Towards an Australian Rangeland Biodiversity Monitoring Framework

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A discussion paper developed from a biodiversity monitoring workshop convened by Australian Collaborative Rangeland Information System (ACRIS) held at the University of Queensland, Brisbane on 30-31 October 2013

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Cover photos:

Top left- Rangelands in central Australia near Kings Canyon, Northern Territory (Photo by Melissa Bruton, the University of Queensland)

Top left - Rangelands in north-west Queensland (Photo by Michiala Bowen, the University of Queensland).

Bottom – Kultarr, *Antechinomys laniger*, Southwest Queensland (Photo by Michael Mathieson, Queensland Herbarium).

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Executive summary

There is a protracted history of initiatives aimed at conceptualising and establishing a rangeland biodiversity monitoring program, however they have made little progress and consequently there is no coherent national program that provides long-term biodiversity information for reporting on trends. This discussion paper is the outcome of a rangelands biodiversity monitoring workshop convened with the primary aim to learn from past and present monitoring initiatives and pragmatically move the issue forward. The workshop was commissioned by Australian Collaborative Rangeland Information System (ACRIS) held at the University of Queensland, Brisbane on 30-31 October 2013. The objectives of the workshop were to:

1. Explore to what extent the existing state and territory rangeland monitoring systems might contribute toward developing a nationally consistent rangeland biodiversity monitoring infrastructure.
2. Identify what gaps (spatial, temporal and thematic) are present in the current infrastructure.
3. Identify what additional scientific resources, sponsorships, champions and partnerships would be needed to fill gaps and make the proposed nationally consistent rangeland biodiversity monitoring infrastructure an operational and enduring regional and national reporting framework.
4. Discuss how other biodiversity monitoring infrastructure / systems might also contribute toward the proposed nationally consistent rangeland biodiversity monitoring infrastructure.

The purpose of this discussion paper is to outline a strategy for the establishment of a nationally consistent framework for monitoring rangeland biodiversity; noting that the rangelands should be an integral component of an Australia-wide biodiversity monitoring and reporting framework. It presents the case for establishing and managing a long-term rangeland monitoring and reporting initiative which is designed to improve our knowledge and understanding of:

- Ecological patterns and processes, and detecting spatial and temporal changes and trends in rangeland ecosystems and biota;

- What are priority management interventions, including identifying the critical response periods when key interventions are required (i.e., cause and effect); and
- What are beneficial management interventions, which is a critical step in adaptive management?

To date, gaining support for, and implementing a long-term biodiversity monitoring program designed to detect and report trends in rangeland biodiversity has not been acknowledged as a deserving priority for public-private investors, or by sponsoring and/or regulatory agencies.

Taking into account that rangelands are an integral component of any future Australia-wide biodiversity monitoring and reporting framework, a priority for public-private stakeholder institutions is to establish a nationally consistent framework for long-term monitoring of rangeland biodiversity.

Key findings:

- Australia's extensive rangelands support a rich diversity of fauna and flora, including many endemic species.
- The rangelands have a history of land degradation and species' extinctions, dating back to the late 1800s.
- While considerable progress has been made in the sustainable use of the rangelands, the long-standing threats of excessive grazing pressure, invasive species and climate variability and their interactions remain, while new threats of large-scale mining and climate change are mounting.
- Currently, biodiversity monitoring in Australia's rangelands is limited and *ad hoc* and lacks a repeatable, systematic approach that is able to detect medium-term to long-term trends in flora and fauna populations.
- Gaining government and industry support for biodiversity monitoring across the rangelands is a persistent and perennial struggle.
- It is timely to adopt a fresh approach to the problem, and to learn from past initiatives.
- Linking biodiversity monitoring to the current long-term pastoral monitoring programs in several states and territories is unlikely to have significant benefit because of the different rationales, objectives and methodologies.

- The Terrestrial Ecosystem Research Network has made major investments in developing national remote-sensing data sets of Australia's vegetation cover and plot-based monitoring (AusPlots Rangelands) of baseline information on vegetation and soils, including genetic and isotope data. However, fauna is not included in rangeland AusPlots surveys and is not currently a priority TERN initiative.
- It is time to act to more effectively develop a comprehensive biodiversity monitoring program for Australia, which includes rangeland biodiversity which is both science-driven and are management-driven.
- It was agreed that biodiversity monitoring should ideally be part of a consistent national biodiversity monitoring system and not just focused or implemented in the rangelands.

1. Recommendations-Strategic:

1.1. **ACRIS develops a business proposal for advancing biodiversity monitoring, evaluation and reporting in the rangelands.** This proposal should incorporate the major findings of this report and the previous unpublished ACRIS report by Price & Wardrop outlining a business case for a national framework for monitoring biodiversity in the Australian rangelands.

1.2. **The business proposal needs to be promoted as part of broader alliance for national biodiversity monitoring, not just for rangeland biodiversity.**

1.3. **ACRIS is not the right body to drive this, but should continue to play a lead role for the rangelands.** This is critical given the uncertainty in funding for ACRIS beyond June 2014.

1.4. **ACRIS identifies critical partners and champions with a view to gaining their support for advocating and lobbying.** Key alliance partners are the Commonwealth Department of Environment, State environment/biodiversity agencies, TERN, the mining, pastoral and tourism industries non-government conservation organisations and Indigenous organisations.

1.5. **ACRIS (or its champion(s)) directly approach the Commonwealth Department of Environment with the business case.** This communication should target new Commonwealth government initiatives including the *Plan for a Cleaner Environment*, including *Threatened Species* and the appointment of a *Threatened Species Commissioner*. It should also emphasise "Priority for action 3" of Australia's Biodiversity Conservation 2010-2030, which specifies a national target "to establish a national long-term biodiversity monitoring and reporting system" by 2015.

1.6. **The Commonwealth Government review the ecological-effectiveness and cost-effectiveness of all current environmental monitoring programs in the rangelands with the aim of developing a more ecologically-effective cost-effective and integrated approach.**

1.7. **The Commonwealth and state and territory governments need to recognise that monitoring is an integral step in good and cost-effective conservation and can do more than track biodiversity decline** - it allows for timely warning and the establishment of early and cost-effective interventions that forestall or reverse declines.

1.8. **The Commonwealth Government conduct a systematic assessment and review of all available information (published and unpublished) on the condition and trend in rangeland biodiversity.** This should include plot-based ecosystem condition information, remote-sensing information and flora and fauna data. This would allow a rangeland-wide assessment of trajectories of change and provide the basis for the design of cost-effective conservation and monitoring programs.

1.9. **The leading researchers working in Australia's rangelands seriously consider forming a consortium to develop a funding application for a National Environmental Research Hub should the Commonwealth Government decide to proceed with NERP2.**

2. Recommendations-Technical

The Commonwealth and state and territory governments:

2.1. **Develop agreed science-driven and management-driven objectives for monitoring and reporting condition and trend in Australia's biodiversity, including rangeland biodiversity**. Integral to the monitoring of biodiversity is its integration with broader landscape-scale surveillance monitoring including the appropriate use of national time series remote sensing archives including foliage projective cover, ground cover anomaly and fractional cover.

2.2. **Move from the current short term, *ad hoc* monitoring programs to a staged a rangeland biodiversity monitoring program** which focuses on the initial establishment of a small number of representative sites that can be used to trial and evaluate the ecological and cost-effectiveness of new fauna monitoring methods and new technologies. Key issues here include what species to monitor (e.g. winners and losers), where and how should they be monitored, and how often? This information should inform the design and establishment of an expanded rangeland biodiversity program to be implemented within a 5 year time-frame.

2.3. **Develop complementary and interoperable information systems with shared infrastructure and analytical tools** for detecting and reporting medium to long-term changes and long-term trends in rangeland biodiversity (fauna, flora as well as ecosystem condition) and for interpreting how these changes and trends vary regionally. This system should be linked with a national environmental information system for reporting and interpreting environmental change.

2.4. **In partnership with key universities and regional natural resource management agencies, evaluate the effectiveness of land management actions** that aim to conserve and restore the diverse components of rangeland biodiversity. This should include the identification of causal factors that drive biodiversity changes including the interacting threats of land management, land use change and climate variability**.** Promote the findings among land managers, government agencies, industry groups and indigenous organisations.

Rationale – why do we need a program for monitoring biodiversity in the rangelands?

In 2008, the first major national report on changes in biophysical and socio-economic indicators of the Australian Rangelands, for the period 1992 and 2005, concluded that the available spatial and temporal environmental data were inadequate for monitoring and reporting changes in rangeland biodiversity. Overcoming this lack of reliable information is a critical national challenge and is the focus of this discussion paper.

It is widely acknowledged that high quality, evidence-based information is necessary for improving the condition of natural resources and biodiversity, and for state and national State of the Environment (SoE) reporting. Rangeland stakeholders include all levels of government, industry groups including pastoralists, mining and tourism, Indigenous groups, and the wider community. Currently, our best available information on the condition and trend of biodiversity in the rangelands is sourced from a series of *ad hoc* monitoring and management programs. In general, the data from these programs can only be used to monitor and report natural variability for specific areas, and cannot be used to inform rangeland managers of the requirement and approaches to change land management practices to improve biodiversity outcomes.

The problem is that currently there is a lack of credible spatial and temporal information on how and when the use and management of the rangelands causes declines in the condition of biophysical indicators and trigger the loss of native fauna and flora species. Equally, there is lack credible information on how rangeland management can be used to improve the functioning of key ecological processes that sustain biodiversity.

There are numerous impediments to establishing a nationally consistent biodiversity monitoring and reporting framework. Principal among these is a widely held view that historic and contemporary use and management of the rangelands has minimally affected the condition of the rangelands and its associated biodiversity. Despite mounting evidence indicating declines in rangelands biodiversity, establishing a causal link between how the rangelands are used and managed, and their condition, is still particularly challenging. Currently, there is a general lack of acknowledgement of these processes, both publically and privately, and a general inertia exists among some key stakeholders of the need to investigate or substantiate this issue.

There are also opportunities for engaging existing and new stakeholders in broader strategic partnerships and influential networks to share the costs and benefits of establishing and maintaining a nationally consistent biodiversity monitoring and reporting framework.

1. Introduction

Australia's rangelands are landscapes where land use is dominated by pastoralism involving extensive sheep and cattle grazing on native and introduced pastures (Lesslie *et al.* 2006). Rangelands occupy approximately 80% of the Australian continent and occur in 52 bioregions, across five states and territories (Queensland, New South Wales, South Australian, Western Australia, and the Northern Territory) and comprise savannas, woodlands, shrublands and grasslands — extending across arid, semiarid and some seasonally high rainfall areas (NLWRA 2001). These biomes support a diverse and unique range of fauna and flora. The density of human settlement of rangelands in Australia is relatively low compared to the higher rainfall, intensive agricultural regions of eastern, south east and south west Australia. However, rangelands are economically important for the grazing of livestock, and mining and gas/oil exploration and extraction (Holmes 1996; 2002). Australia's rangelands also provide important resources for Indigenous communities and are an important tourism destination.

Rangelands in southern and central Australia are characterised by low (< 400 mm per year) and highly variable rainfall, while in the tropical northern rangelands mean annual rainfall is high as >2000 mm in some regions, but is seasonal, with the majority falling between December and March. The high variability in seasonal and annual rainfall produces so-called 'boom and bust cycles' of flora and fauna, and as a result, rangelands in general do not support dryland cropping.

Today, compared to the intensive land use zone of eastern, south-east and south-west Australia, the landscapes of the Australia's rangelands remain relatively 'intact', largely free of intensive human settlement and agricultural development. Regions such as Cape York Peninsula, Central Desert, Top End and the Kimberley are remote from, and largely undisturbed by, the impacts and influence of large scale development, and are recognised for their wilderness values. However, land use pressures, along with introduced plant and animal species, are key threats to biodiversity in the rangelands. For example, some naturalised pasture species, including buffel grass (*Cenchrus ciliaris)* are now the dominant grass species in many regions. Furthermore, many of Australia's threatened species occur in the rangelands, particularly reptiles, birds and mammals (Figure 1). The natural climate cycles are expected to be altered by climate change, with more frequent severe droughts and high temperatures likely (CSIRO 2007), and this will drive further change to rangeland ecosystems. The impacts of climate change on Australia's rangelands are unknown, however, increased frequency of severe droughts (by up to 40%) is expected over much of the continent (Mpelasoka *et al.* 2008), and consequently, significant declines in biodiversity are likely.

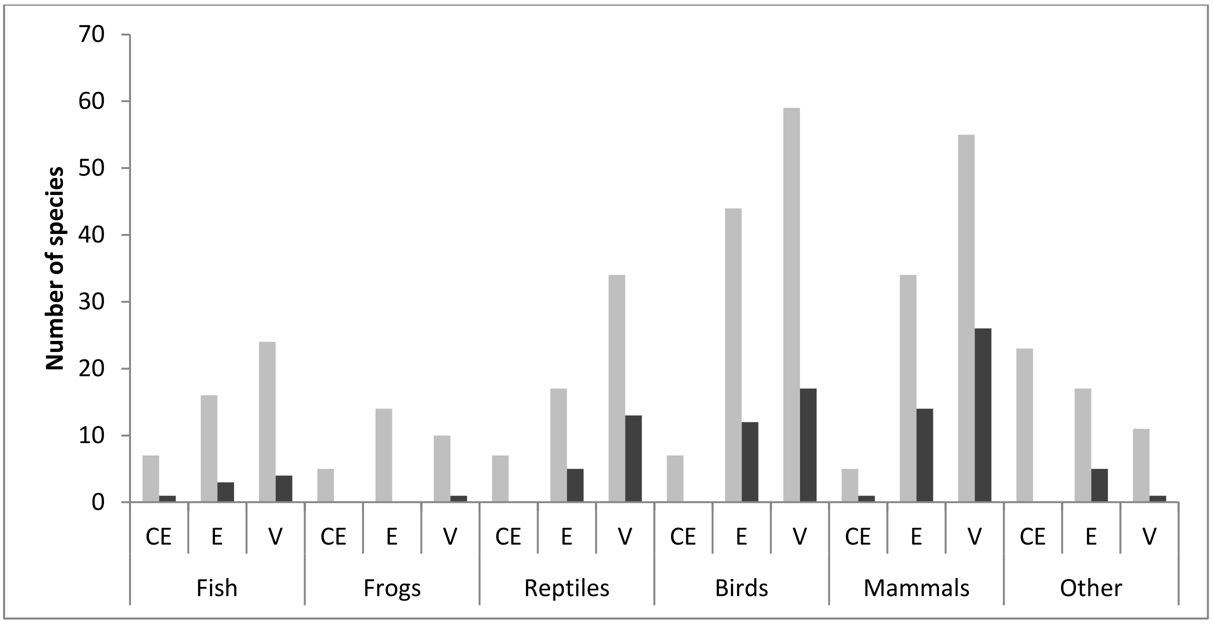

Figure 1. The total number of EPBC listed threatened fauna species in Australia (grey bars) and those that occur in the rangelands (black bars). Listing abbreviations are: CE – Critically Endangered; E – Endangered; and V – Vulnerable. Source: The Australian Government Department of the Environment EPBC Act List of Threatened Fauna.

Despite considerable progress in the science underpinning sustainable rangeland management, the widespread implementation of this knowledge remains a national challenge that requires a collaborative approach involving State, Northern Territory and Australian Governments. To address this problem, the Australian Collaborative Rangeland Information System (ACRIS) was formed in 2003 to monitor and report changes in resource condition and biodiversity in the rangelands. In 2008, ACRIS released the first comprehensive and detailed national report of biophysical and socio-economic change to the Australian rangelands for the period 1992 and 2005 (Bastin and the ACRIS Management Committee 2008). The intent of that report was to use evidence of changes in biodiversity and resource condition as a basis for improving rangeland management.

A key finding of that report was that while there was evidence of substantial declines in rangeland biodiversity, changes in landscape function were variable (Bastin and the ACRIS Management Committee 2008). The authors however, concluded that spatial and temporal biodiversity data was inadequate to inform rangeland stakeholders of the management implications necessary to improve the condition of key biophysical processes and the faunal and floristic elements of biodiversity. Despite the report's finding, key researchers and concerned scientists note the continuing lack of development of a recurrently funded consistent national monitoring and reporting framework across Australia's rangelands.

Gaining support for a systematic and comprehensive biodiversity monitoring program in the Australian rangelands is a continuing challenge. Since 2001, there has been a series of initiatives to conceptualise and establish cross-jurisdictional biodiversity monitoring programs in the rangelands. The first of these by Whitehead *et al*. (2001) clearly articulated the need for a rangeland biodiversity monitoring framework. This was followed by widespread consultation through a series of workshops aimed at advancing biodiversity monitoring and identifying key indicators and surrogates (Smyth *et al.* 2003). These proposed indicators were revisited and refined by Fisher *et al*. (2006), who reached the conclusion that, despite increasing interest, few monitoring programs were ever actually implemented. This sentiment was reiterated by ACRIS, who concluded that Australia cannot adequately report on change in biodiversity due to the lack of coherent and relevant datasets (Bastin and the ACRIS Management Committee 2008). In an effort to prompt progress towards addressing the lack of appropriate biodiversity data, ACRIS supported the development of a Biodiversity Monitoring Framework for the Australian rangelands, which aimed to present a practical, collaborative and cost-effective approach (Kutt *et al*. 2009; Eyre *et al*. 2011). A pilot study, aimed at testing how well the proposed framework can be implemented, has revealed a number of barriers (ACRIS MC in prep). At about the same time, the Terrestrial Ecosystem Research Network (TERN) was established to collect and integrate ecosystem data across broad spatial and temporal scales to address national-scale problems in ecosystem science and environmental management. Core TERN programs include TERN's AusCover, AusPlots, Long Term Ecological Research Network Sites (LTERN) and the TERN SuperSite Network. The geographic coverage of these programs includes the rangelands. The recent TERN Ecosystem Science initiative aims to "ensure we have a cohesive vision and plan for sustaining and developing ecosystem science in Australia". However, to date there has been no indication that fauna will be included in this initiative, mainly due to a lack of funding.

Monitoring programs must have an explicit purpose and justification that goes beyond reporting environmental change if they are to retain recurrent funding (McDonald-Madden *et al.* 2010). For example, monitoring for management purposes must be linked to management actions, otherwise there is no foreseeable endpoint, and therefore such programs are unlikely to attract funding. Furthermore, particular monitoring programs require the collection of different information depending on the questions that monitoring is trying to answer. Lindenmayer and Likens (2010) observed that there is a record of failure of many monitoring programs because they often lack well-defined key questions and therefore have a limited ability to diagnose the cause of change; are designed poorly; and fail to articulate what, why and where to monitor. Consequently, it is critical to articulate why such a monitoring initiative is important when considering the development of a rangeland biodiversity monitoring and reporting system.

This discussion paper presents the case for establishing and managing a long-term rangeland monitoring and reporting initiative which is designed to improve our knowledge and understanding of:

- Ecological patterns and processes, and detecting spatial and temporal changes and trends in rangeland ecosystems and biota;
- What are priority management interventions, including identifying the critical response periods when key interventions are required (i.e., cause and effect); and
- What are beneficial management interventions, which is a critical step in adaptive management?

2. Unmet demands for national rangelands biodiversity monitoring information

There is significant demand for national-level biodiversity monitoring data and information (Price and Wardrop unpublished). Many organisations, businesses, groups and individuals use biodiversity data and information, and have specific data needs that differ in type, scale or location. Price and Wardrop (unpublished) identified three main user requirements for biodiversity monitoring information across a wide range of stakeholders:

1. Audit and reporting information are used for regulatory or audit reporting (e.g., to meet leasehold or licence-to-operate conditions);

2. Condition and trend information for evaluating the ecological effectiveness and cost-effectiveness of management activities or interventions (e.g., for a monitoring, evaluation, reporting and improvement (MERI) framework, to support planning and adaptive management through continuous improvement, to assist cultural management, and to develop better land management); and
3. Trend information is used to identify and measure changes at large spatial or temporal scales that are not due to recent management actions (e.g. due to climate change or species adaptation).

Price and Wardrop (unpublished) also noted that governments are the primary users of data and information because of their legislative, regulatory and policy roles, and because they invest in a wide range of Natural Resource Management (NRM), biodiversity and resource condition activities. Several key information requirements include:

- The State and Northern Territory governments have data and information requirements to meet regulatory, planning, policy, licensing and permitting functions, and have direct involvement in most aspects of rangeland ownership and NRM, establishing priorities for land use and management, responsibilities for management of natural resources and conservation of biodiversity, and State of the Environment (SoE) reporting at jurisdictional level.
- The Australian Government has data and information requirements to implement and report on international treaties on biodiversity, sustainable development, climate change and national SoE reporting. In addition, it has the lead funding and coordinating role in the National Reserve System, species recovery plans, assessment of developments in relation to the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), and NRM programs. It also has a coordinating role in the collection, curation and publishing of biodiversity data and information at the national scale. The Australian Biodiversity Conservation Strategy 2010-2030 (Australian Government 2010) explicitly identifies a target to establish a national long-term biodiversity monitoring and reporting system to determine whether conservation efforts are improving biodiversity outcomes.

Other users of biodiversity data and information include regional NRM bodies/Catchment Management Authorities, Indigenous land owners and managers, and biophysical scientists and researchers. Several key information requirements include:

- Regional NRM organisations have data and information requirements to meet their regulatory, planning and on-ground management and reporting obligations to their community and funding bodies.
- Indigenous land owners and managers have data and information requirements to meet their regulatory, planning and on-ground management and reporting to their community and funding bodies. They also have a broader role as independent land owners in regard to conservation, mining, pastoral and tourism interests.
- Scientists and researchers have data and information requirements to improve the understanding of cause and effect relationships, and information on long-term trends, including their causes and trajectories, and inform rangeland management and planning programs.

For the rangelands, the current status of biodiversity data and information falls short of meeting most requirements for reporting rangeland biodiversity trends and meeting stakeholder's requirements. A lack of comprehensive, consistent and representative data and information for our rangeland biodiversity poses significant risks to the effectiveness of government natural resource management and conservation programs. This includes financial risks, through late recognition and ineffective management response to emerging issues, and insufficient data to provide predictive capability and adopt adaptive management programs (Price and Wardrop unpublished).

Inadequate biodiversity data and information also compromises the ability of science and policy agencies to report against statutory requirements and to evaluate the outcomes of government-funded management activities worth at least $100 m annually (Price and Wardrop unpublished).

3. A new impetus for monitoring biodiversity in the rangelands

The rangelands biodiversity monitoring workshop convened by ACRIS and held at the University of Queensland, Brisbane in October 2013, reviewed the current status of monitoring and reporting of biodiversity in Australia's rangelands.

Workshop participants (see Acknowledgements) agreed that current monitoring in the rangelands is limited and *ad hoc* and lacks a repeatable, systematic approach for the detection of medium to long-term trends in flora and fauna populations, and the causes of environmental change on rangeland biodiversity. This deficiency effectively prevents informed land management decisions to improve the conservation management of key elements of biodiversity in the rangelands. Of particular concern was the absence of rangeland-wide long-term monitoring of trends in fauna populations.

The workshop participants also noted several reasons why it is difficult to attract support and funding for a systematic rangelands biodiversity monitoring infrastructure, including:

- The enormous size of Australia's rangelands.
- A small human population-base and a narrow set of sectoral interests focussed primarily on pastoralism.
- A perceived duplication and competition for funding and other resources by sponsoring and/or funding agencies.
- A perceived view that pastoralism in the rangelands has minimally impacted biodiversity, hence there is little or no desire among sponsoring and/or regulatory agencies to go beyond monitoring and reporting of broad-scale natural variability.

The participants noted and discussed the requirements of policy and land management decision makers for evidence-based information to detect and quantify long-term trends in biodiversity across space and time. There was broad agreement that the current rangelands monitoring infrastructure is deficient in both its design and implementation for reliably detecting changes and trends in biodiversity, and the processes involved.

Ideally, a rangelands wide biodiversity monitoring program should be part of a national biodiversity monitoring infrastructure, established for monitoring and reporting trends in Australia's biodiversity. Eyre *et al*. (2011) identified that a comprehensive and adaptive biodiversity monitoring framework for the rangelands should:

- Include a plot-based survey network that is representative of Australia's rangeland's biodiversity.
- Integrate with other ecological data, including landscape-scale time series remote sensing data and spatial geographic information, and localised, targeted field-based sites that would include existing activity.

Such a framework will require collaborative negotiation and agreement on indicators and drivers to monitor; cooperation among relevant institutions and jurisdictions; careful coordination from a – preferably – independent, collaborative unit such as ACRIS or TERN; coordinated and effective integration of data and information from existing programs; and adaptive feedback loop to policy and management and adequate, long-term funding (Eyre *et al.* 2011). However, outcomes emerging from a pilot project aimed at testing a broadscale biodiversity monitoring framework suggest that these are not trivial challenges and can wear out the most driven of champions (ACRIS MC pers. comm.).

If Australia is serious about tracking biodiversity condition, then we cannot continue with the status quo, as biodiversity appears to be in decline but we are unable to address why this is or how we can address it effectively (Woinarski and Fisher 2003; Bastin *et al.* 2009; Australian Government 2010; Eyre *et al.* 2011).

Whether a 'deluxe' comprehensive approach to monitoring is undertaken (e.g., Lindenmayer and Likens 2010; Eyre *et al.* 2011), or a 'pragmatic' approach involving the effective integration of existing or previous programs on select indicators in select areas in Australia, an integrated, co-ordinated, and collaborative approach is required. This will enable biodiversity monitoring and reporting in the rangelands to be an integral and consistent part of any proposed national biodiversity monitoring and reporting framework. In this way, stakeholders and decision makers would have the capacity to generate appropriate spatial and temporal biodiversity trend information, thus providing a basis for improving future land management decisions.

Set against this context, the following sections outline the case for a rangelands biodiversity monitoring framework using the following five key questions:

1. What are the key biodiversity information requirements for monitoring? (Section 4)
2. What are the key assets and threats to rangeland biodiversity? (Section 5)
3. What are the gaps in existing rangelands monitoring infrastructure? (Section 6)
4. What are the drivers of change and threats to biodiversity – why, where and how to monitor? (Section 7)
5. What are examples of rangeland biodiversity monitoring initiatives? (Section 8)
6. What are the strategies for promoting and establishing an Australian rangeland biodiversity monitoring program? (Section 9)

4. Key biodiversity data and information requirements

Monitoring initiatives are characterised by the following five benefits described by Possingham *et al*. (2012):

- Learning how ecological systems function and respond to environmental cycles and management actions as part of the adaptive management cycle (cause and effect).
- Communicating to policy makers and the public about long-term ecological changes (trends).
- Choosing management actions that are relevant to changes in the state of the system being monitored.
- Engaging the public in ecological issues to increase effort and support for monitoring and management.
- Uncovering unexpected events, such as threats to biodiversity, serendipitously.

Biodiversity monitoring initiatives in the rangelands are grouped into two broad types:

1. Science-driven monitoring initiatives.
2. Management-driven initiatives.

4.1. Science-driven monitoring initiatives

Many enduring long-term biodiversity monitoring initiatives in the rangelands were initially established as long-term research plots by researchers. Subsequently, most of these initiatives have been integrated into the Long-term Ecological Research Network (LTERN) facility in 2012 (TERN 2013). These initiatives include Chris Dickman and Glenda Wardle's University of Sydney Desert Ecology Group research site in the Simpson Desert (> 20 years); David Keith's University of New South Wales Mallee Plot Network in Tarawi Nature Reserve and the Australian Wildlife Conservancy's Scotia Wildlife Sanctuary in south-west New South Wales (1997); CSIRO's Dan Metcalfe Desert Uplands Plot Network in central Queensland (2004); and Jeremy Russell-Smith of Bushfires NT and Charles Darwin University sites for long-term monitoring of the relationships between fire and carbon in tropical savannas of the Northern Territory (TERN 2013). Most of these programs are ongoing.

One of the longest running monitoring science-policy programs is the kangaroo monitoring program, which is considered one of the most robust and scientifically rigorous fauna monitoring programs in Australia, if not globally (Pople and Grigg 1999; Pople *et al.* 2010). The enduring success of this publicly-funded program is due in part because kangaroos are harvested for commercial purposes and also because of the perception of over-abundance and need for pest control (Woinarski *et al.* 2001).

Another enduring science-policy monitoring program is the use of aerial surveys for monitoring waterbirds in wetlands of eastern Australia that was repeatedly conducted from 1983 to 2004 (Kingsford 1999). Aerial surveys were recently recommenced following the end of the Millennium Drought, because extensive high rainfall events in 2010-2012 over eastern Australia resulted in huge increases in breeding waterbirds over the central and eastern rangelands.

In 2010, the Australian Government funded the development of a consistent scientific approach for establishing a national plot-based research network in the rangelands – AusPlots – as part of the Terrestrial Ecosystem Research Network (TERN) (White *et al.* 2012). Implicitly, the AusPlots initiative acknowledged the deficiencies of the State and Northern Territory plot-based infrastructures for monitoring and reporting key biophysical characteristics (i.e., vegetation and soils within the rangelands). However, the current plant-focus and geographic configuration means that the permanently located, long-term AusPlots sites are far from being representative and comprehensive of the rangeland's biodiversity, especially fauna. These sites have potential to partially contribute to a broader-based program and infrastructure for monitoring and reporting rangeland biodiversity. In addition, the AusPlots infrastructure is only in its formative stage, being established as a baseline against which future monitoring can be conducted and does not have secure long-term funding for reporting of change and trend against that baseline.

4.2. Management-driven initiatives

Australia has a number of management-driven monitoring initiatives linked to state and Commonwealth funded biodiversity management programs. Ten case studies of management-driven initiatives in the rangelands are presented in Section 7. However, these initiatives are primarily *ad hoc* in their design and implementation, for the purpose of a specific goal or goals. Furthermore, they are not comprehensive or wide-ranging.

In 2008, the *Taking the Pulse* report, Bastin and the ACRIS Management Committee (2008) concluded that the available spatial and temporal environmental data was not adequate for the purpose of influencing land managers to change their management practices to improve or enhance the management and conservation of biodiversity. Despite this finding, there has been little industry and government support to establish a consistent national framework for monitoring and reporting of changes and trends in rangeland biodiversity.

To address these deficiencies in biodiversity data from Australia's rangelands, an alternate grouping of monitoring and reporting requirements for biodiversity information in the rangelands was presented by Price and Wardrop (unpublished). This was prepared for the ACRIS Management Committee as part of a business case, calling for the establishment of a national framework for monitoring biodiversity in the Australian rangelands:

1. **Audit and Reporting.** The data are used for regulatory or audit reporting, for example to meet leasehold or licence-to-operate conditions.

2. **Underpin management.** Data are used to evaluate the effectiveness of management activities or expenditures (e.g., for a MERI framework), to support planning and adaptive management through continuous improvement, to assist cultural management, or to develop and test hypotheses about cause and effect relationships (e.g., to provide capacity to predict likely effects of different types and levels of stressors) and to develop lead (rather than lagged) indicators of change.

3. **Identify trends.** Data are used to measure, analyse and identify trends at large spatial or temporal scales that are not due to recent management (e.g., due to climate change or species adaptation).

Price and Wardrop (unpublished) noted that these requirements are not mutually exclusive, where requirement 3 provides the context in which both 1 and 2 are measured and considered . They also observed that these requirements may help in analysing the differing data needs of particular stakeholder groups, and how these requirements could be accommodated within a national system for monitoring rangelands biodiversity that all stakeholder groups can contribute to and in turn draw support and information from.

Table 1. Characteristics of data and information for the three monitoring requirements. (Derived from Price and Wardrop (unpublished)).

	Monitoring requirements		
	Audit and reporting	**Underpin management**	**Long-term trend**
Monitoring Characteristics:			
Area	Small area	Small to medium area	Large area
Resolution	High	High to medium	Low
Frequency	High	Medium	Low
Duration	Short-medium	Medium	Very long
Site location	Areas affected by management*	Areas affected by management*	Areas not affected by management
Indicators	May need to focus on stressors and surrogates	May need to include stressors or surrogates	Focus on direct measurement of Biodiversity

* may need to compare with starting condition of unaffected/reference areas

5. Key assets and threats

The threatening processes and their impact on rangeland condition are well documented, and include: modification of rangelands by clearing native vegetation; excessive total grazing pressure (livestock, kangaroos, feral animals), causing soil erosion and degradation of herbaceous vegetation cover and composition, resulting in a loss of productivity; changes in hydrology and water regimes; introduction of non-native vertebrate pests, such as rabbits (*Oryctolagus spp*.), foxes (*Vulpes vulpes*), cats (*Felis catus*), pigs (*Sus scrofa*), donkeys (*Equus asinus*), goats (*Capra aegagrus hircus*), camels (*Camelus dromedarius*) and cane toads (*Rhinella marinus*); introduction of invasive exotic grasses such as buffel grass (*Cenchrus ciliaris*), and woody weeds such as parkinsonia (*Parkinsonia aculeate*) and prickly acacia (*Acacia nilotica*); climate change; inappropriate fire regimes; disease; mining; hunting; and commercial harvesting of native wildlife (see Whitehead *et al.* 2001).

Past grazing management practices may have changed the state of rangeland landscapes, and in many instances these practices have caused declines in the condition of rangeland ecosystems (Tongway and Hindley 2000; Fitzhardinge 2012). Introduced animals also have exacerbated degradation of rangeland landscapes and costing $100s million, mainly in lost agricultural production (Bomford and Hart 2003). There are approximately 370 noxious weed species in Australia, many of these also occurring in the rangelands and the worst of these have displaced many native species, at a cost to the agricultural industry of several billion dollars per annum (Thorpe 2005). Changes to Aboriginal fire regimes since the introduction of pastoralism has led to hotter fires that occur late spring and summer (Fitzsimons *et al.* 2012). This has caused a loss of biodiversity in some regions, particularly in the tropical savannas (Franklin 1999).

Animal diseases can significantly reduce wildlife populations. A prominent example (although outside the rangelands) is the devil facial tumour disease (DFTD) which has reduced Tasmanian devil (*Sarcophilus harrisii*) populations by more than 60% since its discovery in 1996 (McCallum 2008), demonstrating that wildlife disease can quickly emerge and have significant impacts over short time scales. Animal disease in Australia's rangelands mainly includes parasitism and pathogens that are transmitted through livestock and feral ungulates, and have been suggested as contributors to declines in some rangeland wildlife populations (Tidemann *et al.* 1992; Braithwaite and Griffiths 1994). Catastrophic declines in mammals of Western Australia's rangelands in the 19th Century were likely to be caused by disease (Abbott 2006) and highlights that rangelands wildlife can be vulnerable to disease in some circumstances.

Mining and gas exploration and extraction are economically important activities that threaten the biodiversity of many rangelands such as in Western Australia's Pilbara and Kimberley regions, and central and western Queensland. Mining and gas operations have local direct impacts on biodiversity through habitat destruction and fragmentation, while indirect impacts are wide ranging and include greater presence of humans in wild areas, changes in water regimes and quality, and the introduction of pathogens (Butt *et al.* 2013).

Hunting of native wildlife by Aboriginal people for the use of traditional food, and by recreational hunters, is common in the rangelands. However, monitoring the impact of these activities is limited, particularly in the remotest parts of the rangelands. Commercial harvesting in the rangelands is conducted on native flora and fauna. This includes timber harvesting, and commercial hunting of kangaroos for meat and skins. Currently these are not seen as threats to the biodiversity of the rangelands, however, if the economic pressures increase in rural communities, increasing commercial harvesting operations might be used for economic purposes and will place pressure on biodiversity (Whitehead *et al.* 2001).

6. Identifying gaps in the existing rangeland monitoring infrastructure

The requirement for long-term biodiversity monitoring in Australia's rangelands has long been recognised, and the methods regarding what to measure/observe and how to monitor have been established (e.g., Whitehead *et al.* 2001; Fisher *et al.* 2006; Eyre *et al.* 2011). To date, these efforts have found little or no traction among key stakeholders and as a result these proposals have largely been ignored. Consequently, there is still a significant gap in identifying changes or trends in the rangeland's biodiversity. As a consequence, the ability to effectively use monitoring-based evidence to engage land managers for the purpose of changing land management practices is resrticted, even where land management practices are suspected of having a negative impact on biodiversity.

Monitoring changes to pastoral systems in the rangelands is variously conducted in rangeland jurisdictions to assess whether grazing practices are sustainable. This monitoring was established to inform decision makers about the sustainable use and management of rangeland pastures and their condition, and therefore monitoring for this purpose mainly focuses on changes in the condition of soils and pastures. The current infrastructure for monitoring and reporting of the status of rangeland health varies among the States and the Northern Territory in implementation and effectiveness, and does not include monitoring for changes in biodiversity, especially fauna (Table 2). As it stands, the infrastructure used for pastoral monitoring was purpose built for each jurisdiction, and is not adequate or representative for monitoring and reporting medium to long-term trends in biodiversity across all of Australia's bioregions and land use/land tenure classes.

Table 2. Current status of the infrastructure for pastoral and biodiversity monitoring and reporting in the rangelands.

	Is there a state-wide infrastructure for monitoring and reporting?	
Jurisdiction	**Pastoral**	**Biodiversity**
Western Australia	Yes (Western Australian Rangeland Monitoring System- WARMS), but resourcing is a persistent issue and there is limited evidence that reported results contribute to improved management and administration of pastoral leases.	No. There are some good examples of monitoring projects but these are small in area and number, and are not representative of all biodiversity.
Queensland	Yes, and is used in the Delbesie State Rural Leasehold Land Strategy. Its effectiveness and the role of long-term monitoring is unclear.	No. There are some good examples of monitoring projects but these are small in area and number, and are not representative of all biodiversity.
South Australia	Yes, but monitoring sites do not cover all areas and are infrequently revisited (often up to 14 years).	No. There are some good examples of monitoring projects but these are small in area and number, and are not representative of all biodiversity. Activity is ad hoc for the purpose of answering specific questions.
New South Wales	Yes, but now it has been 'moth-balled' due to lack of funds. There is 25 years of data from 350 sites, but cannot report on trends.	No. There are some good examples of monitoring projects, including a handful of ad hoc long-term study sites, but are not representative of all biodiversity. Heavily reliant on remote sensing.
Northern Territory	Yes, and known deficiencies are being addressed by redesigning the system, including expanded use of remote sensing.	No. There are some good examples of monitoring projects but these are patchy/variable and are not representative of all biodiversity.

7. Drivers of change and threats to biodiversity - why, where and what to monitor

The Australian rangelands are characterised by high spatial complexity, high temporal variability and unpredictable reaction to disturbance (Stafford Smith *et al.* 2000). Drivers of biodiversity change and trend in the rangelands are related to direct and indirect human use and management which influence the vegetation structure, and species composition and regenerative capacity (function) of plant communities. Rangeland management practices influencing the modification of plant communities include pastoralism, altered fire regimes, invasive plants and animals, clearing of native vegetation, mining activities and climate change (Woinarski and Fisher 2003). Thackway and Lesslie (2008) and Thackway (2012) provide practical guidelines for monitoring the effects of land management practices on plant communities and a simple tool for reporting change and trend in management of plant communities. This practical approach includes a hierarchy of key ecological characteristics and indicators that are affected by land management practices representing vegetation structure, species composition and regenerative capacity (function).

Depending on the perspective of the stakeholder, pastoral management of the rangelands may be seen as an aid to conservation of rangeland systems or as a threat (Curtin *et al.* 2002). Experience among rangeland ecologists has shown that parts of the Australian rangelands are inherently prone to land degradation (Stafford Smith *et al.* 2000). McKeon *et al*. (2004) showed a causal association between degradation events in Australia’s rangelands and increased livestock numbers in response to good rainfall years prior to drought. Tongway and Hindley (2000) describe how ecosystems are either robust or fragile in their capacity to resist stress and disturbance that cause desertification and erosion. Rangelands systems are generally fragile in this respect, and therefore management is particularly challenging because these ecosystems do not respond in predictable ways to disturbance. Stafford Smith *et al*. (2000) note that errors of judgement by land managers reflects a lack of information and knowledge regarding the dynamics and fragility of rangeland ecosystems.

Arguably, the lack of a consistent and well-designed national rangelands monitoring system for tracking change and trend in biodiversity is likely to further perpetuate errors of judgement by policy and land management decision makers.

8. A brief overview of rangeland biodiversity monitoring initiatives

This section presents ten case studies that are relevant to monitoring biodiversity outcomes in Australia’s rangelands. These case studies include science-driven and management-driven monitoring initiatives; however, many of these initiatives focus on a single species and only provide limited information about biodiversity. The focus of these case studies is not necessarily monitoring biodiversity *per se*, although one of the outcomes of program monitoring, evaluation, reporting and improvement (MERI) as part of adaptive management is typically a benefit for biodiversity conservation and/or protection.

This section concludes with a brief discussion of the lessons that can be learnt in considering the development of a national infrastructure for monitoring and reporting Australia’s rangeland biodiversity.

8.1. Ten case studies

8.1.1. Improving asset protection through managing feral animals

Australian Feral Camel Management Project

Numbers of camels in the rangelands have been opportunistically monitored for several years because the increasing numbers of feral camels was threatening key ecological and biodiversity values of central Australia.

In response to this problem, the Australian Feral Camel Management Project (AFCMP) commenced in 2010 to reduce the number of feral camels threatening the ecological and biodiversity values of 18 sites that were identified as threatened from high levels of camel damage, and to protect vegetation and soils on pastoral lands over 1.3 million km^2 of the rangelands (Ninti One 2013). The project was a collaboration between the Australian, rangeland State and Northern Territory Governments, Indigenous organisations, NRM groups, the pastoral industry, commercial operators, animal welfare and conservation groups, and research organisations (Ninti One 2013). The project received an initial allocation of $19 million in funding from the Australian Government, which was reduced to $15 million because of operational delays. Despite the delays, approximately 160,000 camels were removed, which met the targets for reducing camel densities (Ninti One 2013).

Several management methods were applied to reduce camel densities, including both aerial and ground based culling and mustering. The project had a Monitoring, Evaluation, Reporting and Improvement (MERI) plan that included monitoring camel populations, and their environmental impacts on vegetation condition and water quality (Ninti One 2013). Camel population monitoring was conducted at sites across the NT, SA, Qld and WA, using a variety of methods, such as motion-activated cameras, and limited aerial surveys, while vegetation and water assessment was conducted by scientists and Indigenous rangers (Ninti One 2013).

The project is considered a success, and managed to account for the broad motivations of pastoral and Indigenous landholders, which often overshadow the environmental issues, by including economic and employment opportunities, plus addressing productivity and cultural priorities (Ninti One 2013). The success of the project is attributed to its clear and transparent governance structure, with strong leadership and effective communication between collaborators, and maintaining a clear focus on feral camel management by not allowing non-camel related issues to jeopardise project discussions and operations (Ninti One 2013). Cross jurisdictional differences were resolved by the use of state/territory operations groups that shared information and could still coordinate cross border culls and surveys (Ninti One 2013).

The AFCMP ran until 31 December 2013, and the final report was released, recommending ongoing support for further camel management.

Photo credit: Robert Sleep, Ninti One 2013

8.1.2. Improving landscape and habitat values through managing invasive species

Bounceback, South Australia

This project was initially conceived in 1991 as a window of opportunity with the impending release of the rabbit haemorrhagic disease (RHD) into the rangelands of South Australia. The Bounceback program commenced in 1992 as a landscape-scale conservation project aimed at protecting and restoring the environment of the semi-arid Flinders, Olary and Gawler Ranges (DEWNR 2013). Bounceback operates in National Parks, Aboriginal land, private properties and pastoral land (Brandle, R. Personal communication).

The key activities of Bounceback include broad-scale (aerial and ground)fox baiting, coordinated goat control involving mustering and shooting, rabbit control, and weed control. The project is designed to reduce predation on native mammals, particularly the yellow-footed rock wallaby (*Petrogale xanthopus*), and to reduce the impact of feral animals and weeds on the environment. Monitoring is conducted to assess the impact of management interventions, and focusses on predators, rabbits and macropods using spotlight surveys along transects. Mark-recapture and helicopter surveys of yellow-footed rock wallabies are conducted, while small vertebrates are monitored within two degraded habitat types. Grazing pressure is also assessed using long-term herbivore exclusion plots and periodic Land Condition Assessments using the South Australian pastoral assessment program methods. Bounceback's achievements include recovering populations of yellow-footed rock wallabies, reductions in the abundance of feral goats, fox and rabbit populations, regeneration of native vegetation, and strengthening links between private and public land managers (Brandle, R. Personal communication).

The success of the program has largely been attributed to the support of partners, including government, and collaborations between landholders, park managers, volunteers and the wider community. The program has been operating for more than 20 years and is ongoing, with plans for future monitoring and research to inform of the level of success across a wider range of taxa and managed areas for longer periods of time (Brandle, R. Personal communication). This information will be used to assess the program's effectiveness and inform on management outcomes on an annual basis.

Photo credit: South Australian Department of Environment and Heritage, 2002

8.1.3. Improving the identification of key assets through regional biological surveys

Lorna Glen, Western Australia

Beginning in 2002, biannual surveys and monitoring of ground-dwelling vertebrates were conducted at Lorna Glen, which straddles the Murchison and Gascoyne bioregions in central Western Australia. The project aims to gain information on the species richness and community structure (Australian Government 2008). The property was shown to support one of the highest levels of floristic and fauna diversity in Australia's arid zone, including 480 plants and 220 vertebrate species (Australian Government 2008). Long-term monitoring is required to understand the temporal dynamics of ecological communities represented.

Lorna Glen is a 244,000 hectare former pastoral station that was purchased by the WA government in 2000 and is currently being formally set aside as a conservation park (Australian Government 2008). Management actions have included the closure of artificial water points, destocking, and the erection of stock-proof fences on the boundaries, with the purpose of reducing total grazing pressure (Australian Government 2008). Furthermore, feral cat numbers have been significantly reduced through baiting, reducing the predation pressure, and allowing fauna species to be reintroduced (Australian Government 2008).

Management of Lorna Glen is conducted by the Western Australian Department of Parks and Wildlife, and the Ngaanyatjarra Native Title claimants from the Wiluna area (Australian Government 2008). The current adaptive management and operational monitoring is designed to run until 2020, and includes continuing and expanded biosecurity evaluation, feral animal control, fire management, and reintroductions of fauna (Australian Government 2008).

Photo credit: Government of Western Australia, Department of Parks and Wildlife

8.1.4. Improving multiple benefit outcomes through fire management, Northern Territory

The West Arnhem Land Fire Abatement Project, Northern Territory

The West Arnhem Land Fire Abatement Project (WALFA) is a large-scale fire management program across 28,000 km^2 of western Arnhem Land (Fitzsimons *et al.* 2012). It is a partnership between the Aboriginal Traditional Owners and Indigenous ranger groups, ConocoPhillips oil and gas company, the Northern Territory Government and the Northern Land Council.

The project has been in development since 1996 from a regional approach that integrates fire management across many Indigenous groups in western Arnhem Land, and was prompted by the recognition that the prevailing fire regime was highly detrimental to the environment (Russell-Smith *et al.* 2009). The fire regime in the region had shifted from early and mid-dry season burns that were part of traditional management in the region, , to hot late-dry season burns that were relatively hotter and increasing in frequency (Fitzsimons *et al.* 2012). The changes in fire timing and frequency were deemed to have negative effects on biodiversity, and were also found to be emitting significant greenhouse gas emissions, such as carbon (Fitzsimons *et al.* 2012). Between 2005 and 2010, there was a reduction of up to 50% in greenhouse gas emissions. In 2006 an innovative greenhouse gas offset agreement was formed, where emissions were traded with industry partners to fund the continuing of the WALFA project. This funding has aided the social benchmarking and biodiversity monitoring for the project, , delivering both social and ecological benefits to the local community (Fitzsimons *et al.* 2012).

The WALFA program demonstrates that carbon-based investment in Indigenous fire management can deliver substantial and tangible social, economic and environmental benefits, and consequently, similar agreements to the WALFA model have been considered or introduced in other regions in northern Australia.

Photo credit: Jawoyn Association (http://www.jawoyn.org/land-management/controlled-burning)

8.1.5. Improving multiple benefits outcomes through fire management, Western Australia

Kimberley EcoFire, Western Australia

The Kimberley EcoFire project is run by the Australian Wildlife Conservancy (AWC) and funded by the Federal and Western Australian Governments to address the problem of high intensity mid to late dry-season fires (Australian Wildlife Conservancy). The expected outcomes of reducing these fires is improved biodiversity protection and pastoral production, and to limit damage to cultural sites (Australian Wildlife Conservancy).

The project commenced in 2007 with initial burns covering 2,400,000 hectares, and by 2008 this area was increased by almost 5 million hectares, including private pastoral and Indigenous properties and the AWC managed wildlife sanctuaries of Mornington and Marion Downs (Australian Wildlife Conservancy). Project partners include the Western Australia Government through its Fire and Emergency Services Authority, Department of Agriculture and Food, and the Kimberley Land Council (Legge *et al.* 2009). The change in fire patterns has modified the spatial patterns of vegetation and frequency of fire, with an increase in spatial and temporal heterogeneity of vegetation (Legge *et al.* 2009).

The success of the EcoFire project has been attributed to effective engagement with the local community in fire management, with support from multiple-stakeholders and organisations over large spatial scales. Continued support for Ecofire is an important deliverable of the Kimberley Science and Conservation Strategy (Government of Western Australia 2013).

Photo credit: Australian Wildlife Conservancy

8.1.6. Improving multiple benefits outcomes through Indigenous Protected Areas (IPAs)

Birriliburu, Western Australia

Indigenous Protected Areas (IPAs) is a program funded by the Australian Government through the Caring for Country program, and aims to support Indigenous land owners to develop and manage protected areas on their lands using traditional ecological and cultural knowledge, as part of Australia's National Reserve System (NRS) (Australian Government).

Currently there are 42 IPAs, covering 24 million hectares across Australia, representing 23% of the NRS. Birriliburu is one such IPA in central Western Australia, and is managed by the Martu people, who are the Birriliburu native title holders. The Birriliburu IPA covers a region of 6.6 million hectares straddling the former Canning Stock Route that crosses central Western Australia's Little Sandy Desert, Great Sandy Desert and the Gibson Desert. Several groups, including Rangelands NRM, Central Desert Native Title Services (CDNTS), the Martu community group Kanyirninpa Jukurrpa (KJ), and the Western Australian Department of Parks and Wildlife (DPW), are collaborating to integrate traditional knowledge and science for the purpose of protecting biodiversity in the Birriliburu IPA (Rangelands NRM WA 2013). The bilby (*Macrotis lagotis*) is one of the main species that requires monitoring, and indigenous rangers are a key component of monitoring activities (Rangelands NRM WA). Monitoring and maintaining traditional waterholes are another task that is critical to the ecological and cultural management of the Birriliburu IPA (Rangelands NRM WA 2013).

Photo credit: Australian Government, Department of the Environment (http://www.environment.gov.au/indigenous/ipa/declared/birriliburu.html)

8.1.7. Improving recovery of endangered species through mining offsets

Northern quolls in the Pilbara, Western Australia

The Pilbara region of north-west Western Australia has abundant mineral deposits, including one of the largest iron ore deposits on Earth. Many mining companies have claims in the region, which have significant impacts on local biodiversity. One species that occurs in the region is the northern quoll (*Dasyurus hallucatus*), which is a carnivorous marsupial species listed as endangered under the federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), critically endangered under the Northern Territory's Territory Parks and Wildlife Conservation Act 2000, and is considered rare or likely to become extinct under the Western Australian Wildlife Conservation

Act. Though once widespread, it now occurs in small disjunct populations across north-western Australia due to habitat destruction, predation by feral cats and foxes, poisoning by cane toads, changes in fire frequency and intensity (Australian Government 2005). Mining is a major contributor to habitat destruction, particularly in the Pilbara, and a northern quoll monitoring program has been implemented by using funds gained from mining companies (Atlas Iron 2012). Mining is a major contributor to habitat destruction, particularly in the Pilbara, and mining companies represent a potentially important source of funds for biodiversity monitoring, particularly if they are linked to biodiversity offset programs.

Photo credit: Outback Ecology (http://www.outbackecology.com/index.php?option=com_content&view=article&id=92:monitoring-endangered-northern-quolls-in-the-pilbara&catid=1:news&Itemid=5)

8.1.8. Improving eco-tourism through regional landscape management partnerships

Kimberley Science and Conservation Strategy, Western Australia

The Kimberley Science and Conservation Strategy was released in June 2011, and is designed to establish a system of interconnected marine and terrestrial reserves coving more than 3.5 million hectares, known as the Kimberley Wilderness Parks; manage fire and introduced weeds and animals at the landscape-scale; create employment opportunities for local Aboriginal rangers; invest in the scientific and cultural knowledge, and make the information widely accessible; and create significant nature-based ecotourism opportunities in the region (Government of Western Australia 2011). The program had an initial budget of $63 million for five years, and was increased to $80.5 million in 2013 (Government of Western Australia 2013). The program plans to use outcome-focused adaptive management, based on landscape-scale conservation of biodiversity, to enhance ecosystem reliance and scientific knowledge in the region (Government of Western Australia 2011). The strategy is developing a new approach in the north Kimberley through collaborative action with land managers at a landscape scale to manage fire and to address the threats posed by introduced animals and weeds, which extend across property boundaries.

Photo credit: Government of Western Australia, Department of Environment and Conservation

8.1.9. Improving species conservation through citizen science

Bird Atlas

Watching and recording birds has a long history of private and community interest and engagement in Australia and internationally. Citizen science is where members of the non-scientific community engage in monitoring activities, and is becoming more common because of an increased interest in scientific activity and inadequate funding of scientific monitoring programs (Tulloch *et al.* 2013). One of the largest and most successful citizen science programs is the Birdlife Australia's Atlas and Birdata resources, which has run since 1998 (Birdlife Australia 2014). The Atlas allows observers the option to use a number of different standardised survey techniques, including two hectare timed searches, fixed-route monitoring, area searches, and incidental reports (Birdlife Australia 2014). Weston *et al*. (2006) reported that approximately 9000 volunteers were contributing to the Atlas, and that the project has led to an increase in the survey skills of participants. While citizen science programs are rarely used for management purposes, because management requires more detailed habitat information and includes issues such as scale, they can be useful for monitoring change in management regimes (Tulloch *et al.* 2013). The Birdlife Atlas is cited regularly by the scientific community in universities and government departments, but is also accessed by environmental consultants, non-governmental organisations, affiliated groups and projects, and corporate entities (Dunn and Weston 2008).

Photo credit: Andrew Smith

8.1.10. Improving landscape productivity through weed control

Weeds of National Significance (WONS) – Pilbara mesquite management committee (PMMC)

There are over 200 weed species that have been identified as causing significant economic and environmental damage in Australia (Thorp and Lynch 2000). The WONS program was established in 1999 to deal with 20 weed species that were considered to be a threat to primary industry, land management, human or animal welfare, and biodiversity conservation, with an additional 12 species added to the list in 2012 (Weeds Australia 2012). The Pilbara mesquite management committee was established in 2000 to control mesquite (*Prosopis spp*.) (CSIRO), an invasive introduced legume that has large thorns, is long lived, is adapted to hot and dry conditions, reproduces readily, has no natural predators in Australia , and has the ability to spread over large areas of grazing land (Queensland Department of Natural Resources and Mines 2003). The PMMC received funding from WONS and conducted research to determine the effectiveness of fire to manage mesquite; improve management of infestations; optimise the impact of biological controls; and raise awareness and participation in mesquite management at a regional and national scale (CSIRO).

Photo credit: (Queensland Department of Natural Resources and Mines 2003)

8.2. Evaluation of current monitoring programs

The public-private funded programs outlined above show that successful biodiversity monitoring has been, or still is, conducted in the rangelands. However, these initiatives are limited in their focus and geographic extent, without reference to an overarching strategic biodiversity monitoring and reporting framework. What these programs do demonstrate is that conducting successful biodiversity monitoring is achievable. The critical factors that contributed to the success of each program include: setting out to achieve a specific goal(s), have strong government support, and involve industry and Indigenous stakeholders, and the wider community. Gaining support requires explicit and achievable goals that are recognised as worthy causes, such as invasive species management or Indigenous conservation programs, or stimulate the interest of sections of the community, such as birdwatchers taking part in the Bird Atlas.

Once support for a program is gained, it must be maintained. Strong and clear leadership and communication are critical for continued support by governments, other stakeholders, and the community. For example, the Australian Feral Camel Management Project (AFCMP) demonstrated that combined strong leadership and communication, with the strict focus on camel-related issues only between partners during discussions and operations, leads to successful project implementation and support. The ability to demonstrate visible results to the community also has allowed several programs to maintain support, such as Bounceback, WALFA and Kimberley EcoFire. Furthermore, programs that have an important social context by involving local communities, such as at Lorna Glen and the Indigenous Protected Areas, are successful because they engage communities directly in conservation management, which not only gives them a sense of ownership of the program, but allows personal observation of the program's outcomes. Community support is enormously important to the continuation of a project where gaining the help of interested groups who volunteer their time to contribute to a project is critical, such as with the bird Atlas.

Continued support from government and industry for some of these programs is not guaranteed, even when the program is considered a success. Conversely, it may be appropriate to recognise that there may also be a need for a stop-point for some monitoring projects: there should not be an inbuilt expectation of ad infinitum; rather, a reasonable pre-defined review period, and staged objectives. Therefore, program leaders must not only demonstrate that the program is meeting the expected outcomes, but they must also demonstrate that the program is still relevant in the future. For example, the AFCMP was completed at the end of 2013; however, Ninti One (2013) demonstrate there is still a need to control and manage feral camels, and consequently they argue that funding be made available for the continuation of the project. Like the feral animal control programs, WONS receives critical funding and support from government and industry because the known ecological and economic risks of several invasive plant species to the pastoral industry are too great if they are not dealt with at the appropriate scale. Projects such as WALFA and Kimberley EcoFire demonstrate that changes in fire regimes not only prevent hot late dry season wildfires, but they also have biodiversity benefits, including increased spatial and temporal heterogeneity of vegetation communities. Projects such as these are achieving their goals, but on-going support is required to maintain and build on local and region capacity where it is already in place. It is important to note that this applies for any future biodiversity monitoring program.

Gaining long-term industry funding to supplement government funding appears to be critical for several projects. Mineral and energy resource exploration and extraction can have negative effects on the environment and many companies look for partnerships to offset damage to the environment and/or to manage landscapes in areas where resource extraction is conducted. For example, the WALFA project has an important offset agreement with the local gas industry, which has become an important source of funding, because they could demonstrate that changes in fire management would reduce greenhouse gas emissions from wildfires in Arnhem Land. In the Pilbara, mining for iron ore supports critical funding of scientific research into northern quoll populations which would otherwise have restricted funding opportunities.

Biodiversity monitoring across the rangelands can draw on a number of key points from these successful examples, where long-term success and support requires successful integration with stakeholders, where it is critical to secure and maintain partnerships. The problem is that examples of 'successful' monitoring are disparate at the national scale and localised, and report on questions specific to their program. What we need is the 'big picture' question to be addressed regarding biodiversity and its decline – and clarification of the questions, and appropriate scale of reporting.

8.2.1. Inability to clarify the impacts of land use and management

One key barrier for establishing a rangeland biodiversity monitoring system is that rangeland biodiversity is characterised by complex biological and physical patterns and processes that are occurring at a range of spatial and temporal scales. These ecological patterns and processes are highly heterogeneous, occur over very large areas, and are linked to 'boom and bust' pulses that respond to highly variable rainfall patterns in the central and southern rangelands (Stafford Smith *et al.* 2000), and wet and dry seasons in the tropical north. Rangeland biodiversity is therefore highly variable, both spatially and temporally. It is widely acknowledged that long-term spatial and temporal patterns of productivity in the rangelands are much lower compared to other more mesic systems (e.g., temperate pastoral systems). This also is partly due to soils having inherently low fertility in many rangelands landscapes. Consequently, a range of thematic data needs to be collected over large spatial scales and maintained for long periods of time (Table 1), and a monitoring program in the arid and semi-arid rangelands should span many years, in order to tease signal from noise.

Attempts to raise and answer key questions regarding any negative impacts of the various land use sectors in the rangelands, including the requirement for a consistent national biodiversity monitoring and reporting infrastructure, have not been supported and funded by government and industry stakeholders, either inside or outside the rangelands. The greatest challenge in developing a biodiversity monitoring and reporting framework will be gaining the support and agreement of these and other stakeholders with a view to engaging them as equal players in the design, establishment and maintenance of a rangeland monitoring and reporting infrastructure.

8.2.2. How to define what is sustainable use and management?

Pastoralism has contributed significantly to the economy of the rangelands but is under increasing market, environmental and economic pressures because product quality, production and ecological sustainability, and water-resource issues, are challenging aspects of livestock production. The revenue base of pastoralism is relatively low compared to mining and tourism. Mining and tourism in the rangelands collectively contribute about 2.8% to Australia's gross domestic product (GDP). This contrasts with pastoralism, which in 2000–01 contributed gross revenue of $1.8 billion, or about 0.2%, to GDP (NLWRA 2001). Given this contribution to GDP it is questionable whether the pastoral industry should be asked to bear a large share of the cost of establishing and maintaining a biodiversity monitoring infrastructure.

Ultimately, the development of a long-term rangeland biodiversity monitoring framework will involve a trade-off between public and private benefit. Stafford Smith *et al*. (2000) commenting on sustainability issues affecting the pastoral industry noted that this is a complex issue which varies regionally, nevertheless some general observations were made:

- Rangeland ecosystems vary in management risk and susceptibility to damage resulting from inappropriate land management.
- Economically optimum production may not always support the long-term regional sustainability of ecosystems and processes.
- Low-productivity environments will only support a modest investment in restoration.

Arguably, to evaluate whether the use of rangelands is tracking sustainably in space and time, and assessing progress on these issues in the long-term requires the development of a rangeland biodiversity monitoring framework.

8.2.3. Perceived duplication of existing monitoring systems

The States and Northern Territory have variously established long-term, plot-based systems for monitoring and assessing the impacts of pastoralism on rangeland function and productivity. While these jurisdictional infrastructures are generally suitable for their original purposes, they represent an inappropriate basis for developing a national standardised monitoring and reporting framework for tracking changes and trends on biodiversity. In addition, it is worth noting that these disparate jurisdictional infrastructures have not been developed using a standardised national set of criteria or guidelines, thus hindering consistent national reporting. In fact, in some states and the Northern Territory, evaluations of these plot-based monitoring systems for assessing rangeland function and productivity monitoring programs have raised questions of their value and relevance for meeting multiple-purpose needs for information on the condition of rangeland ecosystems and resources, including biodiversity (Rob Lesslie pers. comm.). However, the participants at the rangelands biodiversity monitoring workshop observed that many sponsoring and/or funding agencies believe that developing a rangelands-wide biodiversity monitoring program would be tantamount to duplication and competition with other monitoring resources.

9. Strategies for promoting and establishing an Australian Rangeland Biodiversity Monitoring program

Managing rangelands presents many difficulties because they are spatially and temporally highly variable systems (Ash and Stafford Smith 2003), and management not only requires information on how systems are functioning, but also on where and when change is occurring (Bastin *et al.* 2009). Current monitoring follows a disaggregated model that is underfunded and *ad hoc* in execution, resulting in inadequate data that fails to inform rangelands management decisions at broad scales. While many current monitoring and management programs are highly important for the specific purpose each was designed for, the danger in continuing to rely on data collected from *ad hoc* programs for rangeland-wide management could result in declines in ecosystem condition and biodiversity that go undetected, or are detected too late with no ability to report on the cause.

There are opportunities to collaborate with TERN's new Ecosystem Science initiative and also AusPlots; however past experience has shown that biodiversity monitoring, especially fauna, is not a TERN priority. It is worth noting that recent developments by TERN regarding the availability of key spatial and temporal data infrastructure provides rangeland decision makers with unprecedented access to information at a higher resolution, including fire frequency and extent, projective foliage cover and bare ground indices. These data will provide important context for analysing broader changes and trends in rangeland biodiversity and comparing the rangelands to more mesic landscapes. It also should be noted that it is often impossible to detect fine-scale changes in biodiversity from remotely sensed time series images. Furthermore, the imagery requires calibration and validation via access to high quality representative ground-based monitoring sites, such as proposed in this discussion paper. Many of these patterns are associated with different expressions of land use and management practices. Remote sensing and GIS data sets are no substitute for developing a detailed understanding of biodiversity in space and time.

To address these gaps, Eyre *et al.* (2011) have outlined the requirement and model for a well-designed and comprehensive monitoring system which avoids many of the failures of previous monitoring programs by setting relevant questions and appropriate design, for the purpose of informing management decisions. The gaps in current monitoring demonstrate that there is an opportunity for a rangelands biodiversity monitoring program that could be part of an Australia-wide program. Such monitoring would be nationally driven and ACRIS' structure makes it a likely candidate to provide expert advice on its formation and operation, with following tasks of cross-jurisdictional data collation, analysis, synthesise, and of change/trend to stakeholder groups. The ACRIS Management Committee should promote the design and implementation of an Australian rangeland biodiversity monitoring program that:

- Detects spatial and temporal changes to rangeland ecosystems and biota;
- Informs and prioritises management actions, including identifying the critical points at which interventions are required;
- Detects the benefits of management actions, which is a critical step in adaptive management;

- Reports regularly to managers of monitored lands and makes all relevant data readily accessible to interested parties;
- Can flexible scale up and down from national overviews to individual landholdings; and
- Provides a model that is appropriate for roll out to a national biodiversity monitoring program.

Three options and their advantages and disadvantages are outlined in Table 3.

Table 3. Advantages and disadvantages of three options for rangeland biodiversity monitoring.

Type of monitoring program	Advantages	Disadvantages
Status quo disaggregated ad-hoc individual monitoring programs/projects	• Easy and convenient for researchers and managers to operate in isolation • Capacity to meet monitoring and evaluation requirements of existing programs/projects • Minimal disruption to localised *modus operandi* i.e. local, regional and state level: standards, information systems, analyses and reporting • Requires no new resources for coordination, integration and synthesis • Requires minimal innovation and collaboration.	• Ability to answer emerging questions raised by management and research is very limited, particularly at the rangeland-wide level • Current rangeland *post hoc* rangeland-wide reporting via snap-shot status reports produces uncertain ecological change and trend because comparing results from different methods over time • Lack of coordination between programs/projects leads to reinventing the wheel and duplication of high cost natural resource information management systems • Costly and tedious to integrate / synthesise findings across diverse programs/projects because of a lack of development and adoption of national coordinated standards • Lack of economies of scale between research

		and management agencies across jurisdictions • Cannot give an authoritative account for 'cause and effect' and demonstrate with evidence patterns due to natural environmental variability, climate change and/or land management practices
Retrofitted existing rangeland-wide monitoring infrastructure (e.g. AusPlots and LTER sites or key state sites) by implementing a designed, staged a Rangeland Biodiversity Monitoring program which focuses on the establishment of a small number of sites. Use these sites to trial new fauna monitoring technologies.	• Pragmatic and achievable in short time frame at relatively low cost • Could be expanded into larger program as more resources become available • Can utilise existing programs/project infrastructure to make rapid progress on a narrow set of research and management questions • A middle of the road cost solution - can make use of existing information, analyses and reporting requiring low set-up costs	• Ability to answer emerging questions raised by management and research is limited, particularly at the rangeland-wide level, because of existing rigid design of many programs/projects • Risk of sending mixed messages i.e. 'only doing half the job and badly at that'; because fails to detect rangeland-wide trends • Cannot give an authoritative account for 'cause and effect' and demonstrate with evidence patterns due to natural environmental variability, climate change and/or land management practices
Gold-plated adaptive monitoring comprehensive, adequate and representative system across the entire rangelands; linked to remote sensing, and coordinated national monitoring of plant and fauna and other biophysical data	• Provides a repeatable and scientifically defensible monitoring framework for detecting real change and trends in rangeland biodiversity • Provides a baseline from which to discover previously unknown ecological patterns and processes • Provides opportunities to achieve economies of scale between research and management agencies across jurisdictions and internationally	• Expensive and difficult to get funding partners to invest in setting-up long-term programs • Politically not realistic in current fiscal environment • Requires national coordination of programs/projects i.e. standards, research and management questions, information systems,

	• Is driven by flexible statistical design and tractable questions enabling new information to emerge as management and research questions change • Encourages the development of an appropriate experimental design to underpin an adaptive monitoring program • Provides greater veracity to explain observed ecological change and trend because results come from the same consistent methods over time • Can generate an authoritative account for 'cause and effect' and demonstrate with evidence patterns due to natural environmental variability, climate change and/or land management practices	analyses and reporting • Recurrent funding of long-term monitoring has high levels of uncertainty due to political cycle linked to three year funding cycles • Requires a partnership model to enable fair and equitable buy-in and sharing of, and ownership in, the inputs and outputs and outcomes

10. Conclusions

1. Reporting timely data and information on changes and trends in rangeland biodiversity is an essential part of the management process.
2. Monitoring can do more than track biodiversity decline. It is an integral step in good and cost-effective conservation, it allows or timely warning and the establishment of early and cost-effective interventions that forestall or reverse declines.
3. It is critical to reliably informing key decisions made about how the rangelands are used and managed at national and regional scales and enabling corrective action to be identified and interventions taken, tracked and reported as required. The results of these interventions, seen as trends relative to a baseline or reference state, add to our store of knowledge and are available to support further decision making.
4. At present, the absence of a consistent national rangeland monitoring and reporting framework means decision-makers are unable to build such a knowledge base and in turn influence on-ground management and biodiversity conservation outcomes.
5. If a national rangeland biodiversity monitoring system is not developed and implemented, the *status quo* will likely prevail, where reporting will be based on data

sourced from short-term and *ad hoc* monitoring programs, or spuriously relevant information (e.g., number of species recovery plans, or the extent of the national reserve system. Data from such programs have been found to be inadequate for management decisions, which will likely compromise the condition of rangeland ecosystems and cause a further decline in biodiversity.

6. The lack of comprehensive and reliable spatial and temporal data and information about changes and trends in flora, fauna and ecosystems poses significant risks to government policy and programs. These risks include financial risks through late recognition and ineffective management response to emerging issues, and insufficient data to provide the impetus to embrace adaptive management and predictive capability.
7. A systematic long-term biodiversity monitoring program needs to be designed so as to avoid many of the failures of previous monitoring programs. This includes setting relevant questions and an appropriate design, for the purpose of informing management decisions, integrated with information about the broader landscape. ACRIS has already made important progress in designing such a systematic program.
8. New investment of effort and resources is required to engage key stakeholders in the rangelands, to seek and gain commitments of resources to enable change and trends in key biodiversity assets (i.e. flora, fauna and ecosystems) to be detected and quantified in space and time in our rangelands.

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13. Appendix - Threatened species occurring in the rangelands, with their jurisdictional listing status

Genus, Species, sub species	Common name	Category	EPBC Act	Qld	NSW	SA	WA	NT
Bidyanus bidyanus	silver perch, bidyan	Fish	CE		V	E		
Saccolaimus saccolaimus nudicluniatus	bare-rumped sheathtail bat	Mammal	CE	E				
Chlamydogobius micropterus	Elizabeth Springs goby	Fish	E	E				
Macquaria australasica	Macquarie perch	Fish	E		E			
Scaturiginichthys vermeilipinnis	redfin blue eye	Fish	E	E				
Bellatorias obiri	Arnhem Land Egernia	Reptile	E					E
Egernia stokesii badia	western spiny-tailed skink, Baudin Island spiny-tailed skink	Reptile	E				V	
Elseya lavarackorum	gulf snapping turtle	Reptile	E	V				
Liopholis slateri slateri	Slater's skink, floodplain skink	Reptile	E					E
Lucasium occultum	yellow-snouted gecko	Reptile	E					V
Botaurus poiciloptilus	Australasian bittern	Bird	E		E	V	E	
Epthianura crocea tunneyi	yellow chat (Alligator Rivers)	Bird	E					E
Erythrura gouldiae	Gouldian finch	Bird	E	E				V
Melanodryas cucullata melvillensis	hooded robin (Tiwi Islands)	Bird	E					CE
Manorina melanotis	black-eared miner	Bird	E		CE	E		
Neochmia ruficauda ruficauda	star finch (eastern & southern)	Bird	E	E				
Pezoporus occidentalis	night parrot	Bird	E	E	EXT	E	CE	CE
Poephila cincta cincta	black-throated finch (southern)	Bird	E	E	E			
Psephotus chrysopterygius	golden-shouldered parrot	Bird	E	E				
Rostratula australis	Australian painted snipe	Bird	E	V	E	V	E	V
Turnix olivii	buff-breasted button-quail	Bird	E	V				
Tyto novaehollandiae melvillensis	masked owl (Tiwi Islands)	Bird	E					E
Bettongia penicillata ogilbyi	woylie	Mammal	E			R	CE	
Dasyurus hallucatus	northern quoll	Mammal	E				E	CE
Hipposideros semoni	Semon's leaf-nosed Bat, greater wart-nosed horseshoe-bat	Mammal	E	E				V
Lagorchestes hirsutus unnamed subsp.	mala, rufous hare-wallaby (central mainland form)	Mammal	E				E	
Lasiorhinus krefftii	northern hairy-nosed wombat, yaminon	Mammal	E	E	EXT			
Notoryctes caurinus	karkarratul, northern marsupial mole	Mammal	E				E	

Notoryctes typhlops	itjaritjari, southern marsupial mole, yitjarritjarri	Mammal	E			V	E	V
Onychogalea fraenata	bridled nail-tail wallaby	Mammal	E	E	EXT			
Perameles bougainville bougainville	western barred bandicoot (Shark Bay)	Mammal	E				E	
Rhinolophus philippinensis (large form)	greater large-eared horseshoe bat	Mammal	E	E				
Sminthopsis douglasi	Julia Creek dunnart	Mammal	E	E				
Sminthopsis psammophila	sandhill dunnart	Mammal	E			V	E	
Zyzomys palatalis	Carpentarian rock-rat, aywalirroomoo	Mammal	E					CE
Zyzomys pedunculatus	central rock-rat, antina	Mammal	E				CE	E
Croitana aestiva	desert sand-skipper, aestiva skipper	Invertebrate	E					E
Euploea alcathoe enastri	Gove crow butterfly	Invertebrate	E					E
Mesodontrachia fitzroyana	Fitzroy land snail	Invertebrate	E					CE
Semotrachia euzyga	a land snail	Invertebrate	E					E
Sinumelon bednalli	Bednall's land snail	Invertebrate	E					E
Chlamydogobius squamigenus	Edgbaston goby	Fish	V	E				
Maccullochella peelii	Murray cod	Fish	V					
Mogurnda clivicola	Flinders Ranges mogurnda, Flinders Ranges purple-spotted gudgeon	Fish	V			CE		
Pristis pristis	largetooth sawfish, freshwater sawfish, river sawfish, Leichhardt's sawfish, northern sawfish	Fish	V					
Litoria raniformis	growling grass frog, southern bell frog, green and golden frog, warty swamp frog	Frog	V		E	E		
Acanthophis hawkei	plains death adder	Reptile	V					V
Anomalopus mackayi	five-clawed worm-skink, long-legged worm-skink	Reptile	V	E	E			
Aprasia pseudopulchella	Flinders Ranges worm-lizard	Reptile	V					
Ctenophorus yinnietharra	yinnietharra rock-dragon	Reptile	V				V	
Ctenotus angusticeps	Airlie Island Ctenotus	Reptile	V				V	
Ctenotus zastictus	Hamelin Ctenotus	Reptile	V				V	
Denisonia maculata	ornamental snake	Reptile	V	V				
Egernia rugosa	yakka skink	Reptile	V					
Egernia stokesii badia	western spiny-tailed Skink, Baudin Island spiny-tailed Skink	Reptile	V				V	
Lerista vittata	Mount Cooper striped Lerista	Reptile	V	V				
Liasis olivaceus barroni	olive python (Pilbara subspecies)	Reptile	V				V	

Liopholis kintorei	Great desert skink, tjakura, warrarna, mulyamiji	Reptile	V				V	V
Ophidiocephalus taeniatus	bronzeback snake-lizard	Reptile	V			R		E
Amytornis barbatus barbatus	grey grasswren (Bulloo)	Bird	V	R	E	R		
Amytornis modestus	thick-billed grasswren	Bird	V		CE			
Erythrotriorchis radiatus	red goshawk	Bird	V	E	CE		V	V
Falcunculus frontatus whitei	crested shrike-tit (northern), northern shrike-tit	Bird	V					NTD
Geophaps scripta scripta	squatter pigeon (southern)	Bird	V	V	E			
Geophaps smithii blaauwi	partridge pigeon (western)	Bird	V				V	
Geophaps smithii smithii	partridge pigeon (eastern)	Bird	V					V
Leipoa ocellata	malleefowl	Bird	V			V	V	CE
Malurus coronatus coronatus	purple-crowned fairy-wren (western)	Bird	V				E	V
Malurus leucopterus leucopterus	white-winged fairy-wren (Dirk Hartog Island), Dirk Hartog black-and-white fairy-wren	Bird	V				V	
Neochmia phaeton evangelinae	crimson finch (white-bellied)	Bird	V	E				
Pachycephala rufogularis	red-lored Whistler	Bird	V		CE	R		
Pedionomus torquatus	plains-wanderer	Bird	V	V	E	E		
Polytelis alexandrae	princess parrot, Alexandra's parrot	Bird	V			V		V
Polytelis anthopeplus monarchoides	regent parrot (eastern)	Bird	V		E	V		
Polytelis swainsonii	superb parrot	Bird	V		V			
Tyto novaehollandiae kimberli	masked owl (northern)	Bird	V	V				V
Bettongia lesueur lesueur	burrowing bettong (Shark Bay), boodie	Mammal	V				V	
Conilurus penicillatus	brush-tailed rabbit-rat, brush-tailed tree-rat, pakooma	Mammal	V				V	E
Dasycercus cristicauda	crest-tailed mulgara	Mammal	V	V	EXT	E	V	V
Dasycercus byrnei	kowari	Mammal	V	V		V		
Isoodon auratus auratus	golden bandicoot (mainland)	Mammal	V		EXT	E	R	
Leporillus conditor	wopilkara, greater stick-nest rat	Mammal	V		EXT	V	V	
Macrotis lagotis	greater bilby	Mammal	V	E	EXT	V	V	V
Mesembriomys macrurus	golden-backed tree-rat, koorrawal	Mammal	V				V	CE
Myrmecobius fasciatus	numbat	Mammal	V		EXT	E	V	EXT
Notomys aquilo	northern hopping-mouse, woorrentinta	Mammal	V	V				V
Notomys fuscus	dusky hopping-mouse, wilkiniti	Mammal	V	E	E	V		E

Nyctophilus corbeni	south-eastern long-eared bat	Mammal	V	V	V	V			
Petrogale lateralis MacDonnell Ranges race	warru, black-footed rock-wallaby (MacDonnell Ranges race)	Mammal	V			E	V		
Petrogale lateralis West Kimberley race	black-footed rock-wallaby (West Kimberley race)	Mammal	V				V		
Petrogale lateralis lateralis	black-flanked rock-wallaby	Mammal	V				V		
Petrogale xanthopus xanthopus	yellow-footed rock-wallaby (SA and NSW)	Mammal	V		V	V			
Phascogale pirata	northern brush-tailed Phascogale	Mammal	V					E	
Phascolarctos cinereus	koala	Mammal	V		V				
Pseudantechinus mimulus	Carpentarian Antechinus	Mammal	V					NTD	
Pseudomys australis	plains rat, palyoora	Mammal	V	E	EXT	V	V	E	
Pseudomys fieldi	Shark Bay mouse, djoongari, Alice Springs mouse	Mammal	V			E	V	EXT	
Pteropus conspicillatus	spectacled flying-fox	Mammal	V						
Rhinonicteris aurantia (Pilbara form)	Pilbara leaf-nosed bat	Mammal	V						
Sminthopsis butleri	Butler's dunnart	Mammal	V				V	V	
Xeromys myoides	water mouse, false water rat, yirrkoo	Mammal	V	V					
Zyzomys maini	Arnhem rock-rat, Arnhem Land rock-rat, kodjperr	Mammal	V					V	
Idiosoma nigrum	shield-backed trapdoor spider, black rugose trapdoor spider	Invertebrate	V				V		

CE = Critically Endangered; E = Endangered, V = Vulnerable; EXT = Extinct; NTD = Near threatened; R = Rare

Information on listings obtained from the Australian Government Department of the Environment EPBC Act List of Threatened Fauna - http://www.environment.gov.au/cgibin/sprat/public/publicthreatenedlist.pl#mammals_critically_endangered