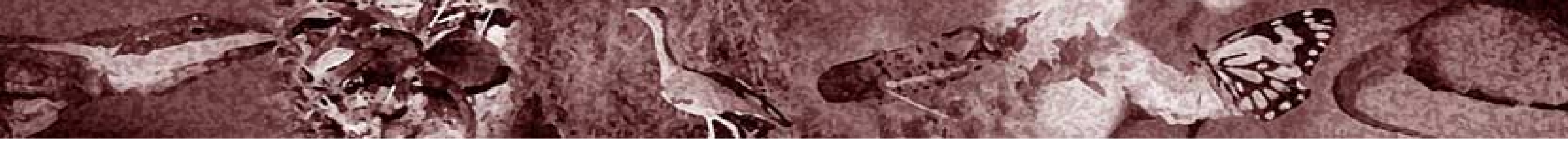


Table 3.6 Assessment of the monitoring techniques for measuring attributes of wild harvesting using measurement criteria and the biota they target

Pressure	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Limitations of monitoring technique	Ability of pressure attribute to indicate biotic response	Targeted biota
		Spatial	Temporal					
Kangaroo harvesting	Licensee returns	Region	'Annual'	Region	High	Relies on assessment of impact, relationship between harvest and population size; other techniques required if harvest is high	Low	Kangaroos
Wild harvesting	Licensee returns	Region		Region	Low	Relies on assessment of impact, relationship between harvest and population size; other techniques required if harvest is high	Low	Fish, quail, wildflowers, various bush foods
Recreational fishing	Licences, inspection	Region		Region	Low	Relies on assessment of impact, relationship between harvest and population size; other techniques required if harvest is high	Low	Fish
Commercial waterfowl harvesting	Licensee returns	Region		Region	High	Relies on assessment of impact, relationship between harvest and population size; other techniques required if harvest is high	Low	Waterfowl

Table 3.7 Assessment of the monitoring techniques for measuring attributes of grazing using measurement criteria and the biota they target

Pressure	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Limitations of monitoring technique	Ability of pressure attribute to indicate biotic response	Targeted biota
		Spatial	Temporal					
Grazing—total	Aerial survey	km²	1–3 years	Paddock/ region	High	Needs context for interpretation; doesn't reveal fine-scale pressures	Low to high	Plants, native herbivores, 'landscape'
Grazing—livestock	Stocking rate returns	Property	Annual	Property	High	Only done in SA and WA; some credibility issues; paddock level would be more useful	High	Vegetation, landscape health
	Land tenure change	Usually 50 000 ha	1– 5 yearly	Shire to region	High	Requires inferences about land tenure and land-use/grazing relationships	Low to high	Plants, native herbivores, 'landscape'
	Aussie GRASS	Shire	Monthly	Enterprise to region	Low to high, varies among states; lower where shires are large	Constrained by level of confidence in model output	Medium	Vegetation
	Remote sensing—grazing gradients	Hectare	Annual	Region	Medium	Unknown linkages to other elements of biodiversity; lacks established capacity		Vegetation patterns, landscape health
	Distance from water	Hectare	Annual	Paddocks to region	High	Confounded by other factors—stocking rate, fire, etc.	Low to medium as pressure varies with stocking rate	Vegetation, ecosystem function
Grazing—various	Transect counts—tracks, droppings, animal activity indicators	Hectare	Months	Hectare to paddock	Variable, low to high	Not reliably extrapolated across scales—most appropriate for restricted, high conservation value areas	Medium	Plants, herbivores, landscape
Grazing—kangaroos and pigs	Shooters' returns	Region	Annual	Region	High	Requires context, e.g. kangaroo number relative to total herbivores; resources required to determine impact on plants	Low generally, medium to high for kangaroos	Plants, riparian habitat, kangaroos

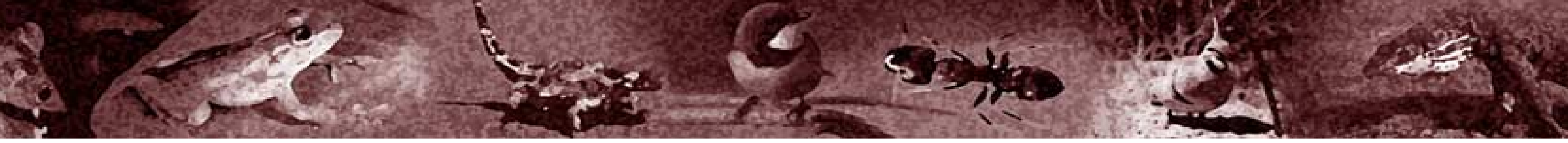


Table 3.8 Assessment of the monitoring techniques for measuring attributes of weeds using measurement criteria and the biota they target

Pressure	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Limitations of monitoring technique	Ability of pressure attribute to indicate biotic response	Targeted biota
		Spatial	Temporal					
Woody weeds	Remote sensing	Hectare	Years	Paddock to region		Limited capability; not possible for all species	Low	Generic for plants and animals
	Stratified transects—aerial	Hectare	Years	Paddock to region	High	Time consuming; can be expensive; links to particular elements of biodiversity not well documented	Low	Generic for plants and animals
	Stratified transects—aerial	Hectare	Years	Paddock to region	Medium	Time consuming, expensive; limited areal extent; links to particular elements of biodiversity not well documented	Low	Generic for plants and animals
Aquatic weeds	Remote sensing					No proven techniques for large-scale monitoring; generally difficult to distinguish native and exotic species remotely, with some exceptions; requires context for interpretation		
Weedy perennial grasses	Remote sensing	Hectare	Years	Hectare to region	High	Cost; not species specific; requires 'ground-truthing' and contextual information; testing required	Probably good, but not quantified	Generic for plants and animals
	Ground survey—BOTANAL	m^2	Years	Hectare to region	High at finer scales	Expensive, time consuming; limited capacity for large areal extent	Probably good, but not quantified	Generic for plants and animals

Table 3.9 Assessment of the monitoring techniques for measuring attributes of landsurface changes using measurement criteria and the biota they target

Pressure	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Limitations of monitoring technique	Ability of pressure attribute to indicate biotic response	Targeted biota
		Spatial	Temporal					
Vegetation change	Remote sensing—grazing gradients	25–30 m	Annual or episodic	Paddock to bioregion	Medium	Unknown linkages to other elements of biodiversity; lacks established capacity	High	Vegetation patterns, landscape health
	Remote sensing-cover change SLATS, *AGONCAS?*	Hectare	Annual	Paddock to bioregion	Medium	Unknown linkages to other elements of biodiversity; lacks established capacity	High	Vegetation patterns, landscape health
	Remote sensing—VHRRS	m^2	Months	Paddock	Medium	Does not sample composition well; lacks established capacity	High	Vegetation cover and pattern, landscape function
Watercourse flow	Flow data logging	Watercourse	Continuous	km^2 to catchment	High	Cost; 'skill requirements'	High	Aquatic biota, birds
Flooding, overland flow	Remote sensing—Landsat	Region	Weekly	km^2 to region	High	'Skill requirements'	High	Aquatic biota, birds
Water quality	Water turbidity, salinity, nutrients	Site	Variable	Watercourse/ catchment	High	'Skill requirements'; cost	High, depending on resolution	Aquatic biota and terrestrial dependents
Air and soil pollution	Plant bioindicators	Hectare	Years	Enterprise	High, if temporal variability is accounted for	Biotic responses are seldom linear	Low	Any sensitive biota
	Chemical assays	Hectare	Minutes	Enterprise	High, if temporal variability is accounted for	Biotic responses are seldom linear	Low	Any sensitive biota
Water pollution	Chemical assays	Hectare	Minutes	Enterprise to catchment	High, if temporal variability is accounted for	Biotic responses are seldom linear	Low	Any sensitive biota
	Sediment assays	Hectare		Enterprise to catchment	High, if temporal variability is accounted for	Biotic responses are seldom linear	Low	Any sensitive biota

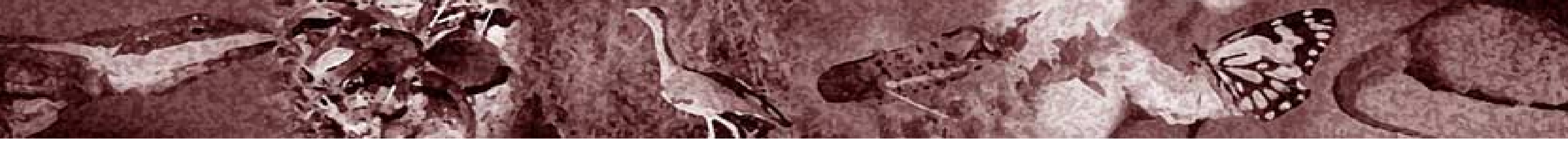


Table 3.9 cont.

Pressure	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Limitations of monitoring technique	Ability of pressure attribute to indicate biotic response	Targeted biota
		Spatial	Temporal					
Fire	Ground-based survey of fire intensity	< 1/2 hectare	Event driven	Small site: paddock to park	High	Field-work intensive; needs links to spatial information	Low to medium; limited knowledge of rangeland fire histories limits interpretation	Plants
	Ground-based GPS mapping of fire areas	Up to 1/2 hectare	Event driven	Small site: paddock to park	High	Suited to small areas in intense impact locations—parks or 'fire-sensitive' communities	Low to medium; limited knowledge of rangeland fire histories limits interpretation	All elements, but higher potential for plants
	Satellite mapping of fire areas—Landsat TM, MODIS, AVHRR	2–200 hectares	2–32 days	Landsat TM: hectare to region; MODIS: paddock to region; AVHRR: region to national	Landsat TM; MODIS: medium; AVHRR: low	Essentially burnt/unburnt data, lacking intensity information; requires skilled interpretation; large spatial extent of fires restricts accuracy of mapping and fire frequency calculations; limited knowledge of rangeland fire histories limits interpretation	Low to medium	All elements, but higher potential for plants
Climate	NDVI greenness—MODIS, NOAA	MODIS 200 m^2, NOAA 1 km^2	Daily	Region or greater	Medium	Needs interpretation; generally poor understanding of direct relationships between seasons and population dynamics	Variable, 'low to medium'	Generic indicator
	Bureau of meteorology station rainfall data	Point	Daily	Region or greater	High	Needs interpretation; generally poor understanding of direct relationships between seasons and population dynamics	Variable, 'low to medium'	Generic indicator
	Rainfall surfaces—SILO	Less than km^2	Daily	Region or greater	Medium	Needs interpretation; generally poor understanding of direct relationships between seasons and population dynamics	Variable, 'low to medium'	Generic indicator
Lake bed land-use change				Lake bed to region	High	Cost and skill requirements	High, depending on resolution	Birds, and more general

Table 3.10 Assessment of the monitoring techniques for measuring attributes of plants using measurement criteria and the pressures indicated

Attribute	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Ability to detect change	Limitations of monitoring technique	Ability of taxon to indicate pressure	Targeted pressures
		Spatial	Temporal						
Plant structure, biomass, health, soil surface	Photopoints	m^2	Annual	Paddock to region	High	High	Cannot be used in isolation, needs inter-relational framework, qualitative data	Cannot be used in isolation, needs inter-relational framework, qualitative data	Grazing, fire, clearing, erosion
Plant community composition (highly palatable, perennial, rare species, weeds), functional groups, structure, demography, health	Plot-based surveys	m^2, km^2	'Days'	Paddock to region	High at site but low when aggregated across broader scales	High at site, variable at broader scales	Spatial resolution limits the number of plots; dependent on available resources; dependent of rigour sampling design	Spatial resolution limits the number of plots; dependent on available resources; dependent of rigour sampling design	Grazing, fire regimes, weed invasion, clearing, land-use change, disease, changes to water regimes
Loss or decline in extent of cover, communities or ecosystems (incl. threatened ecosystems)	Analysis of satellite and vegetation mapping data, airborne photography	m^2, km^2	1–2 years	Paddock to region	Low to medium	Medium to high	Calibration for regional differences, based on general assumption that is a surrogate for loss of habitat and biodiversity	Calibration for regional differences, based on general assumption that is a surrogate for loss of habitat and biodiversity	Loss of habitat from modification and clearing, total grazing pressure (grazing gradient approaches), water points, infrastructure change, fire regimes

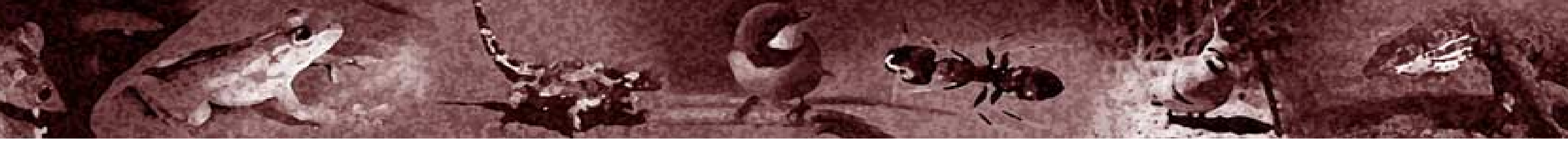


Table 3.11 Assessment of the monitoring techniques for measuring faunal attributes using measurement criteria and the pressures indicated by them

Taxon	Monitoring technique	Minimum resolution of measurement		Reporting scale of measurement	Measurement quality	Ability to detect change	Limitations of monitoring technique	Ability of taxon to indicate pressure	Targeted biota
		Spatial	Temporal						
Grazing-sensitive ants	Pitfall traps	Hectares	2–5 days	Paddock	High	High	Low charismatic value; resource intensive to sort	High, good indicator for other invertebrates	Any land-use change
Aquatic invertebrates	Micronetting and volume sampling	m^3	Hours	Waterhole to catchment	Medium to high	High	Taxonomic issues; timing critical in episodic systems; benchmarks needed; lack charisma	High	Grazing (erosion, increased nutrients), hydrological changes, clearing, cropping and others
	Macronetting and volume sampling	m^3	Hours	Waterhole to catchment	High				
Frogs	Auditory recording, pitfall traps, opportunistic surveys (toxicology, frog-watch), aural recordings (see Grigg)	Hectares	'Episodic'	Paddock/ waterhole to region/ wetland/ catchment	Low	Low for census but high for bioassays	Availability for episodic sampling—climate driven	Low	Water pollution, wetland changes, cane toad invasion, disease/ pathogens
Reptiles	Pit trapping, searching	m^2–hectares (large mobile species)	Annually	Paddock to subregional	Medium for high sampling effort	Low to medium for abundance/ activity; medium for species composition	Differential capture; variability in time; high effort for return	Low to medium for reptile assemblages; low for indicating other taxa	Grazing, fire, feral predation
Fish	Netting/trapping, electrofishing	m^3	Annually	Waterholes, streams, drainages	Variable, influenced by flows	Unknown	Difficult to extrapolate from locality to locality		Water quality and flows
Birds	Ground-based plot or distance sampling surveys	Hectares	Seasonal to annual	Hectare to region	High with replication and maximising detectability	Medium to high	Sampling intensity affects statistical power of technique	High	Landscape change, grazing, feral predators, water quality
	Community atlasing	Region	20-year interval	Region to continent	High	Low to medium using supplementary data	Sampling intensity and timing affects statistical power; observer variability		
	Aerial surveys	km^2	Annually	Water bodies	High	High	Sampling intensity and timing affects statistical power; observer variability		
Mammals	Pit/Elliot traps	Hectares	Monthly	Hectares	Medium to high	Low	High sampling effort required; very high seasonal and between-year variation	Medium to high	Feral predators, grazing, fire, land clearance
	Animal counts (day or night)	Hectares	Monthly	'Region'	'Low'				
	Scat counts/ analysis	Hectares	Monthly	'Hectares'	'Low'				
	Annabat recordings	Hectares	Monthly	'Region'	Low to medium	Low to medium	Requires reference calls and training		
	Track counts	Hectares	Monthly	Paddock to land system	Medium to high	Medium to high	Depends on track network, densities; approximates activity; no measure of densities; substrate dependent		
	Opportunistic sampling	'Region'	'Episodic'	'Region'	'Low'	'Low'	Biased sampling		
	Hair tube/tongue pads	'Hectares'	'Monthly'	'Region'	'Low'	'Low'	'Indication of presence only; tongue pads uncertain; costly DNA'		
	Aerial survey—fixed-wing plane	Region	Annually	Region	High	Medium to high	Relies on subjective assessment of impact		
	Mark, release, recapture	Hectares	Days	Paddock	Variable	High	Number marked and recaptured must be high; resource intensive		
	Telemetry	Hectares	Days	Paddock	High	High	Limited to reintroductions and threatened species; costly		

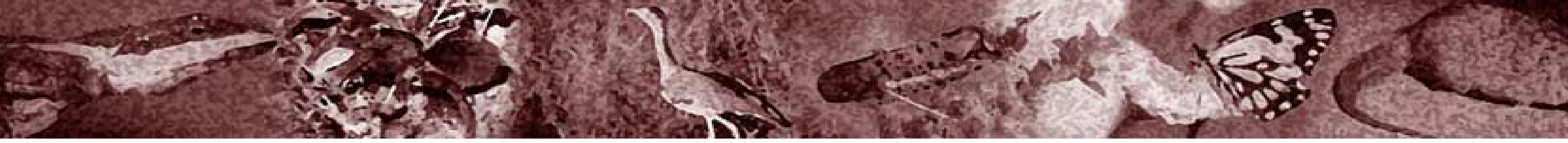


Table 3.12 Assessment of the monitoring techniques for measuring ecosystem attributes using measurement criteria and the pressures indicated by them

Attribute	Monitoring technique	Minimum Resolution of measurement		Reporting scale of measurement	Measurement quality	Ability to detect change	Limitations of monitoring technique	Ability of attribute to indicate pressure	Targeted pressures
		Spatial	Temporal						
Aquatic ecosystems, riparian habitats	Water quality and flow	Hectares	Not reported	Region	High	High	Episodic measures; hard to access when wet; indicator of themselves	Variable depending on where in landscape	Total grazing pressure
	Satellite data, API (flooding patterns, water-course breaches, sediment accumulation)	Hectares	Depends on imagery, runs	Hectares	High	High			
	Ground water sampling	Hectares		Region					
Aquatic biota, key species		Hectare		Hectare to region				'Total grazing pressure'	
Habitat structure complexity/ patchiness	Remote sensing, airborne photography	m^2	Annual, episodic	Paddocks to regions	Medium	High at suitable resolutions	Not sufficiently tested but intuitively limited evidence connecting patchiness and biodiversity; not suitable for all landscape types	Good in 2-D, poor in 3-D but potential improvement with radar	Grazing, fire, watering points, infrastructure change, highly integrative indicator
	Ground-based transects, photos, plots	m^2	Episodic, inter-episode	Regional with limits	High	Medium			

Appropriate indicator and technique sets for monitoring purposes of different clients

4.1 Process

This workshop focused on client requirements for biodiversity monitoring at regional and local scales.

Firstly, all participants drew on personal experience to identify:

- functional client groups
- local- and regional-scale biodiversity monitoring needs
- purposes for conducting biodiversity monitoring to confirm the purposes described in Section 2.2.1.

The workshop then broke into five working groups based on functional groups and their scales of operation to further consider specific information requirements and appropriate indicators.

A brief plenary discussion of progress was held and then groups re-formed to:

- identify appropriate indicators
- identify required monitoring and reporting scales
- justify indicator selection.

4.2 Workshop outcomes

Five reporting scale/function groups of clients were identified during the first phase of the workshop. The five groups and their associated clients and monitoring purposes, scales and resolutions are presented in Table 4.1. It was recognised that this may not be an exhaustive list, given the requirement that participants have personal experience in dealing with the scale/function groups they identified.

It was noted that it may be appropriate to design 'tiered' monitoring programs with different degrees of rigour to cater for the particular needs and resources of individual clients. For instance, one tier could be designed to meet the regulatory requirements for pastoral leases, while a higher tier might be designed to meet additional requirements for 'clean-green' product certification. Three tiers with different monitoring intensities were described:

- limited attributes, qualitative results
- additional attributes, semi-quantitative results
- comprehensive attributes, quantitative results.

Table 4.2 lists the individual indicators that were identified as appropriate to support the five function/ scale groups, with a brief explanation of the reasons for selecting each indicator. There is one striking difference in the monitoring needs of the five groups. All six of the indicators listed for regional compliance reporting and five of the six indicators for local matrix management are response indicators, but the other three groups have more balanced mixes of pressures and responses. While this may accurately reflect differences in monitoring needs, it might also indicate deficiencies in the indicator lists or in the required standards (particularly in the case of regional compliance reporting).

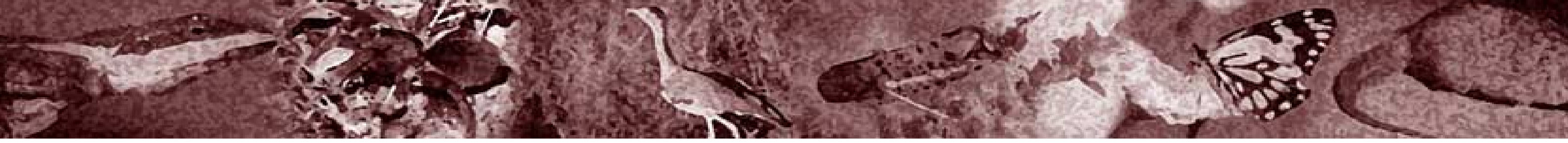


Table 4.1 Purposes, resolution and reporting scales for local and regional clients of biodiversity monitoring

Reporting scale and function	Clients	Purposes for monitoring	Resolution of monitoring	Scale of reporting
Local reporting—matrix[a] management	Pastoralists	Maintain biological integrity Legislative compliance Maintain landscape productivity	Hectares	km^2
Local reporting—special biodiversity values	State government Pastoralists Indigenous communities Harvesting enterprises Mining industry Tourism enterprises Conservation NGOs	Identify problems Avoid contentious areas/situations Environmental accreditation Demonstrate good governance Legislative compliance Watchdog on industry	Hectares	Enterprise or subregional
Regional reporting—compliance	Federal government State government NRM groups Local government ACRIS	Legislative compliance Demonstrate good governance	Regional	Regional+
Regional reporting—investment allocation	NRM groups State government Federal government	Identify problems Demonstrate problems Assess investment needs Assess cost/benefit of investment	Catchment and subregional	Catchment and subregional
Regional reporting—regulatory	State government Local government NRM groups	Meet regional targets	Catchment and subregional	Regional

[a] The mosaic of land types and associated ecological communities.

Table 4.2 Appropriate indicators for regional- and local-scale biodiversity reporting functions, and reasons for their selection

Reporting scale and function	Indicator description	Indicator type	Indicator explanation
Local reporting—matrix management	Abundance of feral herbivores	Pressure	Manage populations of feral mammalian herbivores to maintain acceptable low levels
	Composition of ant fauna	Response	Ants are a ubiquitous, grazing-sensitive group that can be taken as surrogate for invertebrates as a whole
	Composition of bird fauna	Response	Different suites of birds are good indicators of different pressures, based on mobility/ dispersal characteristics
	Cover and structure of perennial terrestrial vegetation	Response	Broad indicator of a number of pressures, e.g. grazing, fire, flood, drought, weed invasion, land clearing
	Composition of perennial terrestrial vegetation	Response	Aimed at maintenance of pastorally productive plant species and habitat for other elements of biodiversity
	Increase in area of disturbed and eroded land	Response	Indicates overall change in function of areas within a property. Can expand if not checked
	Abundance of feral predators	Pressure	Removing predation is a critical management factor in looking after critically endangered species. Manage populations of feral mammalian predators to maintain acceptable, low levels
Local reporting—special biodiversity values	Abundance of introduced fish species	Pressure	An indicator of invasive problems in aquatic systems
	Abundance of invasive weeds	Pressure	Controlling invasive weeds is a critical management factor in looking after endangered species
	Effective recruitment in populations of special biota	Response	Recruitment is key to persistence in species or ecosystems of high value
	Localised grazing pressure	Pressure	Specific to plant communities that need some areas protected from grazing pressure (e.g. from rabbits)
	Extent and severity of environmental pollutants	Pressure	Mining discharges and emissions may have significant local effects on sensitive communities
	Fire frequency and extent within fire-sensitive communities	Pressure	Monitoring fire impact as a threat is first step; link to recruitment measurements for some indicator species within fire-prone communities
	Flooding regimes in relation to rainfall events	Response	Hydrologic regimes needed for wetland health
	Infrastructure to protect special areas	Response	Fences to remove stock, firebreaks, etc. are indicators of care for special areas and taxa
	Proportion of amphibian populations with deformities	Response	Discharges and emissions (e.g. from mining, cropping) may have significant effects on local frog communities

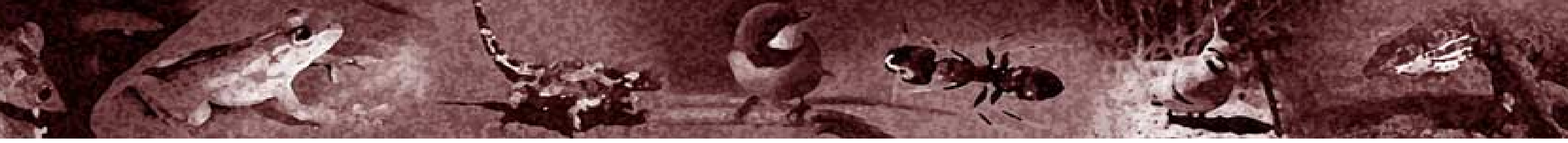


Table 4.2 cont.

Reporting scale and function	Indicator description	Indicator type	Indicator explanation
Regional reporting—compliance	Composition and abundance of waterbird fauna	Response	Sensitive to changes in water quality and pollution. An integrating indicator because they are at the top of the food chain
	Composition of perennial terrestrial vegetation	Response	A long-term attribute of landscape function and habitat for other elements of biodiversity
	Composition of terrestrial fauna	Response	Direct measure of biodiversity. Differential responses among subgroups may indicate nature of pressures
	Cover and structure of perennial terrestrial vegetation	Response	A long-term attribute of landscape function and habitat for other elements of biodiversity. Provides qualitative insights into integrity and function of meso-scale landscapes (hectares). Easy to measure and readily interpretable by pastoralists. Has likely links to ground-dwelling/nesting fauna
	Status of threatened species and ecological communities	Response	Improving condition of environment if threatened species and ecological communities are being delisted
	Kangaroo abundance	Response	Confidence in sustainability of harvest and to set quota
Regional reporting—regulatory	Abundance and distribution of feral pest animals	Pressure	Considered to be main determinant of decline in small mammal species
	Composition and abundance of waterbird fauna	Response	Indicates wetland health and there is functional linkage to hydrological change. Easily understood and has social appeal
	Abundance and distribution of aquatic and semi-aquatic vegetation	Response	Directly measures the effect of changed flow regimes on riparian vegetation and wetland health
	Extent and distribution of floodwaters	Response	Directly measures the effect of changed flow regimes by monitoring seasonality, duration, extent and frequency
	Landscape pattern change	Response	Indicates potential loss of function and habitat degradation. Simplification of processes but cost-effective at large scales
	Status of threatened species and ecological communities	Response	High public profile and easily collected information, therefore useful for raising profile with decision makers and targeting investment
	Structure of perennial terrestrial vegetation	Response	Well-established link between grazing pressure and vegetation structure and landscape change. Methods well known and have strong links with other ACRIS indicators. Measurement is of percentage cover and patchiness, composition and relative abundance
	Concentrations of pesticides and nutrient pollutants in waterways	Pressure	Reveals levels of pressure on landscape and links to aquatic systems. Indicates potentially unsustainable development
	No. and extent of introduced weed species	Pressure	Implications for regional control costs
	No. of weed species changing to new category	Pressure	Indicates effectiveness of control
	No. of new agricultural species with weed potential	Pressure	Potential for invasive introductions
	Progress towards a CAR conservation network	Response	(a) Assessment of the number of hectares in a bioregion in reserves (b) Percentage of ecosystems in reserves (c) Median size of reserves in bioregion. Easily measured variables showing proportion of land area explicitly managed for biodiversity outcomes and potential reduction in threats associated with land use for production
	Average stocking rates	Pressure	In combination with water point indicators can indicate grazing pressure on ecosystems
	Composition of aquatic invertebrate fauna	Response	Sensitive indicators of aquatic and riparian habitat condition
	Composition of bird fauna	Response	Presence of certain bird species indicates the level of disturbance to environment hence, the presence of some specific species in least pressured areas of the landscape is desirable for persistence
	Composition of perennial terrestrial vegetation	Response	Presence of certain species indicates the level of disturbance to environment hence, the presence of some specific species in least pressured areas of the landscape is desirable for persistence
	Cover of perennial terrestrial vegetation	Response	Broad indicator of a number of pressures, e.g. grazing, fire, flood, drought, weed invasion, land clearing
	Density of artificial water points	Pressure	Surrogate for grazing pressure and land-use intensity but also directly correlated with changes in water-dependent species
	Density of feral and native mammalian herbivores	Pressure	In combination with stocking rate indicators can indicate total grazing pressure on ecosystems
	Distribution and abundance of weed species	Pressure	Try to determine expansion through formalised reporting of new presences
	Distribution of foxes	Pressure	Try to determine expansion through formalised reporting of new presences
	Extent of clearing of remnant native vegetation	Pressure	Habitat loss may directly affect biodiversity of resident communities and connectivity of habitat patches within landscapes
	Fire frequency and extent across landscape	Pressure	Examine role of fire in changing habitat elements of landscape
	Fire frequency and extent in fire-sensitive communities	Pressure	Specifically to examine effects on fire-sensitive ecosystems
	Land tenure change	Pressure	Percentage of land class in each tenure may relate to land use and potential pressures
	Landscape pattern metrics (patch sizes, connectivity)	Pressure	Indicators of fragmentation, etc. leading to slow loss of species
	Per cent of land area that is remote from water points	Pressure	Indicates the extent to which grazing-sensitive and water-affected species have refuges from these pressures
	Vegetation 'greenness' indices	Response	Indicates relative condition of areas, possibly due to drought and/or grazing. Could indicate weed invasion or disturbance around water points
	Water quality	Pressure	Potential indicator of aquatic and riparian habitat condition, but relationship needs to be clarified

Framework for developing biodiversity monitoring systems—guiding principles

5.1 Process

On the first day of the workshop, Anita Smyth presented a preliminary operational framework from the perspective of a natural resource management (NRM) manager. The purpose of this presentation was to provide an example of the types of principles that need to be considered when developing a framework for guiding the designs of biodiversity monitoring systems (BMSs).

As the workshop progressed, two work groups further developed these principles:

- group 1: Simon Ferrier, Angas Hopkins, Jill Landsberg and Anita Smyth
- group 2: AO (Nick) Nicholls and Jeremy Wallace.

The objectives of group 1 were to:

- provide guidance to regional committees about biodiversity monitoring for setting resource condition targets, and planning and implementing a biodiversity monitoring program
- provide information to regional committees about what to report to show progress towards meeting biodiversity targets
- keep the measures as simple, effective, meaningful and affordable as possible.

This group assumed throughout the process that:

- Regional monitoring programs will be informed by, and provide information to, a national support network that has responsibility for providing a national context for issues that transcend regional boundaries.
- The regional committee is able to access and interact with a national coordinating body that manages issues such as data protocols, analytical standards, meta-analysis and reporting standards.
- Other resource condition matters for targets (e.g. land salinity, soil condition, etc.) are detailed in other documents; these resource condition matters also benefit biodiversity, but may not be sufficient for monitoring and/or conserving it.

The objective of group 2 was to:

- identify the generic principles for monitoring.

5.2 Workshop outcomes

5.2.1 Pre-workshop

Smyth's example of an operational framework is shown in Appendix E. The six key principles for guiding the design process are outlined below:

Guiding principles for designing a biodiversity monitoring system (BMS)

- Identify the key practical and 'on-ground' reasons for monitoring biodiversity.
- Identify the feasible scope of the monitoring system. For each purpose, use the process:
  - What is the reporting scale?
  - What is the spatial resolution?
  - How long does the program need to operate for?
- What are the best indicators to monitor to meet evaluation and thresholds for reporting outcomes? For each purpose, adopt the following process:
  - identify the best measures of land-use pressures

  - identify an integrative set of measures for pressures and biotic responses
  - assess whether the indicators deliver measurable outcomes for the identified purposes
  - select a final set of measures as indicators for monitoring using standard criteria.
- Identify the sampling sites, frequency and analytical procedures that will deliver measurable outcomes for the identified purposes.
- Conduct a feasibility/risk assessment of the BMS.
- Identify who is responsible for implementation, evaluation and reporting activities of the BMS.

5.2.2 Workshop

The outcome from group 1 was an example of a set of guiding principles for regional monitoring (see Appendix 6 for details) and is outlined below:

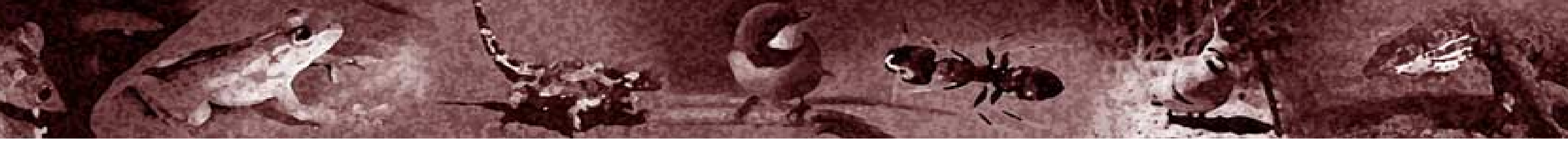
Guiding principles for a regional BMS

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

The details of outcomes from group 2 are presented in Appendix G. The key principles of monitoring are outlined below:

Principles of monitoring

- The primary purpose of monitoring is to detect the magnitude and direction of change over long periods of time, not to establish causality.
- Careful attention should be given to sampling design and evaluation of output. For example, consider:
  - sample versus census
  - the capacity for re-measurement
  - detection of change versus detection of trend
  - statistical power versus ecological significance
  - feedback to sample design.
- The outcomes of BMSs need to be communicated simply without loosing the detail and targeted to suit different audiences.
  - An outcome of a BMS should be to communicate that a BMS may need to run for a long time before any change is detected.
- The frequency of monitoring should reflect the episodic nature of biotic responses to climatic events in the rangelands.
  - Large number of samples should be considered to capture the spatial and temporal variability of monitoring attributes.
- A BMS has many different parts which all need to be considered and require long-term institutional investment for it to deliver successful outcomes including:
  - *Design*: The process should define clear objectives and factors for stratification.
  - *Data collection*: The value of 'existing data' should be assessed against the objectives and desirable outcomes, and data quality should be maintained at all times.
  - *Archiving*: Substantial resources should be committed to archiving data in formats compatible to evolving software over the lifetime of a BMS.
  - *Analysis*: Appropriate, accurate and transparent statistical input should be supported over simple easy-to-apply tests.
  - *Summarising*: Reporting protocols should reflect the assumptions behind reaching trade-offs between the desire to reduce the complexity of biodiversity to manageable reporting units that capture the dynamics.
  - *Communication*: The outcomes of BMSs should be communicated simply without loosing the detail and be appropriate for different audiences. Should also communicate widely that a BMS may need to run for a long time before any change is detected.
  - *Quality assurance*: A BMS should be an integral part of adaptive management.
    - Performance protocols for expected outcomes should be considered.
    - A regular review of the performance of the BMS should be undertaken.
    - Outcomes different from those expected should be identified, evaluated and measures revised if necessary.



5.3 Post-workshop

After the workshop, further discussions were held with Annemarie Watt (EA) and researchers at CSIRO Sustainable Ecosystems in Alice Springs to outline the guiding principles for the development of robust, efficient and comparable monitoring systems.

Nine guiding principles were identified and are outlined below:

Guiding principles for development of a BMS

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

CHAPTER SIX

Knowledge gaps and research needs

6.1 Process

Delegates discussed the knowledge gaps and research needs in small work groups and then these were consolidated in a plenary session.

6.2 Outcomes

A total of 33 knowledge gaps and research needs with reasons for their listing were identified (see Table 6.1). These were categorised into eight broad research areas:

- reserves
- taxonomic studies
- biodiversity and ecosystem-level relationships
- indicators and surrogacy
- monitoring techniques
- resolution and reporting scale issues
- pastoral monitoring
- biodiversity planning issues.

Table 6.1 Knowledge gaps, research needs, and rationale for their importance

Type	Knowledge gaps and research needs	Reason for listing
Reserves	Efficacies of creating conservation 'reserves', i.e. do reserves actually remove threats and protect biodiversity?	If no change then don't buy or invest
Taxonomic studies	Very little systematic or taxonomic information on biota using wetlands (other than birds)	Use of wetlands by birds recognised but not the food chain/resource factors which draw them there, i.e. algae, plants (both aquatic and riparian), micro- and macro-invertebrates
Biodiversity and ecosystem-level relationships	Is there a clear positive association between perenniality of vegetation and biodiversity maintenance?	If this can be established then this could provide a very convenient index of biodiversity
	What is the relationship of plant diversity (richness?) to plant functional group analysis?	A sound functional group approach could reduce time and cost of monitoring plant diversity. Full floristics is not always possible
	What is habitat quality/potential?	Not monitoring structural complexity, connectivity, ecosystem integrity
	Links between fire regimes and consequences for biodiversity	Needs research
	What are the relationships between remotely sensed vegetation attributes and plant and other diversity?	Remote-sensing techniques could give broad regional indication of biodiversity values
	How well established is the linkage between wetland health and catchment health?	Convenient barometer for 'regional' scale monitoring and reporting
	Very little information on response of wetlands to episodic hydrological events	Increasing importance of wetlands as refugia, watering points, etc. No effective monitoring other than isolated/widely separated case studies
	Need to further explore the relationship between water quality and hydrological function, and aquatic invertebrate diversity	This would save having to do time-consuming counts and identification of aquatic invertebrates. What aquatic groups are best indicators?
	Relationship between condition/landscape functionality and biodiversity values	Landscape function is one of the proposed indicators of the TS-CRC report. This is also widely discussed here as an easily measured/assessed value that has meaning to others, e.g. pastoralists, and therefore has additional values. However, its meaning in relation to biodiversity values is unknown and/or poorly understood. Results from grazing gradients only reveal impacts on what remains. Therefore if condition/landscape function is to be used as context or as a surrogate for biodiversity in rangelands, the underlying relationship needs validation

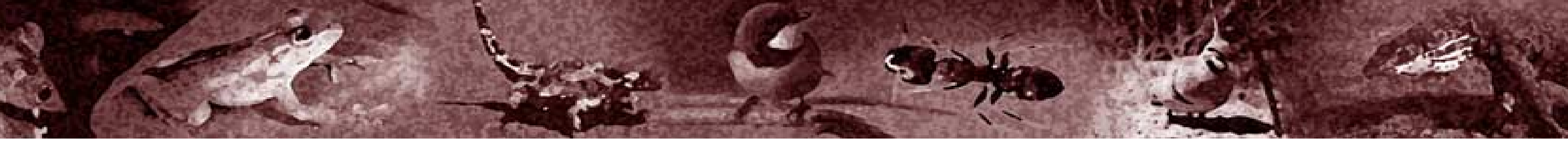


Table 6.1 cont.

Type	Knowledge gaps and research needs	Reason for listing
Indicators and surrogacy	Use of surrogacy	Self-evident
	What inferences can be made about 'valid surrogates'? Then, what are the experimental design features that can justify the inferences?	We need profound surrogates that have rigorous statistical foundations. What is a profound surrogate that says something about change/trend in biodiversity warranting a response in management/policy?
	What is the surrogate value of vegetation cover, etc. obtained from remote sensing?	Only partially established—results from one area not transferable
	Method for quantifying structure and finding an index of structure that has ecological meaning, i.e. turning data into indicators	This is an established habitat parameter and yet we have no way of quantifying it
	Pattern metrics	
	Indicator species responses	Interpretation
	Link LFA with biodiversity and monitor remotely	Obvious
	Setting response thresholds for each indicator in each region	Optimistic?—but needs to trigger action
	Quantify impacts of feral herbivores	Identify nature and scale of threat
	Value of invertebrate groups as indicators	Currently value is mostly unknown
Monitoring techniques	Dog, fox and cat track counts	Need to standardise (to some degree) monitoring techniques, i.e. dragline, vehicle track/plots, and optimum distances between sampling points
	Weed monitoring	Need to incorporate opportunistic and targeted weed monitoring with existing monitoring (based on general survey)
	Biological surveys	Need better baselines
	Pig density estimation (accurate or correction factor)	Monitor threat/disease
	Develop rapid monitoring techniques for ants (nest type/density)	To incorporate ant monitoring into more general monitoring/assessment
	Perhaps insufficient use of remote sensing—based on bulking of ground data with consequent large spatial gaps	
Resolution and reporting-scale issues	Mapping of fire-sensitive plant communities at appropriate scales	To improve interpretation of data on fire occurrence and make better decisions about managing fire-sensitive vegetation
	Species composition data generally based on plot-scale data which are inadequate to establish regional-scale trends	Can't scale it up effectively. Can other regional data help model this?
	Aggregating site-based biodiversity integrity measures at local scale to regional level	Provide general index of biodiversity integrity at regional scales
Pastoral monitoring	Considerable existing data derived from rangeland monitoring which are inadequate for biodiversity, because of types of data collected, spatial sampling design and temporal frequency of sampling	
Biodiversity planning issues	Gross simplification of results in reporting, and loss of data preventing analysis in different ways	Lack of coordination across agencies, and lack of appropriate data management systems. Does not apply evenly across jurisdictions
	How to plan local contributions that together result in progress towards regional targets/outcomes	Require frameworks for change and feedback to check efficacy of changes in land use
	How to better motivate rangeland managers to monitor	To improve uptake of monitoring

Building on workshop outcomes

7.1 Meeting expected outcomes

This workshop has moved one step closer to the development of accurate and reliable biodiversity monitoring systems for the rangelands. It has built on previous major contributions such as that of the Tropical Savannas Report (TS-CRC 2001).

The workshop achieved:

- the bringing together of experts from all rangeland states and the Territory
- consideration and review of recent, and most importantly, often unpublished research relevant to biodiversity monitoring in the rangelands
- development of a common 'state-of-the-art' view and an understanding of the complexity of biodiversity monitoring in the rangelands
- development of a shared view on the most appropriate 'sufficient and necessary' set of attributes and techniques for use now by different clients to monitor changes in biodiversity
- highlighting of the limitations of particular sets of attributes and techniques
- identification of interim guiding principles for rangeland biodiversity monitoring
- identification of knowledge gaps and research needs.

An unexpected outcome of the workshop was the increase in participants' understanding of the complexities of biodiversity monitoring issues as the workshop progressed. This was evident in the participants' completion of templates and provides a good basis for addressing new issues.

It was hoped that the workshop could foresee how a practical set of strategies for biodiversity monitoring could align closely with the Australian Rangelands Information System (ACRIS) framework. However, given that the ACRIS remains to be implemented, it was recognised that this topic would be better dealt with by the state and the Territory government agencies as a follow-up activity.

7.2 Next steps

The next steps leading on from the workshop are:

- a 'how-to' manual (Volume II)
- an e-network
- biodiversity information products for the ACRIS.

The 'how-to' manual will be a combination of principles and examples for a delivery framework of biodiversity monitoring in the rangelands. Theoretical examples and regional case studies at three reporting scales in the states and the Territory will be one approach to evaluate the efficacy of the principles.

The purpose of the e-network is to:

- provide workshop participants with the opportunity to build on workshop outcomes
- draw on participants' expertise and provide an opportunity to consider sampling design issues not covered explicitly during the workshop
- help to inform development of the 'how-to' manual.

With the ACRIS there is a need to progress implementation of it to build good faith and maintain the partnership approach. The outcomes expected are:

- presentation of information at three scales
- description of information for immediate implementation in the ACRIS
- a framework and reporting process at the national scale using the TS-CRC report as a basis
- an approach for delivering information to the ACRIS.

Appendix A

Steering committee members of the expert technical workshop on rangelands biodiversity monitoring

Member	*Affiliation*
Alaric Fisher	NT Department of Infrastructure, Planning and Environment (Natural Systems)
Jeff Foulkes	SA Department for Environment and Heritage
Chris Hill	Qld Environmental Protection Agency
Angas Hopkins	WA Department of the Premier and Cabinet
Craig James	CSIRO Sustainable Ecosystems
Dave Robson	NSW National Parks and Wildlife Service
Anita Smyth	CSIRO Sustainable Ecosystems
Annemarie Watt	Environment Australia

Appendix B

List of delegates at the expert technical workshop on rangelands biodiversity monitoring

Member	*Affiliation*
Allan, Grant	NT Department of Infrastructure, Planning and Environment (Bushfires Council)
Andersen, Alan	CSIRO Sustainable Ecosystems
Anderson, Eric	Qld Department of Primary Industries
Bastin, Gary	CSIRO Sustainable Ecosystems
Beutel, Terry	Qld Department of Primary Industries
Edwards, Glen	NT Department of Infrastructure, Planning and Environment (Parks and Wildlife)
Ellis, Murray	NSW National Parks and Wildlife Service
Ferrier, Simon	NSW National Parks and Wildlife Service
Fisher, Alaric	NT Department of Infrastructure, Planning Environment (Natural Systems)
Foulkes, Jeff	SA Department for Environment and Heritage
Gould, Paul	SA Department for Environment and Heritage
Grice, Tony	CSIRO Sustainable Ecosystems
Hopkins, Angas	WA Department of the Premier and Cabinet
James, Craig	CSIRO Sustainable Ecosystems
Keith, David	NSW National Parks and Wildlife Service
Landsberg, Jill	James Cook University
Ludwig, John	CSIRO Sustainable Ecosystems
Lundie-Jenkins, Geoff	Qld Environmental Protection Agency
Mc Nally, Ralph	Monash University
Nicholls, AO (Nick)	CSIRO Sustainable Ecosystems
Pople, Tony	University of Queensland
Porter, John	NSW National Parks and Wildlife Service
Pringle, Hugh	WA Department of Agriculture
Read, John	Western Mining Corporation Resources Ltd
Richards, Rob	NSW Department of Land and Water Conservation
Richardson, Jeff	WA Department of Conservation and Land Management
Robson, Dave	NSW National Parks and Wildlife Service
Shiel, Russell	University of Adelaide
Smyth, Anita	CSIRO Sustainable Ecosystems

Member	*Affiliation*
Stafford-Smith, Mark	CSIRO Sustainable Ecosystems (Facilitator)
Wallace, Jeremy	CSIRO Mathematics and Information Systems
Watson, Ian	WA Department of Agriculture
Watt, Annemarie	Environment Australia
Whiteman, Grant	CSIRO Sustainable Ecosystems
Young, Peter	Qld Environmental Protection Agency

Appendix C

Questionnaire analysis

Question 2 Describe your functional role in the organisation of enterprise

The functional roles of respondents were grouped into five summary categories. Where respondent's performed more than one functional role, they were assigned according to the major role, as inferred from responses to other questions. The number of respondents in each category is presented in Table 1.

Table 1 Number of respondents performing particular types of principal functional role

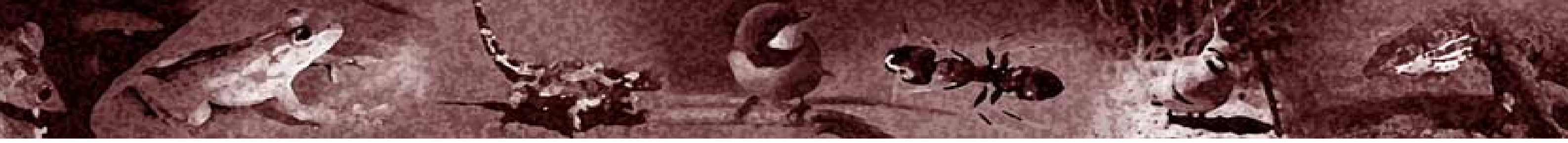
Functional role	No. of respondents
1 Rangeland planning, policy or administration for a government agency	6
2 Rangeland natural resource management research for a government agency	16
3 Private pastoral property owner/manager	2
4 Pastoral company management	3
5 Indigenous lands management	1
Total	**28**

Question 3 What are the key issues on your area of responsibility?

Respondents identified between one and seven key issues each. The nominated issues were then reduced to eight categories. The key issue categories and the number of respondents nominating at least one issue in each category are presented in Table 2.

Table 2 Number and percentage of respondents' key issues in areas of responsibility within particular categories

Key issue category	No. (percentage) of respondents nominating an issue in category
1 Incorporation of biodiversity management into natural resource management	15 (54%)
2 Identifying, developing or demonstrating biologically sustainable, enterprise management practices	13 (46%)
3 Landscape monitoring and assessment	11 (39%)
4 Species monitoring and conservation	9 (32%)
5 Enterprise economics	7 (25%)
6 Development of biodiversity indicators	4 (14%)
7 Development of government standards and policy for rangeland use	2 (7%)
8 Invasive/pest species management	2 (7%)



Question 4 For what purposes do you need or wish to monitor biodiversity in the rangelands?

Table 3 Number and percentage of respondents nominating purposes for biodiversity monitoring in particular categories

Monitoring purpose category	No. (percentage) of respondents nominating a purpose in category
1 To meet legislative obligations regarding biological status, condition and/or trend	21 (75%)
2 To obtain information to improve enterprise-level management decision making	18 (64%)
3 To build capacity for biodiversity conservation by, for example, developing techniques, procedures, enhancing understanding, etc.	15 (54%)
4 To establish a basis for evaluating the efficacy of government legislation, policy and administration	14 (50%)
5 To detect trends in biodiversity change and provide alerting service	13 (46%)
6 For accreditation, certification or showcasing, e.g. for ISO 14001 registration	9 (32%)
7 For maintenance of Indigenous culture	1 (4%)

Question 5 For each purpose identified in Question 4, indicate what information you need

The 28 respondents nominated 81 specific items of information required for biodiversity monitoring purposes. Two respondents did not nominate information requirements, and one of these pointed to problems in translating legislation and the consequent strategic imperatives into clear specifications for biodiversity monitoring programs.

> *… it is simply not possible to determine what information is needed to satisfy the requirements of the Act. Similarly, a whole bunch of strategic documents talk about monitoring biodiversity—but it is well nigh impossible to pin them down to specifics.*

The 81 identified information needs were grouped into seven categories. The information categories, the frequency with which respondents nominated items in each category and the percentage contribution of each category to total information needs are shown in Table 4.

Table 4 Information needs by category

Information category	Percentage of respondents requiring information in this category	Percentage of all requirements
1 Species or species richness mapping	68%	26%
2 Biodiversity indicators	50%	19%
3 Landscape condition and function	46%	21%
4 Effectiveness/impact of enterprise management actions	25%	10%
5 Ecosystem processes/dynamics	21%	9%
6 Pasture description, e.g. species composition cover, condition	21%	9%
7 Location of high-use/impact areas	21%	7%

There was some differentiation in the information needs of respondents according to their principal functional roles. Respondents with principal roles in rangeland planning, policy or administration for governments (see category 1 in Table 1) did not require highly localised information about pasture or impact and use areas (see categories 6 and 7 in Table 4), and information regarding ecosystem processes and dynamics was only required by government researchers or policy makers (see categories 1 and 2 in Table 1).

On the other hand, the three most frequently required categories of information (species mapping, biodiversity indicators and landscape condition) were required to support all functional roles (other than the maintenance of Indigenous culture for information categories 2 and 3 in Table 4).

Question 6 For each purpose identified in Question 4, indicate at what spatial scale the information is needed

Information was frequently needed at multiple spatial scales for any particular purpose, supporting one respondent's observation that: 'In most instances, monitoring programs will only be meaningful if indicator variables are monitored at a number of scales …'

The frequency with which particular scales were required for the categories of purpose identified for Question 4 is shown in Table 5. Overall, the single most frequently nominated scale was regional/subregional, with only slightly fewer requirements for enterprise-scale information. The purposes for which information was required did not strongly affect the nominated spatial scales. Regional/subregional and enterprise scale were the dominant spatial scales for all purposes.

Table 5 Frequency of nomination of spatial scales of biodiversity monitoring for particular purposes

Monitoring purpose	International	National	State	Regional/ subregional	Enterprise	Paddock
1 To meet legislative obligations regarding biological status, condition and/or trend	0	9	11	16	12	2
2 To obtain information to improve enterprise-level management decision making	0	6	7	11	7	2
3 To build capacity for biodiversity conservation	1	3	5	10	8	2
4 To establish a basis for evaluating the efficacy of government legislation, policy and administration	0	8	9	13	16	2
5 To detect trends in biodiversity change and provide alerting service	0	4	4	6	8	0
6 For accreditation, certification or showcasing	0	5	7	12	12	4
7 For maintenance of Indigenous culture	0	0	0	1	1	0
Total	**1**	**35**	**43**	**69**	**64**	**12**

Question 7 At what resolution is the information needed to meet the scale identified in Question 5?

The frequencies of required monitoring spatial resolution or particular purposes are presented in Table 6. The required resolutions for purpose no. 7, maintenance of Indigenous culture, could not be unambiguously determined from the answer given. Overall, regional/subregional resolution was most frequently required, and either regional/subregional or enterprise resolution was the most frequently required for any particular purpose. There were instances in which all scales of resolution from regional/subregional to sub-management unit were required for each monitoring purpose. In a significant number of cases, spread across all purposes, respondents were unable to nominate the required resolution.

This probably reflects practical difficulties in identifying the relevant ecological processes and scales at which they operate. In contrast, the spatial scale at which information is required typically corresponds to either reporting requirements or to physical areas of responsibility and hence was more easily identified by respondents.

Table 6 Frequency of nomination of spatial resolution of biodiversity monitoring for particular purposes

Monitoring purpose	State	National	Enterprise	Paddock	Sub-management unit	Can't say
1 To meet legislative obligations regarding biological status, condition and/or trend	2	10	6	4	4	2
2 To obtain information to improve enterprise-level management decision making	0	3	5	3	4	4
3 To build capacity for biodiversity conservation	1	4	5	5	1	4
4 To establish a basis for evaluating the efficacy of government legislation, policy and administration	2	8	6	3	1	2
5 To detect trends in biodiversity change and provide alerting service	0	5	4	3	3	1
6 For accreditation, certification or showcasing	0	3	3	2	1	1
7 For maintenance of Indigenous culture	–	–	–	–	–	–
Total	**5**	**33**	**29**	**20**	**14**	**14**

Question 8 What is the most appropriate time frame to monitor biodiversity to meet the purposes listed in Question 4?

Three relationships between monitoring time frames and functional roles were apparent. Respondents with roles in government planning, policy or administration were almost exclusively concerned with the 2–5 year range. Among enterprise managers, there was an equally strong emphasis on annual or event-driven monitoring. The requirements of government natural research management researchers were more evenly spread from event-driven or seasonal time frames to as much as 20 years, although periods between two and five years were most common. The only time frame difference relating to purposes for monitoring was that all monitoring for accreditation, certification or showcasing required time frames from one to five years while all other purposes varied from event driven or seasonal to more than five years.

Question 9 How much of your annual operating budget would you allocate to biodiversity monitoring to achieve your purpose(s) in Question 4?

Thirteen respondents (46%) were able to quantify biodiversity monitoring budgets, although is some cases the funding was heavily dependent upon external sources. A further nine respondents (32%) had or anticipated monitoring expenditure but were unable to quantify a budget because the expenditure was incidental to other budgets, or was entirely dependent upon external sources of funding. Six respondents (22%) had nil or 'very little' monitoring budgets, although three of these thought that they may have a budget in the future depending upon policy decisions.

Among those who could quantify a budget, allocations were highly variable in both absolute and proportional terms. Three respondents budgeted less than 10% of total expenditure for monitoring and two budgeted between 10%, while a further three spent more than 30% on monitoring. The maximum proportion allocated was 65%. Allocations in dollar terms ranged from \$20 000 to \$1 000 000.

There was no clear relationship between expenditure intentions and the functional role of respondents.

Appendix D

Abstracts of commissioned papers

The complete text of these papers is provided in portable document format (PDF) on the accompanying CD-ROM.

Theme 1: Background and context

Key conceptual, biophysical and statistical issues for designing a biodiversity monitoring framework for the rangelands

Anita K Smyth

I review the conceptual, biophysical and statistical issues and challenges that have implications for development of a framework to support effective monitoring of biodiversity in the rangelands. To understand the conceptual issues, I appraise:

- the concept of biodiversity
- how this concept can be operationalised within biodiversity monitoring systems to meet specific purposes of NRM managers and the community
- the selection of ecological indicators.

I also highlight what special features of the rangelands and its land uses need to be considered when developing a biodiversity monitoring framework. I conclude by highlighting key statistical issues and challenges in the evaluation of monitoring data to meet the outcomes of monitoring programs effectively. A list of key issues and challenges is provided.

Theme 2: Threats to future biodiversity

Fire regimes and their effects on the landscape

Grant Allan

There are two aspects of fire in the rangelands that can be addressed. The first deals with fire regimes which are perceived as an important factor to survival and/or persistence of many species, both plants and animals. Unfortunately fire regimes are a complex measure; a function of fire frequency, intensity, season, type, patchiness to name a few. Despite this accepted definition, it is still a very difficult factor to define or quantify on a spatial scale. For the vast majority of Australia's rangelands, there is an inadequate record of fires and therefore it is difficult to calculate or describe current fire regimes and impossible to determine the change from past times. In some areas fire has been removed from the landscape and the potential to use and understand its value as an ecological driver is very limited.

The second aspect deals with the direct effects of fire on individual plants and animals. Studies within and beyond the rangelands have contributed information to this area, primarily from observations associated with a single fire event. However, for the majority of species, the direct effect of a single fire remains uncertain. The direct effect of multiple fires and varying fire regimes is even less certain. It is based primarily on observations rather than measurements but this provides the basis for implementing fire management programs within an adaptive management framework.

Watering points and domestic livestock grazing: indicators of pressure on rangeland biodiversity

Hugh JR Pringle and Jill Landsberg

The requirement for livestock to drink regularly makes watering places foci of livestock activity in the rangelands. Thus they are one of the major influences that give spatial expression to grazing behaviour. Using research results from the goldfields of Western Australia we show how distance from water can be incorporated in models of grazing history at different sites within paddocks.

Two surrogates of grazing activity are illustrated: one relying on a commercially available model and one developed from measures of track density. Application of these models shows that numerous interactions need to be considered in addition to distance from long-lasting sources of drinking water. Furthermore, responses in biodiversity to different patterns of grazing behaviour may vary greatly, both within groups of similar organisms and according to hierarchical landscape stratification. We analyse this complexity in terms of implications and opportunities for monitoring biodiversity. Finally, we synthesise information gained from these models and other sources to outline key implications for monitoring rangeland biodiversity of the relationships between grazing activity, distance from water, and other regionally specific factors.

Feral mammals in Australia's rangelands: future threat, monitoring and management

GP Edwards, A Pople, P Caley and K Saalfeld

In this paper we provide an initial brief overview of past changes in the biodiversity of Australia's rangelands. Following on, we focus on current and future threats to biodiversity posed by feral mammals (predators and herbivores) inhabiting the rangelands, exploring trends in populations and options for management. Notably, rabbits have declined in recent years in the wake of Rabbit Haemorrhagic Disease, populations of camels have increased dramatically, while foxes appear to have moved northwards thereby threatening native fauna within their expanded range. Finally we examine how to monitor the impacts of feral mammals so that management can be applied at the correct time and scale. Factors that need to be considered when designing a monitoring program are discussed. While it is pest impact that should ideally be monitored, this is rarely achieved in practice. Rather, monitoring usually involves population assessments, the untested assumption being that higher densities equate to higher impacts. Current 'best practice' methods of monitoring populations of feral mammals in the rangelands are discussed briefly in the closing section.

Weeds and the monitoring of biodiversity in Australian rangelands

AC Grice

Invasion by alien plants is widely recognised as a major threatening process for a great variety of ecosystems worldwide. Australian rangelands already support a large number of alien plant species of a wide variety of growth forms but, in general, quantitative documentation of the effects that they have on biodiversity is poor. Impacts of weeds on biodiversity can be expected because they have the potential to alter virtually any aspect of ecosystem structure and function. There will be value in monitoring how biodiversity responds to weed invasions because it will provide a basis for decision making about weed management in natural ecosystems. The presence, abundance, growth forms and diversity of weed species may also be useful indicators of the health of ecosystems and the biodiversity they contain.

Theme 3: Potential indicators

Monitoring ecological indicators of rangeland functional integrity and biodiversity at local to regional scales

John A Ludwig, David J Tongway, Gary N Bastin and Craig James

In Australia's rangelands, clearing, grazing and fire have variously modified landscape functional integrity, which is the intactness of native vegetation and soil patterns and the processes that maintain these patterns. Intuitively, biodiversity should be strongly related to landscape functional integrity, that is, landscapes with high functional integrity should be maintaining biodiversity and altered, less functional landscapes may have lost some biodiversity, here defined as the variety and abundance of the plants, animals and micro-organisms of concern. Simple indicators of biodiversity and functional integrity are needed that can be monitored at a range of scales, from fine to coarse.

In this paper, we use examples, primarily from Australia's rangeland literature, to document that at finer patch and hill slope scales, a number of indicators of landscape functional integrity have been identified, and these indicators, based on the quantity and quality of vegetation patches and zones, are related to biodiversity. For example, a decrease in the cover and width (quantity) and condition (quality) of vegetation patches and an increase in bare soil, near cattle watering points in a paddock, are significantly related to declines in plant and grasshopper diversity. These vegetation patch cover and bare soil indicators have traditionally been monitored with field-based methods, but new high-resolution, remotely sensed imagery can be used in many rangeland areas for this fine-scale monitoring. At intermediate paddock and small watershed scales, indicators that can be derived from medium-resolution remote sensing are also needed for efficient monitoring of rangeland condition (i.e. functional integrity) and biodiversity. For example, 30 to 100-m pixel Landsat imagery has been used to assess the condition of rangelands along grazing gradients extending out from watering points. The variety and abundance of key taxa have been related to these gradients (the Biograze project). At still larger region and catchment scales, indicators of rangeland functional integrity can also be monitored by coarse-resolution remote sensing and related to biodiversity. For example, the extent and greenness (condition) of different regional landscapes has been monitored with 1-km pixel NOAA AVHRR satellite imagery. This regional information becomes more valuable when it indicates differences due to land management. Although caution is needed, measuring and monitoring landscape functional integrity at finer hill slope to small watershed scales does provide emergent attributes and indicators for understanding processes driving changes occurring at coarser region and catchment scales; this understanding is essential for making sound management decisions such as whether to rehabilitate an area of rangeland.

Finally, we discuss potential future developments that may improve proposed indicators of landscape functional integrity and biodiversity, hence, our ability to effectively monitor rangelands.

The use of invertebrates for biodiversity monitoring in Australian rangelands, with particular reference to ants

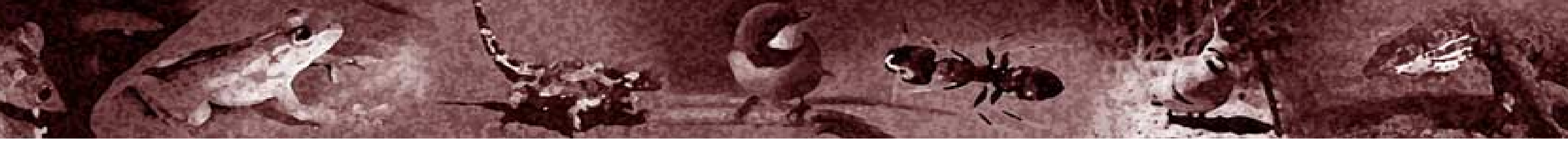
Alan Andersen, Alaric Fisher, Ben Hoffmann, John Read and Rob Richards

The term 'biodiversity monitoring' can mean different things to different people. Here we take it literally to mean monitoring the variety of life, and assume that its aim is to track changes in the biological integrity of ecosystems. The most commonly used operational units for measuring biodiversity are multicellular species (Purvis & Hector 2000), and the vast majority of these are invertebrates, especially insects and other arthropods (Wilson 1988). Given their overwhelming dominance, no biodiversity monitoring program can be considered credible without the inclusion of invertebrates (Taylor & Doran 2001).

The distribution of terrestrial invertebrates is far more finely patterned than is the case for either vertebrates or vascular plants (Oliver et al. 1997; Ferrier et al. 1999; French 1999; Pik et al. 2002), and vegetation has repeatedly been shown to be a poor surrogate for patterns of invertebrate biodiversity (Crisp et al. 1998; Jonsson & Jonsell 1999; Eyre & Luff 2002).

In contrast to vertebrates (Coops & Catling 1997), it is therefore futile to seek attributes of habitat structure that meaningfully act as surrogates for invertebrate biodiversity (Abensperg-Traun et al. 1996; Newell 1997; York 1999). Invertebrates must be monitored directly.

Here we address invertebrates in the context of monitoring biodiversity in Australia's rangelands. We focus on ants because they are the dominant terrestrial invertebrate group in the Australian environment, and are by far the most commonly used invertebrate indicators in land management. We begin by reviewing the use of invertebrates, particularly ants, as bioindicators in Australia, then present a case study involving ant monitoring in rangelands of New South Wales. We conclude by identifying priorities for further research and development.



Sampling ants as indicators of grazing impact in mulga woodlands

Craig D James

I investigated the relationship between species richness and composition of ants and sampling intensity for areas with different long-term histories of grazing intensity in the mulga (*Acacia aneura*) woodlands in northern New South Wales. I tested the hypothesis that increased sampling intensity would result in more species per sample up to a threshold, and that discrimination of areas with different grazing intensities would be stronger if sampling intensity were higher. I sampled ants in pit traps (120 mm diameter) at densities of 2, 4, 6 and 9 pits per 100 m^2. Each treatment density was replicated three times in both heavily and lightly grazed areas, and pit traps were open for four days. Species richness was significantly different between each treatment, increasing linearly with a grazing regime. Species richness tended to be higher for heavily grazed replicates but these sites were also more variable than those in the lightly grazed area. Additional species trapped at high pit-trap densities were mostly represented by one or two individuals in samples indicating that a large 'tail' of rare species was missed by low-intensity sampling.

Threat to wetlands and potential indicators for monitoring

Russell Shiel, Stuart Halse and Joan Plowing

No abstract

Geckos and grazers: a perspective on reptiles in the assessment of rangeland biodiversity

TS Beutel, GS Baxter and RJS Beeton

We examined the response of gecko communities on Currawinya National Park to the removal of domestic grazing pressure in the three years following its conversion from pastoral property to an unstocked national park. We compared species richness and composition on-park with adjacent grazed sites off-park between September 1993 and February 1996. No significant trends were identified. These results broadly reflect previous studies of reptile biodiversity in the rangelands, suggesting that as a taxon reptiles are relatively insensitive to grazing. Given this, reptile biodiversity is unlikely to reflect trends in either rangeland health or other rangeland biota, and given the paucity of resources to monitor rangeland biodiversity, we suggest that biodiversity assessment resources may be better concentrated on other taxa more sensitive to the impacts of grazing.

Avian biodiversity monitoring in rangelands

Ralph Mac Nally, Murray Ellis and Geoff Barrett

Birds have been widely regarded as a key element in monitoring biodiversity both in Australia and elsewhere. We believe that while birds are unlikely to be an umbrella or indicator taxon for other biota (other vertebrates, invertebrates, plants, micro-organisms), they do represent a taxon that can be monitored with greater effect and less effort per datum than other biotic components. It has been shown by the great participation rate of lay observers in several schemes (notably the Birds Australia Atlas projects) that there is a capacity to mobilise the lay community to undertake bird surveying.

While there are many limitations to acquiring high-quality information (scale, dynamism, mobility, paucity of observers over much of the rangelands), we think that these can be dealt with sufficiently well to justify the use of birds as a key component of biodiversity monitoring. There are statistical issues that need to be considered too, and we argue that strict adherence to frequentist philosophies may limit the usefulness of evaluation and subsequent decision making.

Using kangaroos to monitor biodiversity

Geoff Lundie-Jenkins, Tony Pople and D Hoolihan

Broad-scale aerial surveys of kangaroo populations have been conducted regularly over vast areas of the rangelands since the 1970s to monitor population trends and to determine harvest quotas. While there is obvious worth in monitoring kangaroos in their own right they may also be useful as surrogates for other elements of biodiversity and as indicators of environmental change. In the relatively open habitats of the rangelands, conspicuous animals such as kangaroos are amenable to aerial survey. Other survey methods such as direct counts from vehicles or indirect monitoring such as harvest statistics, including catch per unit effort or harvest sex ratio, are restricted in their potential survey frequency and extent due to cost and also vary in their reliability. Kangaroo monitoring programs have several characteristics that make them attractive for monitoring biological diversity in the rangelands. These include systematic design, standardised methods, annual surveys and strong political and bureaucratic support. Other species such as emus and bustards, and feral herbivores such as goats are also counted during aerial surveys, allowing patterns of distribution and trends in their abundance to be determined. Through correlation with rainfall, long-term data for all these species have provided an understanding of their population dynamics. This is valuable, as trend monitoring will be complicated by process error in fluctuating environments. Comparisons of large herbivore population dynamics between areas allows an assessment of varying environmental impacts such as drought, effects of different management regimes such as harvesting and national park management, and longer-term environmental change. Case studies from Queensland are used to illustrate its usefulness for monitoring environmental change at both state and regional scales.

Theme 4: Designing monitoring programs

Monitoring sustainability with a monitoring system that is itself sustainable: addressing the cause and the symptoms

Ian Watson and Paul Novelly

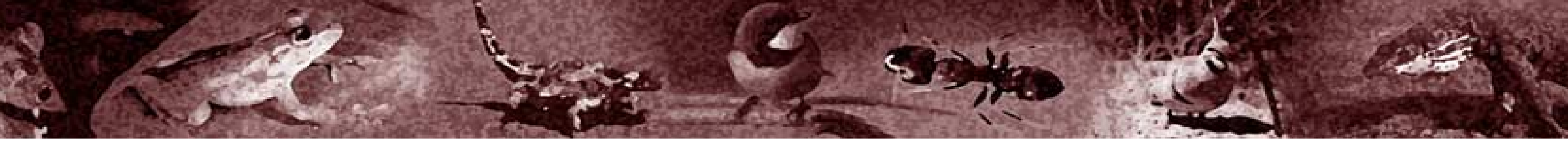
Throughout the 1970s and 1980s much effort was expended on a range monitoring program in Western Australia. Unfortunately, much of the system put in place is now inactive. Such a situation is not unique and the rangelands of the world are littered with monitoring sites that are no longer part of an operating system. A need has emerged for a biodiversity monitoring system in the rangelands and the discussion is currently at the point where the range management discipline was in the early 1970s. Efficiencies can be made when developing the biodiversity monitoring system by learning from the experience of the range management profession.

Monitoring sustainability will only be possible if the monitoring system is itself sustainable. We suggest a number of attributes for the system that need to be in place before the system can be judged at all sustainable. These attributes are a mix of biophysical, social and institutional, and highlight the view that monitoring systems of the type being suggested constitute an unusual mixture of attributes not found in typical scientific activity. The monitoring system is dependent on all of these attributes to function. If any one of them fails, the system fails.

The power of monitoring programs to detect biological change: some examples from Kakadu and Litchfield National Parks, Northern Territory

Owen Price, Alaric Fisher, Jeremy Russell-Smith, John Woinarski and Martin Armstrong

No abstract



Regional-scale monitoring systems—making a case for causality

Ian Watson

Data from range or biodiversity monitoring systems will never be able to test explicit a-priori hypotheses since replication and controls are not possible. Data analysis can only ever build a case for a particular interpretation of causal relationships. Assessing the influence of perturbations such as grazing needs to be based on an understanding of the mechanisms and rates of change of the attributes recorded on the monitoring sites. From this understanding, an expected change for that attribute can be determined and compared with observed change. The degree of departure between observed and expected change is the precursor to building a case for causality. Some of the difficulties associated with attributing causal agents arise from a tendency to confound the questions of whether change has actually occurred, whether the change is ecologically significant, whether value judgements deem the change acceptable and whether a case for causality can be made. Each of these questions is a step in interpretation in its own right and should not be conglomerated into a single, ill-defined question. A range of approaches is suggested for assessing the causal basis for change using the Western Australian Rangeland Monitoring System as an example.

Assemblage fidelity amongst vascular plants, vertebrates and ants in Mitchell grasslands of northern Australia, and implications for biodiversity monitoring

Alaric Fisher

No abstract

'Biohyets': a holistic method for demonstrating the extent and severity of environmental impacts

John L Read, Kelli-Jo Kovac and Tim J Fatchen

Bioindicators are often more sensitive indicators of both ecosystem health and environmental change than measurement of abiotic pollution parameters. The responses of selected plants and animals to particular anthropogenic impacts can be used to assess environmental responses at a variety of spatial and temporal scales. This study maps the response of key plant, reptile, mammal and bird species to airborne contaminants around a large mine and mineral processing operation at Olympic Dam in arid Australia.

The responses of different bioindicators should ideally be integrated in order to comprehend overall changes in the severity and extent of changes to biological integrity adjacent to pollution sources. Assimilation of different bioindicator responses allows greater precision and geographic coverage of the monitored region and reduces potential distortion from unrelated biological or monitoring responses of individual indicator groups. A single, integrated measure of ecosystem health is also of more value to industrial operators and environmental regulators than several disparate responses. Biohyets, which are the contours of multimetric bioindicator index plots, are used to map variability in ecosystem health.

Integration of spatial and temporal data for landscape qualities and monitoring

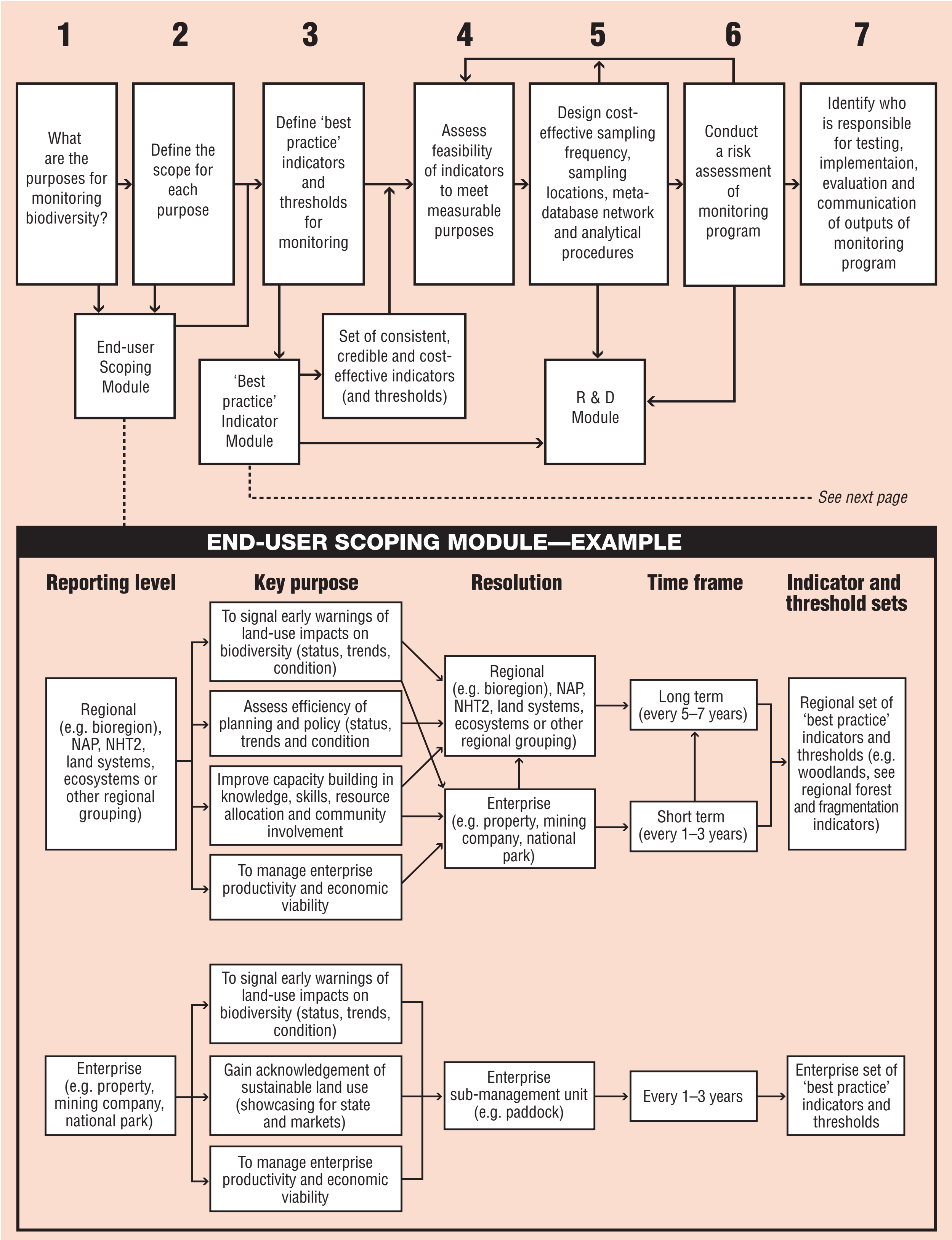
JF Wallace, PA Caccetta and HT Kiiveri

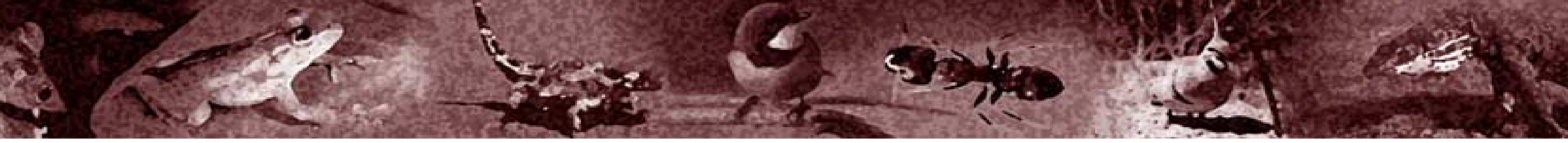
This paper emphasises the role of data analysis in monitoring systems. Concepts of landscape quality (such as condition, conservation value, health, biodiversity) are typically ill-defined or multiply defined. These concepts are rarely quantitative, and involve value systems, as well as process understanding at a range of scales that is generally unavailable. Effective monitoring systems, on the other hand, require repeated quantitative data at suitable temporal density and spatial scale, as well as appropriate methods and a conceptual framework to simplify and interpret these data. Examples are given of recently developed broad-scale operational monitoring systems based on sequences of satellite data, digital elevation (DEM) data and appropriate methods. These same datasets have been used to inform 'landscape qualities'. Examples are given of the production of derived conservation regionalisation and salinity risk maps over broad areas. These results have been achieved as a partnership between ecologists, resource scientists and statisticians.

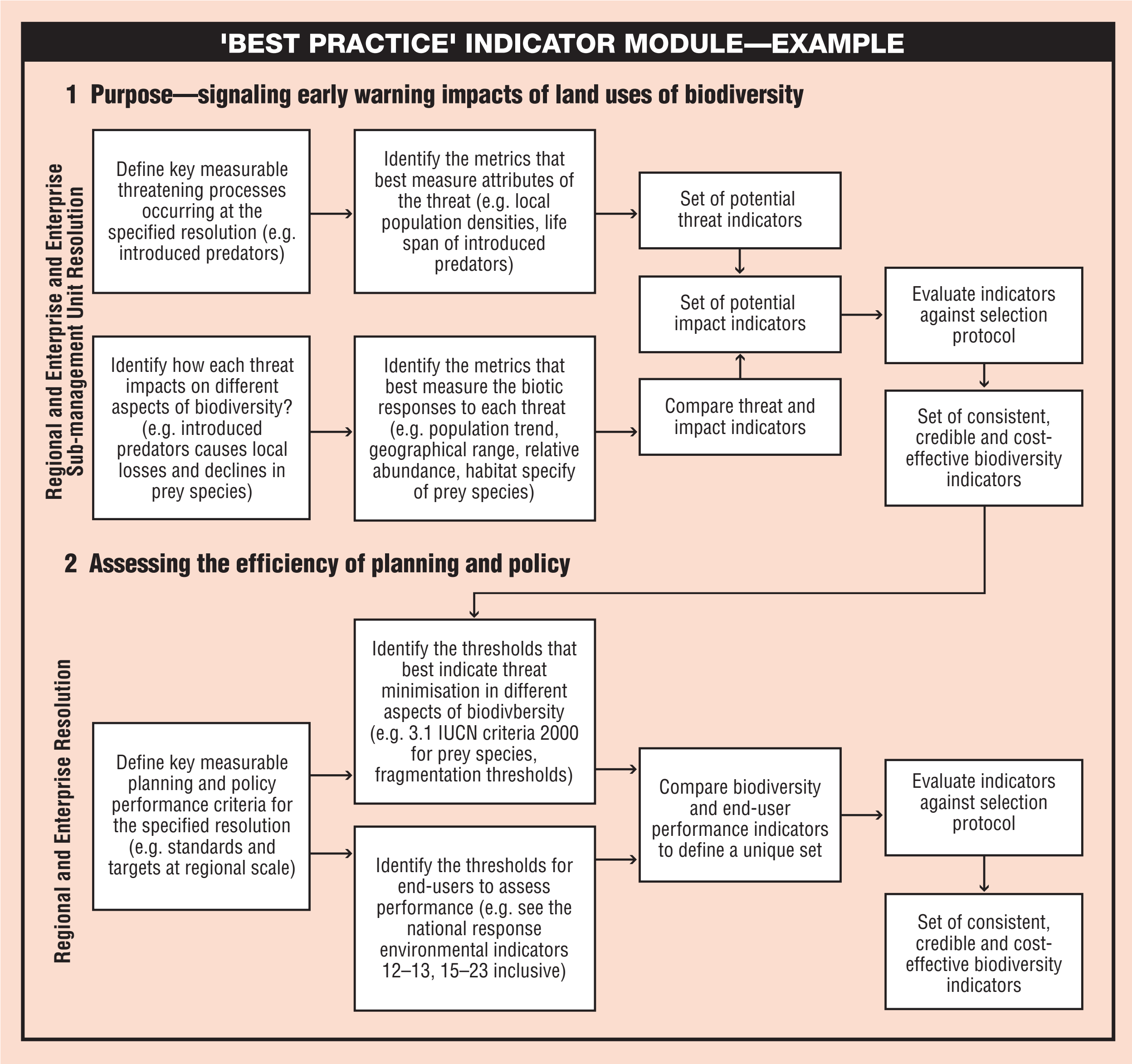
Appendix E

Smyth's pre-workshop example of an operational framework for guiding the design process of biodiversity monitoring systems

Biodiversity is a complex concept that must be made operational on the ground to be of any practical value. We propose a preliminary framework that does this in seven steps as a basis for discussions in the workshop.







Appendix F

The workshop example of an operational framework for guiding the design process of regional biodiversity monitoring by group 1

Guiding principles for an operational framework for regional monitoring of rangeland biodiversity

Jill Landsberg[1], Anita Smyth[2], Simon Ferrier[3], Angas Hopkins[4] and Jeff Richardson[5]

Intent

The intent of this document is to:

- provide guidance to regional committees about biodiversity monitoring for setting resource condition targets

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- provide context for planning and implementing a biodiversity monitoring program
- provide information to regional committees about what to report back to show progress towards meeting biodiversity targets
- keep the measures as simple, effective, meaningful and affordable as possible.

Context

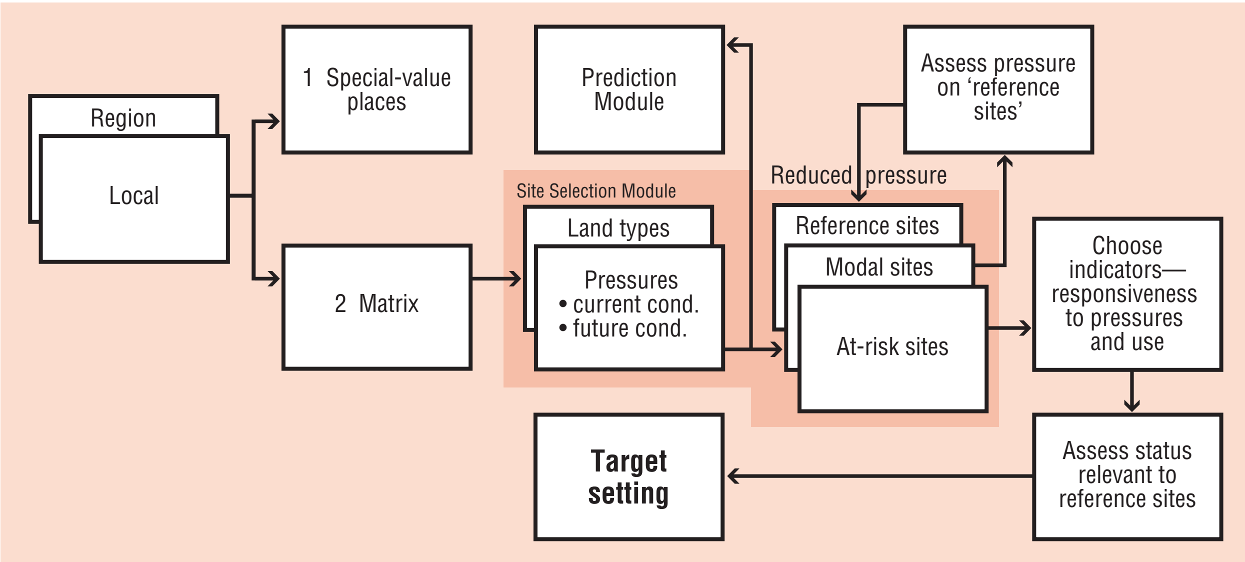
The document assumes that the following information, support and reporting framework will underpin biodiversity monitoring programs undertaken by regional committees:

- Regional monitoring programs will be informed by, and provide information to, a national support network that has responsibility for issues that transcend regional boundaries.
- The regional committee is able to access and interact with a national coordinating body that manages issues such as data protocols, analytical standards, meta-analysis and reporting standards.
- Other resource condition matters for targets (e.g. land salinity, soil condition, etc.) are detailed in other documents; these resource condition matters also benefit biodiversity, but may not be sufficient for monitoring and/or conserving it.

Guiding principles

Monitoring generally is regarded as an activity involving the systematic collecting of certain specified categories of data for specified times and at specific locations for the purpose of detecting change. However, the development of a monitoring system is more complex as it is a multifaceted scientific process (see Smyth in Appendix 4). In this document, we describe the guiding principles for the design of an operational framework for regional monitoring of biodiversity in the rangelands (see Table 7). These principles are viewed as the structure of the design process. An example of the process is given in Figure 1.

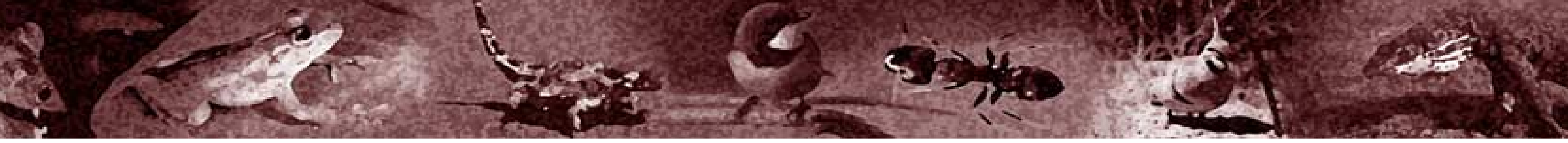
Figure 1 National framework for regional monitoring of rangeland biodiversity



Information resources

Planning a regional monitoring system requires adequate information resources, including information about:

- 'country types'—maps or GIS layers such as regional maps of vegetation, provinces, regional ecosystems, land systems or land units



- the pressures likely to affect biodiversity, and their distribution across the region. This may be in the form of maps or GIS layers of the actual pressure (e.g. extent of clearing), or other information that can be used to provide indicators of regional pressures (see below)
- places that are 'special' for biodiversity and/or require special monitoring because of management actions being undertaken there
- endemics and biota of conservation concern
- any regional management plans, any works pending or any pending changes in land tenure.

Table 7 Guiding principles for designing an operational framework for regional monitoring of biodiversity

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

Country types

Because different habitats support different plant and animal species, some form of environmental stratification will be needed so these differences can be taken into account. The National Vegetation Information System (National Land and Water Resources Audit, 2001; <www.environment.gov.au/atlas>) classifies the Australian continent into major vegetation groups at a scale of 1:5 000 000; this is the minimum level of stratification that should be used. Finer-scale vegetation and/or land type mapping should be used in preference, if it is available. The recommended scale for regional resource inventory in forests is 1:100 000 (JANIS 1997). Regional ecosystems are the preferred mapping unit in Queensland. They comprise similar land types in subregions having characteristic patterns of geology, landforms, soils and vegetation (Sattler & Williams 1999).

Regional pressures

Some of the main pressures that are widespread and likely to affect biodiversity in the rangelands are:

- grazing by domestic livestock, feral animals and elevated populations of kangaroos
- clearing
- feral predators (cats, foxes, feral dogs)
- weed invasions
- inappropriate fire regimes
- hunting (native food gathering and commercial harvesting) (see Smyth in Appendix 4).

The effect of these pressures will vary within and between country types. However, it is imperative that the distribution of these pressures is understood across a region. The best way to identify where high- and low-pressure areas occur in each country type is to overlay maps of the pressures over maps of the country types (either as hard copy or in digital form). If there is no direct information available about the distribution of a particular pressure, then other information should be used to provide an indication of its distribution (see 'Indicator sets for remote monitoring' for examples in tables 3.9 and 4.2). Identifying how different pressures are distributed is important for developing a monitoring system that provides information about the 'typical' biodiversity values of a region.

Special places

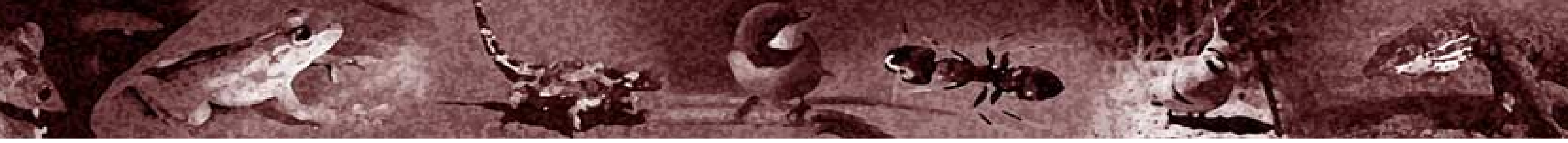
Some places may need monitoring for special circumstances, either because they have special biodiversity values and/or because they are subject to management actions that differ from typical practice. In these places, the monitoring system will need to be specialised to suit the special circumstances. Examples of places that may need special monitoring include:

- areas that are rare or endemic to the region and/or areas that contain plants and animals that do not occur anywhere else in the region. If there is no protection in place, monitoring will be needed to ensure the special biodiversity values are being maintained or enhanced. These may be protected in some way (e.g. by a fence), and need a special approach to monitoring and evaluation of its success
- areas important for landscape function, such as places that need to be protected or restored to minimise flooding or erosion across large areas of landscape
- areas where special conservation management has been undertaken and you wish to ascertain its success at delivering the desired outcomes
- areas where a change in land use is being implemented, where it may be desirable to determine what affect that change has on biodiversity. Examples include a program of intensification of grazing management through fencing and provision of waters, or a program using fire to manipulate stock distribution.

Biodiversity measures

Biodiversity is multi-dimensional, with different entities like genes, species populations and ecosystems having different compositional, structural and functional attributes. All are interdependent and important for maintaining and improving biodiversity but it is not realistic to attempt to measure them all. Pragmatically, there are two dimensions of biodiversity that are especially important for regional sustainability. These dimensions, and societal outcomes desired for them, are:

- *Ecosystems*: The desired regional outcome may be to maintain and enhance ecosystem functioning (e.g. soil stability, nutrient cycling, the infiltration and use of water by ecosystems, vegetation cover and landscape patterns).
- *Plants and animals*: The desired regional outcomes may be to maintain sufficient examples of all native plant and animal species and their habitats to ensure no further species are lost. Maintaining ecosystem functioning is an important foundation for maintaining plants and animals, and many plants and animals will be maintained simply by focusing on ecosystem functioning.



However, some native plants and animals may need additional attention. For example, some native animals may be threatened by exotic predators such as foxes and cats. Without predator control their populations will continue to decline, even in otherwise functional ecosystems. Similarly, some ephemeral plants may be especially vulnerable to being eaten out by grazing animals, and this may occur even in well-maintained and functioning landscapes.

It is neither feasible nor necessary to have the same biodiversity objectives for every parcel of land within a region. Objectives for different areas need to be set according to appropriate scales (e.g. enterprise, district, subregion or region), and the values, threats and feasibility of the specific outcomes desired at each scale.

They also need to take account of the contribution each scale makes to higher or lower scales. In general, maintenance or enhancement of ecosystem functioning should be an objective in most areas. Maintenance or enhancement of especially vulnerable plant and animal species is an objective that is likely to be restricted to areas that are especially suitable.

Biodiversity indicators

Biodiversity indicators are sets of biotic, environmental, pressure and landscape attributes that best signal the effects of pressures caused by human activities on biodiversity. They should also have meaning beyond their individual measurement (Saunders 1998). The operational definition of the different attributes are:

- *Biotic response attributes*: Actual or derived measurements of biotic entities that are collected in the field using ground-based sampling techniques. These can be used to indicate the status or condition of biodiversity (e.g. species richness, the abundance of targeted species).
- *Environmental attributes*: Actual or derived biophysical measures of the environment (e.g. climate, topography, soil properties, LFA attributes, vegetation or habitat characteristics) that can be measured in the field or remotely. These usually measure those variables that drive biotic responses or can be used to derive landscape measures.
- *Pressure attributes*: An actual or derived measure of a threatening process caused by human activities that affect biota. The variables measured are likely to interactively affect environmental and biotic response attributes (e.g. extent and rate of clearing, change in human population density, abundance of foxes).
- *Landscape attributes*: A derived measure using remote-sensing techniques (e.g. satellite imagery, airborne photo/videography, GIS mapping) that measure the environmental and pressure attributes of ecosystems at multiple spatial scales. These may be used as surrogate measures of biodiversity at broad scales (e.g. leakiness index, NDVI, mapping of artificial water points, habitat complexity scores).

The appropriate indicators available for monitoring biodiversity in the rangelands have been presented in Chapter 4 of this report. How you choose the best set for regional monitoring will depend on the purposes for monitoring, the operational constraints of the monitoring system and how well the available indicators meet the standard criteria for selection (see Smyth in Appendix 4).

Indicator sets for remote monitoring

Many of the pressures likely to affect rangeland biodiversity can be assessed using air photos, maps and satellite imagery. Examples include indicators of the distribution of:

- livestock (based on location of watering points, fences and other infrastructure, coupled with information about long-term stocking rates)
- feral grazing animals (based on knowledge of habitat preferences and, where appropriate, location of watering points)
- clearing (based on statewide and territory mapping using satellite imagery; e.g. Barson et al. 2000)
- fires (based on satellite-based assessment of fire history, extent and timing; Allan et al. 2001).

Indicator sets for on-ground monitoring

No single indicator can be sufficient for monitoring the many dimensions of biodiversity, but a set of complementary indicators can show trends in the variety of ecosystems, landscapes, plants and animals of interest (see Smyth in appendices 4 and 5). This set should include indicators that are sensitive to the main pressures acting in different places, so negative trends can be detected in time to take remedial action.

Just as it is not necessary to attempt to achieve the same biodiversity objectives in every parcel of land within a region, nor is it necessary (or feasible) to monitor a full set of biodiversity indicators at every monitoring site. Instead, a necessary and sufficient set of indicators should be selected to provide the level of information appropriate for showing local progress towards regional goals. Examples of different tiers of indicators for different levels of information ranging from adequate to comprehensive and qualitative to quantitative include:

- perennial ground cover or bare soil
  - tier 1: photopoint data (pastoralist)
  - tier 2: plots to measure cover of vegetation types (NRM manager)
  - tier 3: landscape function analysis and remotely sensed basal cover of grasses (NRM manager)
- bird richness
  - tier 1: opportunistic listing of species from year to year along regular water-runs on the property (pastoralist)
  - tier 2: opportunistic species lists at specified sites close and >15 km from any artificial water point (birdwatching volunteers)
  - tier 3: stratified census (2 ha plot for 20 minutes) by country type and season for a specified time frame (conservation officer).

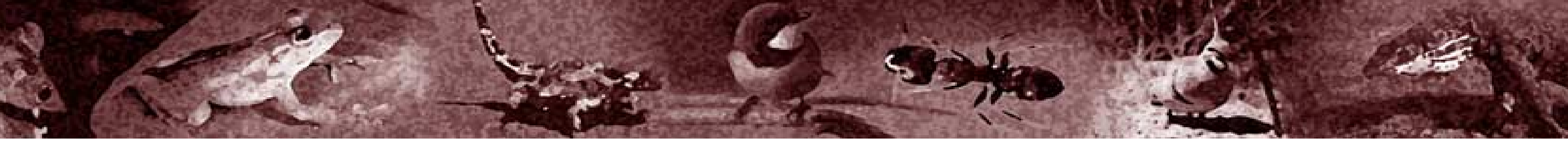
Reference areas

Changes in biodiversity measures, or indicators of them, can sometimes be difficult to interpret, particularly in regions where there are marked seasonal fluctuations and/or there is uncertainty about what constitutes a ‘good’ value. The purpose of reference areas is to show what ‘good’ values can be, in places where land use and other pressures (e.g. feral animals) are low. And because biodiversity varies with country type, each country type needs its own set of reference areas. Possible locations of reference areas can be found by overlaying maps of pressures over maps of country types. Field checking will also be needed, since maps may be incomplete or in error. In some country types, particularly ones that are productive and/or restricted in extent, everywhere may be under pressure; in such cases reference areas should be located to represent the ‘best-on-offer’ state of that country type.

A network of reference areas provides two benefits: it provides points of reference for land managers, by demonstrating what it can be like for representative country types; it also provides regional standards for computing and comparing national change statistics, such as proportional decline in vulnerable species.

The two most important criteria for selecting reference areas are that they represent the characteristic landscapes and habitats of the region to be monitored, and are as little influenced as possible by *all* the major pressures acting on the country type they represent. Where possible they should also be big enough to support the larger-scale processes that sustain biodiversity, such as providing breeding territories for resident birds. National parks and other reserves are a potential source of reference areas, but only if they meet the criteria of representativeness and low pressure.

Some of the most pervasive threats to biodiversity, such as inappropriate fire regimes, weed incursions and feral animals, are largely independent of land-use boundaries. Where there are no areas of low threat, even in national parks, it may be necessary to specially protect some areas and make them the focus of threat mitigation. Examples include local-scale eradication of feral pigs inside fenced seasonal wetlands, and local-scale implementation of patch burning as a conservation tool. Monitoring of created reference areas such as these should aim to:



- define the impacts of the pressure being excluded
- identify and evaluate management options.

Reference areas therefore are relative benchmarks of the 'good' current status and condition of biodiversity when potentially harmful pressures are at their lowest or absent in a particular country type. They will vary among country types, and their condition will vary through time. Their greatest value is as present-day standards for evaluating differences between less-pressured and more-pressured areas in order to identify whether biodiversity has changed over time (see Mac Nally et al. in Appendix 4).

A more robust design would be to select sites that represent gradients in the amount of pressure acting on particular country types, so that changes in biodiversity trends can be evaluated spatially as well as temporally in the region. If the management need was to maintain and protect 'good' biodiversity values, then monitoring would only need to be conducted in the less-pressured areas.

Remote monitoring

Many of the information layers assembled for the monitoring program are themselves amenable to monitoring. This is particularly true of the pressure layers, which can be updated regularly and used for reporting on the status and trend of potential threats to biodiversity. Examples of regional indicators for which regular reports can be summarised include:

- extent of different country types by tenure and land use, relative to total regional area
- area and per cent of clearing by country type, tenure and land use
- area and per cent of country types likely to be subject to high levels of grazing (e.g. within 1 km of a water point)
- area and per cent of country types likely to be subject to low levels of grazing (e.g. more than 10 km from a water point and/or fenced to exclude livestock)
- area and per cent of country types subject to different fire regimes
- area and per cent of weed infestation by country type, tenure and land use
- area and per cent of weed removal by country type, tenure and land use.

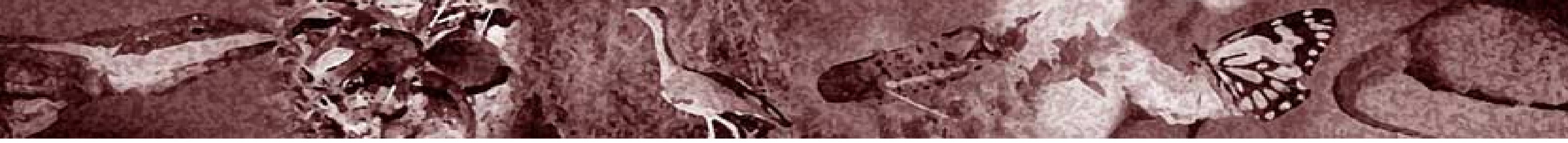
Remote monitoring provides the spatial context for deciding where to locate on-ground monitoring sites, and interpreting the potential extent of trends identified at on-ground sites.

On-ground monitoring

Objectives

Rangeland regions are so extensive and many plant and animal populations are so low that it is unrealistic to expect on-ground monitoring to provide a statistical sample of all the country types and pressures across any single region. One of the aims of on-ground monitoring therefore should be to evaluate the efficacy of remote monitoring for detecting trends in ecosystem functioning, and/or plant and animal populations. Examples of the types of issues that can best be addressed by on-ground monitoring include:

- the nature of relationships between remote indicators of pressure and specific elements of biodiversity (such as how heavy grazing affects particular species of native plants and animals)
- the nature of relationships between different dimensions of biodiversity (such as whether areas with similar ecosystem properties share similar plant and animal characteristics, and the extent to which this is affected by pressure)
- the effectiveness of special protective measures (such as determining whether more native species are able to flourish when reference areas are fenced)
- the impact of changed management strategies (such as determining whether changed fire regimes reduce or increase the populations of any native species)
- trends in the populations of special species, such as those listed as rare, vulnerable or endangered
- the ability of the monitoring program to successfully deliver management outcomes.



Locating sites

Where there is a specific management or biodiversity issue to be addressed, on-ground monitoring sites should be located in the area most suited to that issue. These constitute the ‘special places’ described in the section on information resources.

For more general issues, particularly those addressing the relationships between different indicators of biodiversity, sites should be representative of the different types of biodiversity in the region, and the different pressures acting on them. Wherever possible, monitoring sites should be selected in sets that allow comparison of different levels of pressure for different pressures. Each set of sites needs to be in the same type of country. For example, there is not much point in using rocky hill country as a reference for the kind of biota that could live in riparian zones. A minimum set of sites should include at least the following:

- ‘reference’ sites—places to refer, to see what the biodiversity of a particular country type could be like. Reference areas can be found by looking for places where the biodiversity is under as little pressure as possible from all of the potential pressures that may occur in the region. For example, they may be places that are so far from water that historically livestock seldom go there, so the grazing pressure is light. If everywhere in a region is under pressure, the reference sites should be the ‘best on offer’ for each country type of interest
- ‘typical’ sites—places representing the typical land use and condition of the different country types in the region
- ‘at-risk’ site—those where one or more pressures are particularly high and biodiversity may be at risk.

Generally several replicate sets of sites will be needed to give an indication of how much natural variation exists between sites independent of pressures. The size, location and number of site-sets will depend on the issues being addressed, the elements of biodiversity of interest, the extent and nature of pressures, and the variability of country types in the region. In some cases it may be appropriate to include more of one type of site than of others. For example, if there is a range of pressures acting on a country type one may need to include several ‘typical’ or ‘at-risk’ sites for each reference.

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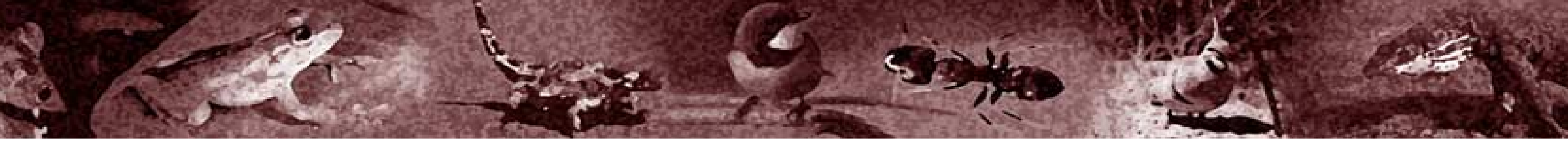

Appendix G

The principles for monitoring by group 2

Principles for monitoring

AO (Nick) Nicholls[1] and Jeremy Wallace[2]

There are three basic features of a monitoring program that need to be considered:

- recognition that the primary purpose of a monitoring program is to detect change over time
- recognition that there is a need to be able to communicate the magnitude and direction of change detected
- recognition of the long time scales over which the monitoring program may need to operate.

Detecting change

While any monitoring program or survey will furnish a picture of the current status, the primary benefit of a monitoring program is that repeat surveys over time also provide a picture of the change over time. The following issues need to be considered:

- sample versus census
- capacity for re-measurement
- detection of change versus detection of trend
- statistical power versus ecological significance
- sample design.

Communication

Failure to provide clear messages from the monitoring program will lead to higher chances of failure. Messages need to be simple but in advocating this we are not suggesting that the issues behind the messages are not complex. We also need to recognise the messages need to be aimed at, and tailored for, different groups. In the simplest cases there are two broad groups: the general public and their representatives; and the special interest groups, for example conservation groups or the pastoralists.

Time scales

The rangelands are characterised by variability, both spatial and temporal. Many biological processes are event driven. These events are unpredictable, again in both spatial and temporal contexts. Consequently, non-mobile organisms may be at very different stages of their life cycles. Likewise, many mobile organisms can move large distances in response to these events, so apparent population declines or increases may be nothing more that the consequences of resource tracking.

The consequences for a monitoring program are numerous. For non-mobile organisms, reporting at scales above the local scale can hide a great variety of responses and generate or contribute to increased estimates of variances and make detection of change more difficult. The frequency of monitoring needs to recognise the event nature of the rangelands. Large numbers of samples may be necessary to capture the spatial and temporal variability of the attributes of interest.

Understanding of the time scales are important also with respect to the communication needs considered above. Not only from the monitoring program's duration but also from the perspective of conveying messages about change to the public. Long time frames may be necessary to detect change or to demonstrate that current management is meeting acceptable standards.

Building a monitoring system that can cope with these features requires investment in a system with many parts, not just an emphasis on data collection with analysis and reporting tacked on as an after thought. This aspect is developed further in the next section.

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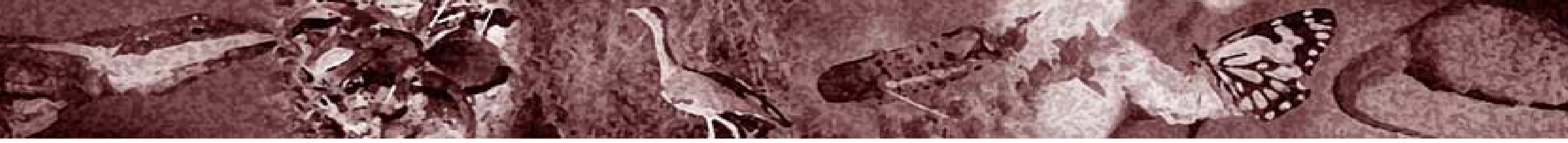

Long-term institutional investment

Monitoring is becoming a disciple in its own right that recognises that there is a need for many components to enhance the chance of achieving a successful productive program. Failure to recognise that all of the following components are necessary to maintain long-term successful monitoring programs is likely to consign the monitoring program to short-term demise.

- *Design*

  Well-defined purpose-driven objectives are essential; they will lay the basis on which all subsequent decisions can rest. Stratification is important. Our view is that assigning causality is not necessarily the purpose of a monitoring program.

- *Data collection*

  Utility of 'existing data' has to be evaluated against the objectives. There may be some questionable trade-offs between accepting the constraints of existing date with the benefits derived from the longer time frame that they would provide. It is likely that existing data come without good stratification. Data quality will need to be maintained at all times. Commitment to developing and maintaining robust data entry and checking protocols is important to ensure confidence in the data over time.

- *Archiving*

  This is perhaps one of the most important components of a monitoring program. Failure to be able to access data from past monitoring events renders the monitoring program virtually useless for the purpose of detecting change over time. Given the pace of IT development the commitment to archiving the data is substantial. Substantial resources may be required to maintain long-term data in formats that remain fully compatible with evolving software packages.

- *Analysis*

  There has been substantial development in statistical techniques over the past few decades that many scientists appear to be ignorant of or at least inadequately informed about. Many techniques are not simple to apply or to interpret. These comments apply to the analysis of monitoring data where temporal dependencies may be strong and repeated observations of the same experimental units are dominant features of the data. The implication for a monitoring program is the need for good biometrical or statistical input rather than depending upon simple easy-to-apply tests.

- *Summarising*

  There are trade-offs between the need to reduce the complexity of the rangelands biodiversity to manageable units that broadly capture the dynamics that we are interested in reporting. As part of the monitoring program development, clear thought has to be given to the reporting measures that will be developed from the data.

- *Communication*

  As part of the preceding point (Summarising) there is also a need to think about the messages to the clients that will arise from the monitoring program. The messages need to be simple. This is not to say that we have to ignore or deny the underlying complexity of the rangelands biodiversity and its response to environmental variation or human manipulation.

- *Quality assurance*

  There is an overriding need to maintain an ongoing, or schedule a regular, review of the monitoring program. Expectations of the outcomes of a monitoring program will change over time, and these need to be met. Understanding of the rangelands biology will increase as will our understanding of the biota's responses to human-induced pressures. A monitoring program established today cannot be expected to anticipate the scope of such increased understanding into the future. The monitoring program will need to evolve but under careful consideration of the consequences for integrity of the monitoring program.