Review of total grazing pressure management issues and priorities for biodiversity conservation in rangelands:

A resource to aid NRM planning

Final Report
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A report to the Australian Government Department of Environment and Heritage prepared by the Desert Knowledge Cooperative Research Centre

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Helping Communities Helping Australia
An Australian Government Initiative

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Contents

1. SUMMARY 8

1.1. Why is managing TGP important for natural resource management? 8

1.2. What is the potential impact of poor management of TGP on the environment? 8

1.3. Report objectives 8

1.4. Report methods and production 9

1.5. Grazing land management zones 9

1.6. Review of previous work relating to TGP management 9

1.7. Review of TGP management 10

1.8. Synthesis across GLMZs 10

1.8.1. Issues and priorities to manage TGP 10

1.8.2. Knowledge and capacity gaps 11

1.8.3. Priorities and opportunities 11

1.8.4. Barriers to progress 12

2. GLOSSARY 14

3. INTRODUCTION 16

3.1. Background 16

3.2. Total grazing pressure and biodiversity in Australian rangelands 17

3.3. Objectives 18

3.4. Structure 18

3.4.1. Personnel and roles 18

3.4.2. Report generation and structure 19

4. GRAZING LAND MANAGEMENT ZONES 20

4.1. Development 20

4.2. Map of zones 22

4.3. Zone 1 – Arnhem Land and Tiwi Islands 23

4.3.1. Regional attributes 23

4.3.2. Biophysical attributes 23

4.3.3. Socioeconomic attributes 24

4.3.4. Pastoral grazing systems and other land uses 24

4.3.5. Wild stock (including feral animals) 24

4.3.6. Current management of TGP 24

4.3.7. Biodiversity issues 25

4.3.8. Previous projects and on-ground work *25*

4.3.9. Knowledge gaps *26*

4.3.10. Opportunities to invest *26*

4.4. Zone 2 – Tropical Savannas **27**

4.4.1. Regional attributes *27*

4.4.2. Biophysical attributes *27*

4.4.3. Socioeconomic attributes *28*

4.4.4. Pastoral grazing systems *28*

4.4.5. Wild stock (including feral animals) *29*

4.4.6. Current management of total grazing pressure *29*

4.4.7. Biodiversity issues *30*

4.4.8. Previous research and on-ground work *31*

4.4.9. Knowledge gaps *32*

4.4.10. Opportunities to invest *32*

4.5. Zone 3 – Mitchell Grass Downs **34**

4.5.1. Regional attributes *34*

4.5.2. Biophysical attributes *34*

4.5.3. Socioeconomic attributes *35*

4.5.4. Pastoral grazing systems and other land uses *35*

4.5.5. Wild stock (including feral animals) *36*

4.5.6. Current management of TGP *36*

4.5.7. Biodiversity issues *36*

4.5.8. Previous projects and on-ground work *38*

4.5.9. Knowledge gaps *38*

4.5.10. Opportunities to invest *39*

4.6. Zone 4 – Einasleigh and Desert Uplands, North Queensland **40**

4.6.1. Regional attributes *40*

4.6.2. Biophysical attributes *40*

4.6.3. Socioeconomic attributes *41*

4.6.4. Pastoral grazing systems *42*

4.6.5. Wild stock (including feral animals) *42*

4.6.6. Current management of TGP *42*

4.6.7. Biodiversity issues *43*

4.6.8. Previous research and on-ground work *44*

4.6.9. Knowledge gaps *45*

4.6.10. Opportunities to invest *45*

4.7. Zone 5 – Arid Deserts **47**
4.7.1. Regional attributes *47*
4.7.2. Biophysical attributes *47*
4.7.3. Socioeconomic attributes *48*
4.7.4. Pastoral grazing systems *48*
4.7.5. Wild stock (including feral animals) *49*
4.7.6. Current management of TGP *49*
4.7.7. Biodiversity issues *49*
4.7.8. Previous projects and on-ground work *50*
4.7.9. Knowledge gaps *50*
4.7.10. Opportunities to invest *50*
4.8. Zone 6 – Central Cattle Grazing **52**
4.8.1. Regional attributes *52*
4.8.2. Biophysical attributes *52*
4.8.3. Socioeconomic attributes *53*
4.8.4. Pastoral grazing systems *53*
4.8.5. Wild stock (including feral animals) *54*
4.8.6. Current management of TGP *54*
4.8.7. Biodiversity issues *54*
4.8.8. Previous research and on-ground work *55*
4.8.9. Knowledge gaps *55*
4.8.10. Opportunities to invest *56*
4.9. Zone 7 – Pilbara: Extensive Cattle Grazing in Tussock and Hummock Grasslands **57**
4.9.1. Regional attributes *57*
4.9.2. Biophysical attributes *57*
4.9.3. Socioeconomic attributes *58*
4.9.4. Pastoral grazing systems and other land uses *58*
4.9.5. Wild stock (including feral animals) *59*
4.9.6. Current management of TGP *59*
4.9.7. Biodiversity issues *60*
4.9.8. Previous projects and on-ground work *61*
4.9.9. Knowledge gaps *61*
4.9.10. Opportunities to invest *62*
4.10. Zone 8 – Southern Australia Sheep and Cattle Grazing in Shrublands **64**
4.10.1. Regional attributes *64*

4.10.2. Biophysical attributes 65
4.10.3. Socioeconomic attributes 65
4.10.4. Pastoral grazing systems and other land uses 66
4.10.5. Wild stock (including feral animals) 67
4.10.6. Current management of TGP 67
4.10.7. Biodiversity issues 68
4.10.8. Previous projects and on-ground work 69
4.10.9. Knowledge gaps 71
4.10.10. Opportunities to invest 71
4.11. Zone 9 – Extensive Sheep Grazing **74**
4.11.1. Regional attributes 74
4.11.2. Biophysical attributes 74
4.11.3. Socioeconomic attributes 75
4.11.4. Pastoral grazing systems 75
4.11.5. Wild stock (including feral animals) 76
4.11.6. Current management of TGP 76
4.11.7. Biodiversity issues 77
4.11.8. Previous research and on-ground work 77
4.11.9. Knowledge gaps 78
4.11.10. Opportunities to invest 78
4.12. Zone 10 – Highly Modified Rangelands **80**
4.12.1. Regional attributes 80
4.12.2. Biophysical attributes 81
4.12.3. Socioeconomic attributes 82
4.12.4. Pastoral grazing systems 82
4.12.5. Wild stock (including feral animals) 83
4.12.6. Current management of TGP 83
4.12.7. Biodiversity issues 84
4.12.8. Previous projects and on-ground work 85
4.12.9. Knowledge gaps 85
4.12.10. Opportunities to invest 86
5. REVIEW OF PREVIOUS PROJECTS **87**
5.1. Introduction **87**
5.2. Project review database **87**
6. TGP: MANAGEMENT ISSUES AND TECHNIQUES FOR THE RANGELANDS **95**

6.1. Introduction **95**

6.2. Issues in the management of the natural resource base **96**

6.2.1. Acknowledging all grazers in estimating and managing grazing pressure *97*

6.2.2. Feral animals – pest or economic resource? *97*

6.2.3. The issue of dietary choice *98*

6.2.4. Soil impacts *99*

6.2.5. Transferability between GLMZs *99*

6.3. Management of domestic livestock **99**

6.3.1. Common grazing management issues *100*

6.3.1.1. Stocking rates, utilisation rates and carrying capacities *100*

6.3.1.2. Drought and risk management *101*

6.3.1.3. Managing spatial impact *102*

6.3.1.4. Riparian management *103*

6.3.1.5. Use of fire *103*

6.3.1.6. Biodiversity *103*

6.3.2. Grazing management systems *104*

6.3.2.1. Continuous grazing *104*

6.3.2.2. Set-stocking *104*

6.3.2.3. Seasonal tracking *105*

6.3.2.4. Set utilisation *105*

6.3.2.5. Rotational grazing and spelling *105*

6.3.2.6. Opportunistic spelling *106*

6.3.2.7. Tactical grazing *107*

6.3.3. General recommendations for grazing systems *107*

6.3.4. Grazing management lessons from the intensive use zone *107*

6.4. Management methods for wild stock **109**

6.4.1. Issues in the management of wild stock *109*

6.4.1.1. Motivation for management *110*

6.4.1.2. Monitoring effectiveness of management/control *111*

6.4.1.3. Spatial issues *111*

6.4.2. Management of wild stock and control techniques *112*

6.4.2.1. Rabbits *112*

6.4.2.2. Goats *113*

6.4.2.3. Camels *116*

6.4.2.4. Horses and donkeys *116*

6.4.2.5. Kangaroos 117
6.4.2.6. Pigs 119
6.4.2.7. Buffalo 120

7. SYNTHESIS 122

7.1. Summary of issues and priorities from GLMZ descriptions 122
7.1.1. Biodiversity issues 122
7.1.2. Knowledge gaps 123
7.1.3. Priorities / investment opportunities 124
7.1.4. Other TGP issues 125

7.2. Management issues and actions 125
7.2.1. Direct management of TGP 125
7.2.1.1. Water points 125
7.2.1.2. Application of 'best-practice' grazing land management 126
7.2.1.3. Feral grazers 127
7.2.1.4. Management 'hotspots' 128
7.2.2. Other land management issues interrelated with TGP 130
7.2.2.1. Weeds (exotic plants species) 130
7.2.2.2. Fire 130
7.2.2.3. Woody vegetation change 131
7.2.3. Integrative issues 133
7.2.3.1. Biodiversity inventories 133
7.2.3.2. Integration of regional and property management/ conservation plans 136
7.2.3.3. Biodiversity monitoring tools 137
7.2.3.4. Barriers to positive outcomes 144

8. References 145

9. Appendices 153

9.1. Appendix 1: List of bioregions and sub-bioregions within the rangelands, with the GLMZ into which they fall 153

9.2. Appendix 2: Summary of the characteristics of each GLMZ. 160

1. SUMMARY

1.1. Why is managing TGP important for natural resource management?

Extensive work over recent years has shown how total grazing pressure (TGP) in the rangelands has two components: that which is exerted by domestic stock associated with the pastoral industry; and a wild stock component, which includes feral species and native macropods. Contemporary pastoral grazing management is now much more in tune with the carrying capacity of the landscape than at the inception of rangeland pastoralism in Australia, and rabbit numbers are relatively lower due to biological control. However, TGPs are still higher and more consistent through time than they probably were throughout recent evolutionary history. This is exacerbated in many regions by high populations of feral and native grazing mammals. Feral goats and kangaroos, for example, are able to maintain substantial populations in regions where artificial sources of water are abundant, and where dingoes have been eliminated to reduce domestic stock losses. As well as goats and kangaroos, other herbivores add substantially to TGP, including rabbits, donkeys, horses, pigs and camels. The larger herbivores are not as widespread throughout the rangelands as rabbits, goats and domestic stock, but they occur in large numbers in particular regions.

Total grazing pressures exceeding the sustainable capacity of the land threaten the proper functioning of ecosystems and the survival of native species. Grazing land management should include a consideration of the impact of both domestic stock and wild stock to ensure conservation of biodiversity and sustainability of grazing industries.

1.2. What is the potential impact of poor management of TGP on the environment?

Extinction and decline in numbers of native species have occurred in the Australian rangelands since European settlement, most notably the extinction of 20 species of mammals. Excessive grazing pressure, from both domestic stock and feral species such as rabbits, is implicated as a factor in many of these extinctions and ongoing decline of extant mammal, bird and plant species, and threatened ecosystems. This will result in a marked change in the structure and functioning of the rangelands and their ability to provide humans with natural resources and ecosystem services.

Other impacts associated with unmanaged TGP include soil erosion, fouled water supplies and weed invasion, all of which affect the value of the rangelands to humans for a range of purposes. These negative impacts can jeopardise the sustainability of the pastoral industry due to the loss of productive potential and the ecosystem services native flora and fauna provide. These impacts will be felt not just by rangeland inhabitants but also by the wider community. For example, rangeland degradation is expected to have consequences for climate change at local and global scales.

1.3. Report objectives

The project objectives were to:

- Develop a framework for organising rangelands into regions with similar TGP and biodiversity characteristics, and managing both.
- Review literature and past projects to determine the main management systems practised and biodiversity issues addressed in different regions.
- Distil reviewed information and compiled data to develop guidelines for managing TGP in regions with different characteristics.

1.4. Report methods and production

The report derives essentially from desktop review and synthesis of existing, disparate information that was brought together by an expert reference group (ERG) and project consultants (PCs) within the Desert Knowledge and Tropical Savannas Management Cooperative Research Centres. The ERG and PC members were chosen because they had expertise in particular topics or in particular regions.

Grazing land management zones (GLMZs) were defined for the rangelands based on data at a subregional resolution and using a modified version of the rangeland boundaries. Data describing the biophysical characteristics, land uses, land modification and stocking characteristics of each biogeographic subregion of the rangelands were gathered from various Commonwealth and state government sources, and used to define the zones. A combination of cluster analysis and expert opinion was used to establish zone boundaries.

1.5. Grazing land management zones

The ten GLMZs defined are: Arnhem Land and Tiwi Islands, Tropical Savannas, Mitchell Grass Downs, Einsleigh and Desert Uplands North Queensland, Arid Deserts, Central Australia Cattle Grazing, Pilbara: Extensive Cattle Grazing in Tussock and Hummock Grasslands, Southern Australia Sheep and Cattle Grazing, Extensive Sheep Grazing, and Highly Modified Rangelands.

For each zone, the regional, biophysical and socioeconomic attributes were described, pastoral grazing systems and wild stock (including feral animals) that predominate were identified, current management of TGP, biodiversity issues for the region, previous research and on-ground work, knowledge gaps, and opportunities to invest were summarised.

1.6. Review of previous work relating to TGP management

We reviewed 37 past (and current) research and management projects relating to TGP and biodiversity conservation in the rangelands in particular, those that were funded through the Natural Heritage Trust. The purpose of the project review was to provide a readily accessible summary of past projects funded through NHT; assess the transferability of the outputs and insights from past projects to other areas of the rangelands; and assist in identifying knowledge gaps and priorities for future investment. Details of the projects reviewed are presented in Section 5.

1.7. Review of TGP management

A review of literature and knowledge about TGP management is presented in Section 6. That section focuses on: general issues relating to managing domestic livestock and wild stock, and some factors affecting pastoralists' perceptions of wild stock species; specific management practices for domestic livestock, and associated issues; the management of wild stock including a summary of appropriate control techniques for the main species of wild stock found in the rangelands; and insights for TGP management in the rangelands that arise from experiences in intensively used areas of south-eastern Australia.

Options for managing total grazing pressure in the rangelands are limited because of the scale of enterprises and management units, the variable and unpredictable climate, the magnitude of pest populations, the limited availability of labour and the limited control that can be achieved over animals and their movements. Economic circumstances for grazing enterprises and the low financial returns that are generally achieved per land unit area in the rangelands have a strong influence too. This is exacerbated by the tendency for some people to see feral species as an economic resource. This conflict applies particularly to feral goats, but also to feral horses, pigs and camels, where opportunistic harvesting of animals has been the norm. Indigenous people also frequently rely on feral species as an economic resource. Many managers have failed to recognise that feral species in fact compete with domestic livestock, and can reduce livestock productivity, so total grazing pressure on the land has often been excessive. Purported economic benefits from harvesting and selling feral animals during periods when income from domestic stock are low, may actually have a net negative effect on the economic position of the pastoral enterprise.

1.8. Synthesis across GLMZs

1.8.1. Issues and priorities to manage TGP

The key, recurring issues across Zones (Section 7) were identified and discussed, along with management approaches to lessen effects on biodiversity. The issues addressed include:

- Proliferation of water points and the ubiquity of grazing pressure across broad landscapes. Water points can be used to control distribution of grazing mammals and they should be introduced/placed in the landscape to create even grazing for pastoralism, *and* leave some unwatered areas for conservation of biodiversity.

- Widespread land degradation due to high TGP across entire landscapes and concentration of grazing pressure on restricted, sensitive and/or high-biodiversity-value habitats. The remedy to this is to involve managers in regional and property planning that highlights problem and biologically important areas, and to identify where and when control of feral animals will be most effective.

- A lack of understanding by land managers about what areas of biodiversity significance are and where they may be on a property. Also a lack of appreciation of how a seemingly un-special habitat may be significant at a regional scale because of its context and/or condition. Education on this front is hampered by a lack of NRM facilitators trained in appropriate processes for working with pastoralists and Indigenous people, and a lack of biological data.

- Threatened species and weed invasions are linked with TGP and grazing management but causes and solutions are not always obvious. Removing all grazing pressure is rarely likely to be effective in ameliorating the problems.

- Changed fire regimes are a significant biodiversity issue in most zones, although the precise nature of the impact on biodiversity is usually unclear. Options for the use of fire are limited in intensively-managed rangelands, while mis-use of fire in hummock grasslands may be detrimental to biodiversity.

- Perennial vegetation thickening effects the viability of a grazing enterprise as well as some elements of biodiversity. Management is associated with TGP and fire regime change. Lack of data on the advancement of vegetation thickening is the biggest problem for action. Prescriptions to manage vegetation thickening vary from region to region and is an area of ongoing research.

1.8.2. Knowledge and capacity gaps

Poor knowledge of biodiversity and of the impact of pastoral use on biodiversity is a serious issue in a number of zones. This has a number of aspects, which are more or less important in different zones:

- Basic knowledge of species distribution.

- Inability to delineate management ‘hotspots’ (important in most zones).

- Inadequate or inaccurate listings of, for example, threatened or priority species and ecosystems.

- Impact of alternate grazing strategies, environmental weeds and fire regimes.

The lack of effective tools (especially for land managers) to monitor effects of TGP and related grazing-land management on biodiversity is an issue across all the zones (although progress in this area is being made currently through DEH-sponsored activities).

1.8.3. Priorities and opportunities

- Integration of regional strategies for the management of TGP with activities at the property level.

- Adoption of recommended best management practice (grazing systems) and use of better tools and infrastructure for controlling grazing pressure (e.g. manipulation of water availability; installation of trap yards and other innovative automated control systems for feral species).

- Provision of information and training for land managers in recognising biodiversity hotspots and 'biodiversity-sensitive' management, and incorporation of biodiversity conservation into property-level planning, integrated with regional priorities, as a result of this training.
- Design and implementation of effective biodiversity and TGP monitoring programs.
- Support for local communities in a range of land management actions (e.g. ranger programs on Aboriginal lands).
- Identification of biologically important and/or sensitive ecosystems, and adequate protection for them from domestic and feral stock. For example, through control of the distribution of water points, strategic fencing, feral animal control, and incorporation into reserves.
- Further biodiversity inventories are required for most regions, particularly for the identification of management 'hotspots'.

1.8.4. Barriers to progress

Barriers to effective management of TGP were summarised. Finding solutions to some of these will result in far better management of rangeland landscapes, and many could be achieved with relatively small budget allocations.

- Misunderstanding of the damaging effect on biodiversity of uncontrolled grazing pressure.
- Misunderstanding of the potentially negative impact of wild stock components of TGP on economic bottom line of an enterprise.
- Lack of appreciation of the potential significance of seemingly common habitat types to regional biodiversity maintenance.
- Lack of resources and knowledge by land managers to know what to do about managing areas that are obviously biologically special (and the areas that they don't yet recognise the value of).
- Lack of formal recognition of landholders who do maintain biologically important areas on behalf of society.
- Government use of incorrect processes and rhetoric in dealings with landholders, which signals an attitude of 'control' that engenders a fear of having things 'taken away' rather than co-managed (e.g. creating small reserves actually disassociates a landholder from a patch of land and dissolves land managers' responsibility for it).
- Poor mechanisms to make data on local and regionally-significant areas available to land managers (once again, an attitude of control, rather than a partnership approach, on the part of those who hold data).
- Lack of incentives for land managers to do things that do not add value to the enterprise.

- Lack of knowledge of the biodiversity benefits of alternative grazing systems (e.g. rotational grazing), which allows pastoralists to dismiss research results in set-stocked systems.

- Poor techniques for monitoring the effects of TGP on elements of biodiversity.

- Inadequate and/or extremely costly techniques for managing TGP (i.e. controlling animals).

2. GLOSSARY

Animal equivalent (AE)	The standardised body weight equivalent of a single beast (*Bos* spp.) herewith based on a 400 kg animal. Used to express grazing pressure of a range of animals of different body sizes in equivalent terms to cattle.
Brucellosis–Tuberculosis Eradication Campaign (BTEC)	A program aimed at eradicating Brucellosis and Tuberculosis from domestic and wild bovids (cattle and buffalo) in Australia. The Australian BTEC commenced in 1970 and was completed in 1993.
Cooperative Research Centre (CRC)	A federal-government funded, virtual network of researchers and end-users from a number of different institutions (e.g., universities, CSIRO, private industries, state government agencies) who cooperate to create new knowledge, generally with commercial and public-good focus. Hence, Desert Knowledge CRC (DK-CRC) and Tropical Savannas Management CRC (TSM CRC).
Dry sheep equivalent (DSE)	The standardised body weight equivalent of a single sheep (*Ovus* spp.) herewith based on a 45 kg animal. Used to express grazing pressure of a range of animals of different body sizes in equivalent terms to sheep.
Environmental Management System (EMS)	A process of planning, doing, documenting and reviewing aspects of an enterprise's effects on the environment. EMSs can be used solely to improve efficiency of use of resources for an enterprise and to underpin claims of good environmental management (http://www.agric.nsw.gov.au/reader/11441).
Feral animal	A non-native animal that is not regularly controlled by pastoralists or pastoral infrastructure (except water). (Only herbivorous feral animals are referred to in this report.)
Grazing Land Management (GLM)	A catch phrase for the integrated set of actions and strategies used to manage land at property scale in a region.
Grazing Land Management Zones (GLMZs)	A classification of areas of Australian rangelands derived in this study that have similar biophysical characteristics (climate, vegetation used by grazing animals), land use characteristics (e.g. irrigation, agriculture, conservation etc), types of domestic stock (sheep, cattle), types of wild stock present, and pastoral infrastructure (water-point proliferation).
Intensive and Extensive Use Zones (IUZ/EUZ)	Division of the Australian landscape based on land use by National Land & Water Resources Audit 2001a: IUZ defines lands that are predominantly cleared or otherwise highly modified for agriculture and urbanisation; EUZ defines lands that are by and large uncleared and are used primarily for livestock grazing, unallocated Crown land, conservation and Aboriginal homelands (i.e. the rangelands).
Interim Biogeographic Regionalisation of Australia (IBRA)	A biogeographic region as defined originally by Thackway & Cresswell (1995) and refined to version 5.1 as used by the National Land and Water Resources Audit 2000–2002 (http://www.ga.gov.au/asdd/)
Irreplacability Index	A measure of the degree to which the species found in a region are unique and therefore no other place could act as a substitute for the conservation of biodiversity. The index ranges from 0 (highly substitutable) to 1 (no other location can substitute to preserve the species found in the region).

National Land and Water Resources Audit (NLWRA)	A federal-government funded project running from 2000-2002 which assessed and reported on the state of a wide range of natural resources in Australia (http://www.nlwra.gov.au/full/index.html).
National Vegetation Information System (NVIS)	A project of the federal government environment department to create a single unified vegetation map for Australia by combining the disparate maps from state government and other sources.
Subregion	Component parts making up a biogeographic region.
Total grazing pressure (TGP)	The combined grazing pressure that all domestic and wild stock exert on the vegetation, soil and water resources of rangeland landscapes.
Western Australian Rangelands Monitoring System (WARMS)	The Western Australia state government Department of Agriculture network of monitoring sites used to assess medium- to long-term change in the productive capability of pastoral leases.
Wild stock	All non-domestic grazing mammals, including feral animals such as goats, rabbits and camels, and native kangaroos and wallabies.

3. INTRODUCTION

3.1. Background

Total grazing pressure refers to the combined impact of the grazing activities of different species of herbivores. Generally TGP is related only to mammalian herbivores, although invertebrate herbivores can sometimes have dramatic effects (principally grasshoppers). Total grazing pressure is an important factor in the management of rangeland landscapes because it is fundamental to the economically and ecologically sustainable use of natural resources. Production from rangelands is derived from low densities of domestic stock, using large tracts of land and harvesting sparsely distributed and variable grass and shrub production. These uses could be sustainable in many regions if domestic stock were the only herbivores harvesting the sparse plant production. However, in most regions where domestic stock grazing is potentially sustainable, native and feral grazing mammals are also present.

The presence of non-domestic stock increases impacts on the landscape in a number of ways: (i) it increases the number of times per day, week or month that individual plants are grazed. The frequency at which a plant is grazed affects its growth form, survival rate and reproductive output; (ii) different species of grazing animals have different taste preferences and so the range of plant species grazed is widened compared with having just domestic stock; and (iii) the majority of herbivores (except rabbits and grasshoppers) need to drink regularly, so there is an increase in the number of animals moving to and from fixed water points. This affects soil crust integrity and non-grazed plant species, resulting in areas of high impact that are often dominated by unpalatable and/or exotic weed plant species, and nutrient accumulation. All three of these factors, frequency, variety and intensity of the disturbance regime, affect animals as well as plants.

The fact that different species of grazing animals eat different plant species, and in different proportions in their diet, means that multiple species can be grazed side-by-side to get more food or fibre production from the same area of the landscape. However, the current situation is that most non-domestic grazing animals are not managed (in terms of numbers, or the areas that they can access), and in proportion to the resources they consume they are not harvested for economic return as efficiently as domestic stock are. This creates a situation where any overlap in the dietary needs of different species results in direct economic competition between stock (harvested for sale) and non-stock grazing animals (mostly not harvested for economic return). Where non-stock grazing animals are plentiful, domestic stock may account for only half of the plant biomass that is harvested. The land manager tries to maintain the growth rates and condition of stock that are competing with other animals for sparse resources. The combination of variable plant production, fixed and free water supplies and economic imperatives means that the combined grazing pressure from stock and non-stock animals exceeds the ability of the landscape to support them, and exceeds the ability of the land manager to adjust for changes in productivity in appropriate time frames.

3.2. Total grazing pressure and biodiversity in Australian rangelands

The plight of biodiversity in inland Australia since European land uses were imposed has been well documented (World Conservation Monitoring Centre 1992). Many explanations for the decline and loss of biodiversity have been proposed (e.g. Burbidge & McKenzie 1989, Morton 1990, Short & Smith 1994, Braithwaite & Muller 1997, Franklin 1999, Bowman 1998, Leigh & Briggs 1992). Despite a large number of explanations and factors being implicated in the decline and loss of biodiversity, authors agree that a share of the problem relates to the pastoral industry, particularly in the period from first settlement to about the middle of the 20th century when extremely high and unsustainable stocking rates caused unprecedented land degradation (Proceeding of the Parliament of South Australia 1868, Parliament of Western Australia 1940, New South Wales Government 1901). In concert with the pastoral overuse of the land, plagues of rabbits contributed a large but unquantified additional grazing pressure, often more extensive than pastoralism because of the rabbits' indifference to the need to drink.

While pastoral grazing management is now much more in tune with the carrying capacity of the landscape, and rabbit numbers are relatively lower (Sandell & Start 1999), grazing pressures are still higher and more consistent through time in many regions than they probably were throughout recent evolutionary history because of high populations of feral and native grazing mammals. Goats and kangaroos are able to maintain substantial populations in regions where artificial sources of water are abundant, and where the dingo has been eliminated to reduce domestic stock losses (Newsome et al. 2001). Artificial water sources are now one of the primary drivers for ongoing management problems in rangelands because they maintain grazing mammal populations and they directly affect other animals that drink, principally birds (James et al. 1999, Landsberg et al. 2002, Landsberg et al. 1999, Dominelli et al. 1999, Fisher 1999, James 2003).

This mix of domestic stock and other native and non-native grazing mammals contributes to the TGP on the landscape. As well as the species mentioned above, other herbivores add substantially to TGP: donkeys, horses, pigs and camels (Wilson et al. 1992, Gooding 1983, Dobbie et al. 1993, Pavlov 1995). These large herbivores are not as widespread as rabbits, goats and domestic stock in rangelands, but can be found in large numbers in particular regions. Donkeys and horses tend to be problems in the rocky ranges of the Central Australian and Kimberley regions, Mitchell grass plains and floodplains (Berman 1995, Choquenot 1995). Camels are found across the sandy deserts of central and western inland Australia (Dörges & Heucke 1995), where they have reached an enormous population size (Glenn Edwards, pers. comm., 2003). The effects of camels on biodiversity are thought to be similar to those of sheep, cattle and goats in so far as selective grazing of palatable species may be causing a decline in the abundance of such species through a disruption of phenological and recruitment cycles. Pigs are usually associated with floodplain environments or seasonally flooded areas and, apart from their impact on the species that they forage for, they have an additional impact as burrowers and rooters of the soil surface (Pavlov 1995).

In the past decade, there has been substantial investment in research and management aimed at improving grazing land management in many rangeland regions, and in the development of much education and extension material aimed at increasing the understanding of the principles of GLM. This effort has been compromised somewhat by an inadequate consideration of biodiversity conservation issues in relation to GLM; by concentrating on the management of stock and ignoring the effects of other herbivores; by a lack of appreciation of the importance of regional differences in approaches to GLM; and by poor communication of successful GLM strategies between regions. This project is aimed at providing objective information that will assist assessors to determine whether National Resource Management (NRM)–related project proposals are likely to be effective in rectifying these problems, although it recognises that different approaches will be appropriate in different regions.

Total grazing pressure issues and solutions vary from region to region, depending on the pastoral infrastructure in place, the type and number of grazing species present, and environmental conditions. In some regions TGP is being managed by controlling access to artificial water points but in other regions this is not as effective because of the availability of natural and ephemeral water sources. Similarly, control of the grazing pressure that kangaroos add to that of domestic stock is not something that pastoralists can control easily, because of the ability of kangaroos to cross fencelines and not be trapped by fencing that traps goats, and because of restrictions on culling. These regional differences require innovative local solutions and the sharing of information across regions about how best to manage TGP on the landscape.

3.3. Objectives

The project objectives were to:

- Develop a framework for organising rangelands into regions with similar TGP and biodiversity characteristics, and managing both.
- Review literature and past projects to determine the main management systems practised and biodiversity issues addressed in different regions.
- Distil reviewed information and compiled data to develop guidelines for managing TGP in regions with different characteristics.

3.4. Structure

3.4.1. Personnel and roles

The project team consisted of an expert reference group (ERG) and project consultants (PCs) within the Desert Knowledge and Tropical Savannas Management Cooperative Research Centres who had expertise in particular topics or in particular regions.

The ERG was the main working body of the review and wrote all sections of the text. This group forms the authors of the report: Alaric Fisher, Leigh Hunt, Craig James, Jill Landsberg, David Phelps, Anita Smyth and Ian Watson.

The PCs included people who are affiliated with the CRCs and who have provided the necessary spatial data coverage, in-depth local knowledge of issues, and other data. They included:

- Amanda Brook (South Australia Department of Water, Land and Biodiversity Conservation)
- Jenni Risler and Craig Hempel (NT Department of Infrastructure Planning & Environment)
- Richard Hobbs (Murdoch University – for unpublished paper on landscape classification framework)
- Mike Hutchinson (Australian National University – for unpublished paper on climate zones)
- Aaron Colbran (New South Wales Department of Infrastructure, Planning and Natural Resources)
- John Arrowsmith (Queensland Department of Primary Industries)
- John Carter (Queensland Department of Natural Resources and Mining)
- Glen Edwards (NT Department of Infrastructure, Planning & Environment)
- Rob Richards (Rangelands Consultant)

3.4.2. Report generation and structure

The report derives essentially from desktop review and synthesis of existing, disparate information that was brought together by the ERG. This was done by:

- A series of telephone meetings in February and March 2004 to establish a work plan and discuss sources of data available for the project.
- Compilation of data outlined in Table 4.1 and Appendix 2, and analysis of data in March to generate interim GLMZs. Also during this period, first draft of Chapters 5 and 6 were written.
- Face-to-face meeting of ERG in Brisbane 29-30 March to establish GLMZs, report structure and begin co-writing some sections.
- GLMZ maps were produced and draft writing of GLMZ descriptions were undertaken by each member of the ERG during April and May.
- Writing synthesis (Chapter 7) in June after GLMZ descriptions reached advanced draft stage.
- Overall editing and completion tasks (e.g., referencing, standardisation of information presented, proof reading, editing) occurred in July and August.

4. GRAZING LAND MANAGEMENT ZONES

4.1. Development

Grazing land management zones (GLMZs) were defined for the rangelands based on data at a subregional resolution and using a modified version of the rangeland boundaries described in *Rangelands – tracking changes* (National Land & Water Resources Audit [NLWRA] 2001b). Data describing the biophysical characteristics, land uses, land modification and stocking characteristics of each subregion were gathered from various Commonwealth and state government sources (Table 4.1). The data were analysed with a multivariate cluster analysis to produce potential GLMZs. The project team agreed that the results from an analysis that derived 15 groupings was the most acceptable but that further expert opinion was required. Using the project team as an expert panel, and informed by data (Appendix 2), some GLMZs were combined and some subregions redistributed to create the final GLMZ outcome shown in Figure 4.1.

Table 4.1: Description of datasets used to build grazing land management zones

Dataset	Description	Access	Source
Biophysical Climate Cool, wet (D5) Warm, seasonally wet/dry (E1–4, E6–7) Warm, wet (F3) Hot, dry (H) Hot, seasonally wet/dry (I1–3) Hot, wet (J1)	Presence/absence of any of 14 climate zones in the specified subregion. These zones are based on plant growth, temperature, moisture and seasonality.	Restricted	Hutchinson et al. manuscript
Vegetation - Rainforests and vine thickets - Eucalypt tall open forests - Eucalypt woodlands - Acacia forests and woodlands - Callitris forests and woodlands - Casuarina forests and woodlands - Melaleuca forests and woodlands - Other forests and woodlands - Eucalypt open woodlands - Acacia open woodlands - Mallee woodlands and shrublands	Proportion of any of 17 vegetation types within the specified subregion. The types were derived from 26 major vegetation groups of NVIS.	Public	Australian Spatial Data Directory (ASDD) http://www.ga.gov.au/asdd/

- Mixed shrublands - Tussock grasslands - Hummock grasslands - Other grasslands, herblands and sedgelands - Chenopod and samphire shrublands and forblands - Mangroves, tidal mudflats, claypans, salt lakes, lagoons, bare			
Land type Primary land uses within subregions	 Proportion of each of the following in subregions comprising the zone: irrigated agriculture, dry agriculture, grazing impact, grazing native, Aboriginal lands, conservation lands, and crop lands	 Restricted	 Landscape health report of the NLWRA, available at ASDD
Land modification Area cleared	 Proportional area of subregions in a zone cleared of native vegetation	 Public	 Landscape health report of the NLWRA, available at ASDD
Area > 6 km from water	Proportional area of the subregions in a zone greater than 6 km from a water point	Restricted	CSIRO Sustainable Ecosystems [Vanessa.chewings@csiro.au]
Area > 9 km from water	Proportional area of the subregions in a zone greater than 9 km from a water point	Restricted	CSIRO Sustainable Ecosystems [Vanessa.chewings@csiro.au]
Property size	Median size of pastoral properties in subregions in a zone	Restricted	Relevant primary industries agency in each state or territory
Density of domestic stock and macropods	The following data were extracted from the AussieGrass program: mean beef density (as AEs km^{-2}); mean sheep density (as DSEs km^{-2}); mean macropod density (as 25 kg animals km^{-2})	Restricted	Contact John Carter [john.carter@nrm.qld.gov.au]
Population size of wild stock	Categorical density classes from 0 to 3 for: buffalo, goats, rabbits and total wild stock (derived)	Public	Landscape health report of the NLWRA, available at ASDD

4.2. Map of zones

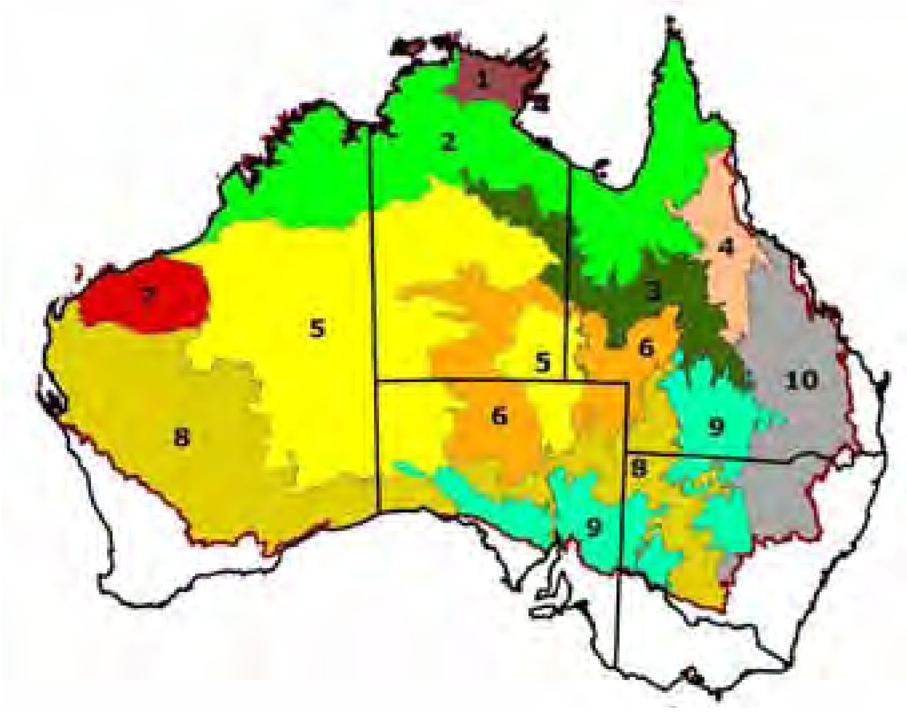


Figure 4.1: Grazing Land Management Zones of the Australian rangelands

1. Arnhem Land and Tiwi Islands
2. Tropical Savannas
3. Mitchell Grass Downs
4. Einsleigh and Desert Uplands, North Queensland
5. Arid Deserts
6. Central Australia Cattle Grazing
7. Pilbara: Extensive Cattle Grazing in Tussock and Hummock Grasslands
8. Southern Australia Sheep and Cattle Grazing
9. Extensive Sheep Grazing
10. Highly Modified Rangelands

4.3. Zone 1 – Arnhem Land and Tiwi Islands[a]

Compiled by Alaric Fisher

Characterised by hot climate with seasonal monsoon rainfall; eucalypt open forests and woodlands and other tropical savanna vegetation; almost entirely Aboriginal freehold land with very little pastoral activity; grazing pressure primarily from feral herbivores and uncontrolled stock.

4.3.1. Regional attributes

Area: 101,025 km^2

Bioregions (sub-IBRAs): Arnhem Coast (ARC1–5); Arnhem Plateau (ARP1–2); Central Arnhem (CA1–2); Tiwi Cobourg (TIW1–2)

NHT regions: Northern Territory

4.3.2. Biophysical attributes

Entirely within climate zone I1: hot, seasonally wet/dry climate with plant growth determined by moisture availability (Table 4.1). Monsoonal climate with annual rainfall between 1000 mm and 1500 mm, falling almost entirely in a five-month wet season.

Vegetation is primarily eucalypt open forests and woodlands, with open woodlands on extensive rocky areas (VG 2,3,9). The understorey is predominantly spinifex *(Triodia* spp.) or mixed perennial tussock grasses, but some areas are dominated by annual *Sorghum*, and there are some extensive

[a] See Appendix 2 for full listing of data for each GLMZ.

areas of floodplain grasslands and sedgelands. There are extensive and diverse mangrove forests and a variety of other littoral communities along the coastline. More restricted habitats include monsoon rainforests, billabongs and riparian woodlands along watercourses, melaleuca forests and swamps, and diverse heathlands on sandstone outcrops.

4.3.3. Socioeconomic attributes

Almost the entire zone is under Aboriginal freehold tenure (91% of area), although a significant area (6.8%) is managed as conservation reserve (Kakadu and Garig Gunak Barlu national parks). There is a very small area of pastoral leasehold on the southern margin of the zone.

Human population density (11.5 per 1000 km^2) is greater than in most of the other GLMZs. Most of the population is concentrated into small- to medium-sized communities, although there are small outstations scattered through most of the zone.

4.3.4. Pastoral grazing systems and other land uses

Very limited areas are managed for pastoral use, although some wild or semi-wild stock (cattle, horse) are harvested for subsistence and economic return, as are some feral grazers (buffalo, pig). There is also safari hunting of some feral animals, notably on Cobourg Peninsula. Sheep are absent, and the density of cattle and the estimated total grazing pressure are much lower than for the other GLMZs (although this estimate does not account for grazing pressure due to feral animals).

Insignificant areas within the zone are used for improved pasture or agriculture. There is also currently little clearing, although large areas are slated for clearing for forestry plantations on Melville Island.

4.3.5. Wild stock (including feral animals)

There are moderate densities of buffalo and pigs throughout the zone, with higher numbers in some habitats. Cobourg Peninsula also has populations of sambar, rusa deer, Timor pony and banteng, the latter forming the basis of a safari hunting industry. Rabbits and goats are absent from this GLMZ.

While there is a moderate diversity of macropod species, the density of large macropods is low compared to most other GLMZs. Agile wallaby (*Macropus agilis*) may congregate in relatively high densities in small areas of favourable habitat.

4.3.6. Current management of TGP

Most of the GLMZ has never been subject to pastoral use, and there is minimal development of pastoral infrastructure. Feral animals depend on natural surface water, which tends to concentrate their impact, particularly later in the dry season. There are historically low levels of unmanaged cattle, but buffalo numbers were not adequately reduced during the Brucellosis–Tuberculosis Eradication Campaign (BTEC) of the early 1980s, and numbers have since increased. There is generally no active management of total grazing pressure outside the national parks, and there are significant numbers of feral grazers within these reserves.

In many areas there is a tension between reducing numbers of feral grazers and retaining useful densities of these animals for subsistence and economic use. While mean population density is not low compared with much of the rangelands, the historic concentration of most of the population into mission settlements has left large areas essentially unmanaged. Successful land management is partly dependent on helping Aboriginal people move back onto country. There is a very low per-capita investment in land management in this zone, with much work dependent on Community Development and Employment Projects (CDEP) or Natural Heritage Trust (NHT) funding.

4.3.7. Biodiversity issues

There are high levels of richness and endemism of both plants and animals on the western Arnhem plateau and Tiwi Islands. Many ecosystems occurring in the zone are well represented by Kakadu and Garig Gunak Barlu national parks, although there are no formal conservation reserves in most of the sub-bioregions. There is a significant number of threatened bird, reptile and plant species in a number of the sub-bioregions, reflecting the very restricted distribution of many species.

Major threatening processes within the zone are:

- Changed fire regimes, notably an increase in extensive, hot late-dry-season fires, which have a negative impact on some vegetation types (e.g. monsoon rainforests, *Callitris* woodlands) and the relatively large number of plant species that are fire-sensitive obligate-seeders.

- Invasion by weeds (notably *Mimosa pigra*).

- Grazing and other effects of feral animals (notably pigs and water buffalo, but also feral cattle, horses and banteng). These have an impact on riparian areas, floodplains, wetlands and monsoon rainforest patches in particular.

- Effects of other feral animals, notably cats and cane toads on native animal species.

- Clearing for forestry plantations, which has an impact on threatened and/or restricted species in particular.

4.3.8. Previous projects and on-ground work

- Some aerial surveys of feral animals, which are likely to continue periodically/intermittently.

- Collaborative research, with Aboriginal traditional owners, ranger groups and land councils, into sustainable use of wildlife, including management of feral animals (Centre for Tropical Wildlife Management, Charles Darwin University).

- Major project to implement improved landscape-scale fire management (partly funded by NHT).

- Biodiversity survey and regional-scale conservation planning (Tiwi Islands and Arafura Swamp catchment).

- Various projects coordinated by Northern Land Council Caring for Country Unit, including weed management.
- Expanding network of Aboriginal ranger groups (varying considerably in capacity to implement land management strategies).
- Feral animal control, and monitoring program for fire, vegetation and biodiversity in Kakadu National Park.

4.3.9. Knowledge gaps

- The impacts of feral grazers on biodiversity have not been fully elucidated, and the priority areas for feral animal management are not well-defined.
- There is need for a rigorous cost-benefit analyses for management of feral grazers, incorporating ecological, economic & social considerations.
- How to implement effective management of feral grazer given social, economic and logistic constraints.

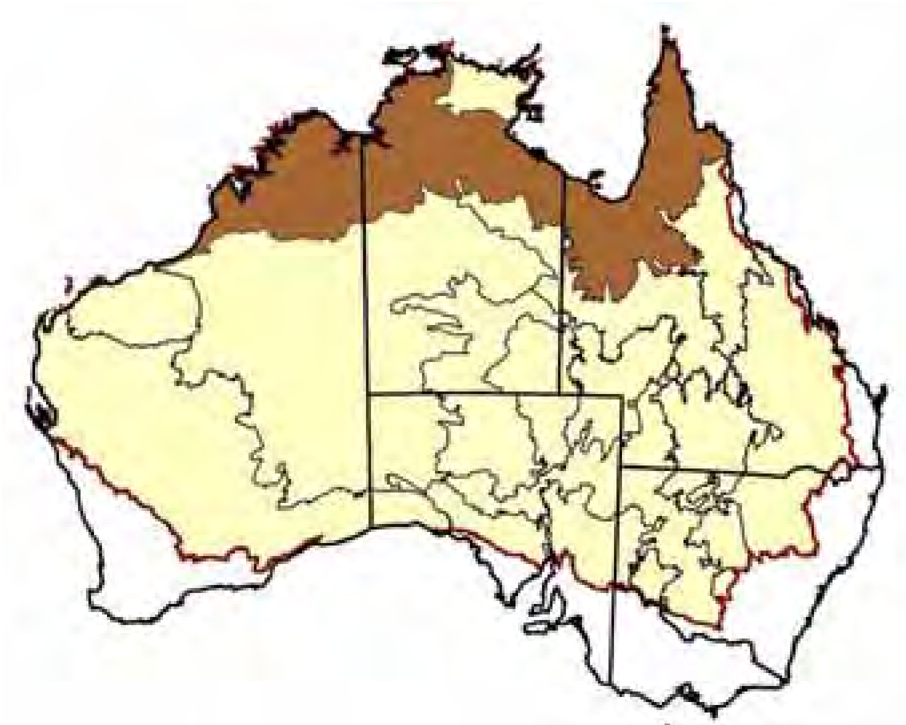
4.3.10. Opportunities to invest

- Continued and expanded support for Aboriginal ranger groups (capacity-building for land management generally).
- Research to determine cost-benefit analyses for feral control, and how to implement effective feral management.
- Incentives to strategically reduce feral animal density.
- Provision of biodiversity and land management information in accessible formats.

4.4. Zone 2 – Tropical Savannas

Compiled by Alaric Fisher

Characterised by tropical monsoonal climate; tropical eucalypt, acacia and melaleuca woodlands with grassy understorey; grazing of cattle on very large leasehold properties with relatively low cattle densities; significant areas of Aboriginal land and relatively undeveloped pastoral land.



4.4.1. Regional attributes

Area: 1,155,500 km^2

Bioregions (sub-IBRAs): Central Kimberley (CK1–3); Cape York Peninsula (CYP1–9); Daly Basin (DAB); Darwin Coastal (DAC); Dampierland (DL1,2); Gulf Fall and Uplands (GFU1,2); Gulf Coastal (GUC1,2); Gulf Plains (GUP1–10); Mt Isa Inlier (MII1–3); North Kimberley (NK1,2); Ord–Victoria Plains (OVP1–4); Pine Creek; Sturt Plateau (STU2,3); Victoria–Bonaparte (VB1–3)

NHT regions: Rangelands (Western Australia), Northern Territory, Southern Gulf (Queensland), Northern Gulf (Queensland), Cape York (Queensland)

4.4.2. Biophysical attributes

The Tropical Savannas GLMZ lies within climate zones I1, I2, H: hot tropical climate with strongly seasonal rainfall. There is a pronounced north–south rainfall gradient, so that southern parts of the zone are semi-arid, with a shorter growing season, less reliable rainfall and higher annual temperature range. Mean annual rainfall is between 350 and 1700 mm.

Vegetation can generally be characterised as tropical savanna, although there is considerable variation throughout the region, determined by rainfall, topography and soils. The most extensive vegetation is eucalypt woodlands and open woodlands (VG3,9), but there are very extensive areas of hummock grasslands (VG14), tussock grasslands (VG13) and acacia open woodlands (VG10). The Northern Gulf area is notable for extensive melaleuca woodlands (VG7). The ground layer is almost always dominated by grasses, with grazing mostly based on native perennial tussock grasses. Dominant pasture grass species include *Chrysopogon–Sorghum*; annual *Sorghum*; *Heteropogon*; *Aristida–Bothriochloa*; *Dicanthium–Eulalia*; *Imperata*; and *Triodia*. There is a variety of mangrove and littoral communities along the coastline.

Relatively restricted but important vegetation types include monsoon rainforests, riparian woodlands and forests, river frontage communities, coastal floodplains, permanent and seasonal wetlands, and heathlands on sandstone ranges and coastal dunes.

4.4.3. Socioeconomic attributes

Approximately 75% of the zone is under pastoral land use, with tenure almost entirely pastoral leasehold. There are significant areas of Aboriginal land (14% of the zone), particularly in the North Kimberley, Cape York and parts of the Victoria–Bonaparte, Gulf Fall and Gulf Coastal bioregions, and some of these lands are used for pastoral production.

There is a moderate level of reservation in the zone overall (6.6%), although the level of reservation is highly variable between sub-bioregions and is biased towards unproductive habitats, so that the majority of ecosystems are unreserved within most bioregions. High levels of reservation are associated with a small number of very large reserves (Prince Regent Nature Reserve, Drysdale River National Park, Gregory National Park, Kakadu National Park, several on Cape York).

There is a very low population density throughout the zone (average 8.1 per 1000 km^2), with a small number of cities and large regional centres, a very sparse rural population and scattered Aboriginal communities, and small service centres.

Property sizes are very large (overall sub-bioregional mean = 211,000 ha), with mean property sizes larger than 350,000 ha in parts of Cape York, Kimberley, Ord–Victoria and western Gulf regions. Mean property sizes in the zone are smallest in the Darwin–Katherine region (including Darwin Coastal, Daly Basin, Pine Creek, and northern Sturt Plateau bioregions) and the eastern margin of the Gulf Plains.

4.4.4. Pastoral grazing systems

The major pastoral system is extensive grazing of cattle on very large properties, although pastoral productivity and the level of infrastructure development vary considerably across the zone. Pastoral management is relatively intensive on company-owned properties in the most productive areas, particularly in parts of the Ord–Victoria, Victoria–Bonaparte, Mt Isa Inlier and Gulf Plains bioregions (with cattle densities of 4–7 AE km^{-2}). There is moderate cattle density (overall mean = 2.7 AE km^{-2}) throughout the region, except for low to very low densities in some rocky and/or undeveloped regions of the Kimberley, Gulf Coast and Cape York Peninsula. Sheep are generally absent, but there are a small number of properties running sheep in some parts of the Gulf Plains and Mt Isa Inlier.

Only a very small percentage of the zone is used for irrigated or dryland agriculture, although there has been significant clearing (up to 9% of sub-IBRA area) in parts of Cape York (e.g. near Cooktown and in the Laura Basin) and the Gulf Plains. Further cropping development is continuing or proposed for some areas (e.g. Darwin rural fringe, lower Ord, Daly Basin). While there are minor areas of improved pasture in many regions within the zone, these account for a very low total area (the largest is 5% of the Claraville Plains subregion of the Gulf Plains).

Pastoral use in many regions within this zone relies primarily on natural surface waters, rather than artificial water points. However, the spreading of water (either through bores or damming of watercourses) is important in some regions, particularly lower-rainfall zones.

4.4.5. Wild stock (including feral animals)

Goats and rabbits are generally absent, although there are localised pest populations of goats (e.g. Pellew Islands) and rabbits are present in low numbers in the Gulf Plains.

Buffalo occur mostly in the Top End and near-coastal areas in the Northern Territory and may still be a problem in some habitats, although numbers were reduced in the 1980s during BTEC. Pigs occur throughout the zone and are in damaging numbers in some habitats (particularly western Cape York Peninsula). Donkeys occur at relatively high densities in some areas (e.g. Ord–Victoria), and there are significant numbers of feral cattle and horses in some areas. Active control programs have successfully reduced numbers of large feral grazers (e.g. Kimberley, Victoria River District), but numbers can increase rapidly once controls are reduced.

Macropod densities are generally low (< 0.5 animals km^{-2}), with densities of large macropods too low for culling programs to be implemented. There may be high grazing pressure from some species (e.g. agile wallaby) in localised areas, such as river frontages. There are moderate macropod densities (1–9 km^{-2}) in parts of the Gulf Plains and Mt Isa Inlier.

The estimated mean total grazing pressure in this zone is low to moderate (2.5 AE km^{-2}) compared to the other GLMZs.

4.4.6. Current management of total grazing pressure

Control of stock and large feral herbivores generally improved greatly in the 1980s as a result of BTEC. In many areas, a previous lack of fencing left a legacy of land degradation around natural water and preferred grazing habitats, which has been addressed in some areas with programs of, for example, riparian fencing and rehabilitation work. Numbers of feral animals are actively and effectively controlled in some areas with high levels of pastoral development (e.g. Victoria River District). In other regions (e.g. parts of Cape York Peninsula), infrastructure development and resources are inadequate to control feral grazers, or even to adequately manage stock. Thus, localised degradation may be ongoing, even in areas of very low stocking rates. Pastoral management in some areas (particularly some areas of Aboriginal land) is basically harvesting of ‘killers’ from wild herds.

Grazing management is generally set-stocking based on the rated carrying capacity of land systems or pasture types. There are moves towards more variable stocking rates based on fixed utilisation and seasonal forecasting, although many producers currently have limited capacity to implement this. As yet, there is only limited uptake of alternative grazing strategies such as wet-season spelling and rotational grazing. In some parts of the region, particularly in areas of relatively high productivity, there are moves towards pastoral intensification through further water-point development and reduction in paddock size.

Within Queensland, three large macropod species are commercially harvested, with regional quotas (between 15% and 20% of estimated population size) set annually by the Queensland Environment Protection Agency and approved by the Commonwealth. Landowners may also cull problem kangaroos under a damage mitigation permit. However, most of Cape York Peninsula is outside the harvest zone.

Other TGP issues in the region include:

- Populations of some feral animals (e.g. pigs, buffalo) and/or uncontrolled stock (cattle, horses) have importance for subsistence and some economic return on many areas of Aboriginal land, resulting in a tension between the need to minimise damage caused by these animals and the desire to maintain useful populations.
- The very low population densities, very poor resourcing and poor socioeconomic conditions in many areas of the zone impose severe limitations on land management capability (e.g. weed and feral animal management).
- There are active control programs for dingoes in most pastoral areas of the zone. Suppression of dingo numbers may contribute to increased macropod numbers in some areas.
- As in many of the zones, the distinction between management of TGP specifically and other land management issues (e.g. fire, weeds) in relation to biodiversity conservation is very blurred, as grazing management is intricately linked to each of these other factors.

4.4.7. Biodiversity issues

There are relatively few listed threatened species and ecosystems in most parts of the zone, with a higher number of threatened birds and plant species in Cape York Peninsula (associated with rainforests) and threatened plant species in Darwin Coastal (associated with monsoon rainforests and wetlands) and Pine Creek (associated with sandstone ranges) bioregions. The highest numbers of threatened ecosystems are in Cape York Peninsula, Northern Kimberley (Mitchell) and parts of the Mt Isa Inlier (Mt Isa Inlier) and Gulf Plains (Karumba Plains, Mitchell–Gilbert Fans, Wellesley Islands).

There have been local extinctions of mammals in some regions (particularly less mesic areas, such as the southern and western Kimberley) and there is evidence of ongoing decline in certain taxa (notably granivorous birds and medium-sized mammals). Decline and local extinction of plant species and vegetation types sensitive to frequent or hot fire has been noted in many parts of the region.

There has been ‘thickening’ of native woody vegetation in some areas, particularly in the eastern Gulf Plains and Ord–Victoria regions, and some grassland ecosystems (and associated species) in Cape York are threatened by encroachment of woody species.

Major threatening processes differ somewhat between land type and level of pastoral development, but include:

- Changed fire regimes, both an increase in extensive, hot late-dry-season fires (e.g. Kimberley) and suppression of fire (in more intensive pastoral areas).
- Serious environmental weeds that potentially can spread over very large areas (notably rubber vine [*Cryptostegia grandiflora*], and mimosa).
- The spread of exotic pasture species outside areas where they are intensively managed, to become significant environmental weeds (e.g. gamba grass [*Andropogon gayanus*], exotic grasses used in wetlands or ponded pasture, buffel grass).
- Feral herbivores (including pigs, donkeys, feral cattle, feral horses and water buffalo), which have a serious impact on restricted and sensitive habitats (e.g. monsoon rainforest patches, riparian areas, other wetlands).
- Other feral animals, notably cats and cane toads.
- Land clearing and fragmentation of habitat (where concentrated in small areas of the zone).
- Proliferation of artificial water points and ubiquity of grazing by stock in the most pastorally developed areas.
- Saltwater intrusion (notably in northern Top End floodplains).

4.4.8. Previous research and on-ground work

- Various programs for aerial surveys of feral animals and macropods in parts of zone, which are likely to continue regularly/intermittently.
- Major NHT investment in Cape York Peninsula, including weed and feral program, threatened species management, property planning.
- Uneven uptake of NHT funding across zone, including fencing of riparian and degraded areas, feral animal control and improved weed and fire management. NHT funding is often primarily targeted at capacity building.
- Effective systems for feral grazer control in some areas (e.g. Victoria River District, Kimberley).
- Detailed biodiversity inventories and bioregional conservation planning in some areas (Cape York Peninsula, Daly Basin, Sturt Plateau).
- Current research on pastoral intensification, including pasture sustainability and biodiversity consequences (Victoria River District).
- Substantial past and continuing research effort coordinated by Tropical Savannas Cooperative Research Centre involving many aspects of sustainable land management, including regional fire management,

documentation of best-practice natural resource management by the beef industry, developing grazing management tools for determining and promoting long-term grazing carrying capacity, biodiversity conservation on grazing lands, bioregional planning in tropical savanna NRM regions, woody vegetation management, documentation of Aboriginal traditional ecological knowledge.

- Various Aboriginal land management programs, primarily focusing on the establishment of ranger programs and building management capacity; usually supported by CDEP and NHT funding.
- Implementation of fire, vegetation and biodiversity monitoring programs on some conservation reserves.

4.4.9. Knowledge gaps

The biodiversity of many areas remains very poorly known, so that it is difficult to identify management ‘hotspots’, or adequately describe the impact of various land management regimes on biodiversity.

- There is inadequate and inconsistent listing of threatened species and ecosystems, inhibiting the accurate prioritisation of management effort.
- Robust data for the density of macropods and feral animals in some areas are lacking.
- The potential impact of recent and ongoing proliferation of artificial water points on biodiversity values is poorly understood.
- There is poor understanding of the appropriate biodiversity monitoring tools (at both fine and broad scales) and very limited capacity to implement effective monitoring programs.
- Many land managers have poor knowledge of biodiversity management issues.

4.4.10. Opportunities to invest

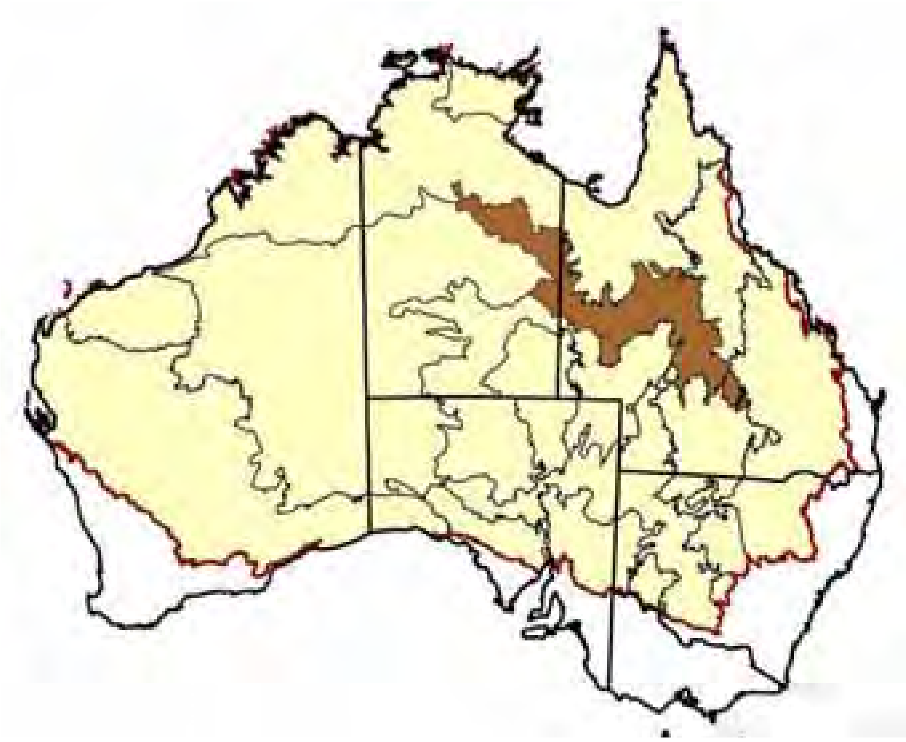
- More than for most other zones, there is still a major requirement for further basic biodiversity inventories and ecological research to identify where management action is most urgently required (e.g. basic vegetation mapping, clarifying fauna species distributions).
- Feral animal control in identified strategic areas (including monitoring of feral populations).
- Weed control (of targeted species) in identified strategic areas.
- Development and implementation of a proper framework, and information, for regional and property management plans that adequately incorporate biodiversity issues and promote ‘off-reserve’ conservation management.
- Integration of property planning with regional conservation planning.

- Provision of meaningful incentives (for public-good conservation), notably in resource-poor areas.
- Provision of basic biodiversity and land management information in forms appropriate to a diversity of land managers.
- Improved reservation in some regions.
- Improved resourcing for management in many conservation areas (e.g. basic fencing of boundaries).
- Implementation of landscape-scale fire management.
- Support of Indigenous land management activities (e.g. through ranger groups).
- Description and promotion of uptake of best-practice sustainable grazing land management.

4.5. Zone 3 – Mitchell Grass Downs

Compiled by Alaric Fisher

Characterised by cracking-clay plains or undulating downs with Mitchell grassland or acacia open woodlands; semi-arid and arid climate with summer rainfall; grazing of cattle on very large properties on leasehold land, or grazing of cattle and sheep on medium-sized properties on freehold land (in the east and south-east); relatively high total grazing pressure; high level of infrastructure development and high density of artificial water points.



4.5.1. Regional attributes

Area: 336,000 km^2

Bioregions (sub-IBRAs): Mitchell Grass Downs (MGD1–8)

NHT regions: Northern Territory, Southern Gulf, Desert Channels

4.5.2. Biophysical attributes

Lies within climate zones G & H: hot, semi-arid to arid. Most of the zone lies within the influence of the northern monsoon, so there is a pronounced summer wet season, but there is also an increased influence of winter rain in the east. Towards the south-west, total rainfall decreases, and rainfall variability and temperature range increase. Mean annual rainfall is between 200 mm and 550 mm.

The zone is characterised by very extensive plains and rolling downs with cracking-clay soils and perennial tussock grasslands, usually dominated by *Astrebla* spp. In some areas, particularly towards the east, there are 'wooded downs' with a sparse cover of acacia, eucalypt, *Terminalia* or other tree species. Other significant vegetation types occurring on heavy clay soils include gidgee *(Acacia cambagei* or *A. georginae)* woodlands, bluebush (*Chenopodium auricomum*) swamplands and eucalypt (e.g. coolibah [*Eucalyptus microtheca* sens. lat.]) open woodlands. The driest margins of the zone have open herb- and grasslands on gravel-covered plains ('stony downs'). Other vegetation types are associated with relatively small areas of coarser-textured soils on low hills and remnant plateaus, including lancewood (*Acacia shirleyi*) woodlands and spinifex plant communities.

The most important restricted vegetation types are associated with wetlands, including natural permanent waterholes, riparian woodlands, and shrublands and woodlands associated with seasonal swamps or intermittent lakes.

4.5.3. Socioeconomic attributes

More than 95% of the zone is under pastoral land use, with pastoral leasehold tenure in western Queensland and the Northern Territory and pastoral freehold in the Northern, Central and Southern Wooded Downs in central Queensland. The area of Aboriginal land in the zone is very small, confined to small community living areas in the Northern Territory.

The overall level of representation in conservation reserves is very low (1.1%), and the area of reserves is very low or zero in most of the sub-bioregions in the zone, with the notable exception of the Southwestern Downs (7.8%), which includes parts of the large Diamantina and Astrebla Downs national parks.

There is an extremely low population density throughout the zone (2.6 people per 1000 km^2), primarily in scattered pastoral homesteads. Population density is greatest (c. 4 per 1000 km^2) in the east and south-east of the zone.

Mean property size across the region is large (187,000 ha), but there is a pronounced trend from very large (400,000 ha) leasehold properties in the west to much smaller (20,000 ha) freehold properties in the east.

4.5.4. Pastoral grazing systems and other land uses

The major pastoral system is extensive grazing of cattle on large properties in the west of the zone, with a mix of sheep and cattle on the smaller properties in central Queensland. There is a moderate cattle density in the zone overall (3.9 AE km^{-2}), with sub-bioregional densities between 2.8 and 6.9 AE km^{-2}. The overall sheep density is low (8.6 DSEs km^{-2}) and sheep are generally absent west of the Kynuna area; sheep densities are highest in the Central Downs region (22.6 DSEs km^{-2}).

The estimate of mean total grazing pressure in this zone (4.8 AE km^{-2} or 48 DSE km^{-2}) is higher than all other GLMZs, except Zone 4 (Einasleigh and Desert Uplands) and Zone 10 (Highly Modified Rangelands).

There is a relatively high level of infrastructure development, with stock primarily watered from artificial water points (bores and tanks). As a result, the percentage of water-distant land is very low: the estimated area further than 6 km from water (9.9%[b]) is lower than all zones except Zone 10, and the area further than 9 km (2.3%) is the lowest of all zones. Again, there is a marked

[b] Note that all estimates of % area of water-distant land are <u>over-estimates</u>, as they are based only on mapped and named water points.

east–west distinction, with the area of land further than 6 km from water being less than 0.25% of land in central Queensland, but between 9% and 32% of sub-bioregions in western Queensland and the Northern Territory.

There are virtually no areas of irrigated or dryland agriculture in the region. An estimated 3.4% of the zone has been subject to clearing, with clearing concentrated on gidgee [*Acacia cambagei*] and brigalow (*Acacia harpophylla*) communities in the east and south-east of the zone (particularly in the Southern Wooded Downs, with 24.2% cleared). Clearing is generally associated with replacement of native pastures with buffel grass or other exotic pasture grasses.

4.5.5. Wild stock (including feral animals)

Goats and rabbits are present, but generally in low numbers, through most of the Queensland portion of the zone, and pigs are present in generally low numbers in the wetter areas.

Macropod densities are low (< 5 animals km^{-2}) in the north-west of the zone, increasing towards the east and south-east, with densities of about 20 km^{-2} in the Southern Wooded Downs.

4.5.6. Current management of TGP

While the total grazing pressure in this zone may be relatively high, stocking rates and the distribution of grazing are relatively well controlled due to the high level of development of pastoral infrastructure. Grazing management is generally set-stocking based on rated carrying capacity or variable-stocking based on set utilisation levels (e.g. 30% utilisation recommended for Queensland Mitchell grasslands), with considerable movement of stock between (at least the company-owned) properties in response to seasonal variation. However, the extent of seasonal variation and local patchiness of rainfall may result in overgrazing in some years, before stock numbers can be reduced.

Grazing distribution is largely controlled by the distribution of water points, and there are general moves towards pastoral intensification (and a more even utilisation) through the continued development of water points and reduction in paddock size. To date, there has been little use of fire to manipulate grazing distribution.

Within the Queensland part of the GLMZ, three large macropod species are commercially harvested, with regional quotas (between 15% and 20% of estimated population size) set annually by QEPA and approved by the Commonwealth. Landowners may also cull problem kangaroos under a damage mitigation permit.

4.5.7. Biodiversity issues

There is a low level of reservation overall in this zone, and very poor reservation of most regional ecosystems at a subregional level (there is no reservation in 4 of the 8 sub-bioregions of the zone, and between 10% and 38% of regional ecosystems are included in reserves in the other 4 sub-bioregions). There are significant numbers of threatened regional ecosystems within the Queensland part of the zone, two of which are considered endangered (4.3.22 – mound springs; 4.4.2 – brigalow & gidgee low woodland on undulating clay plains). There are relatively few listed threatened plant and animal species, the greatest number occurring in the Southwestern Downs (10 species) and Central Downs (11 species); some of the most significant species are represented in Diamantina and/or Astrebla Downs national parks. There is evidence of historical and probably ongoing decline in a number of taxa within this zone, most notably granivorous birds (such as the flock bronzewing [*Phaps histrionica*]).

Habitat diversity within this zone is relatively low, contributing to low overall diversity of species and a low irreplacability index (for plants and birds) compared to other zones. Nevertheless, the cracking-clay ecosystems contain a number of endemic plant and animal species (or species showing a distinct preference for these ecosystems).

The impact of pastoral land use on biodiversity has been relatively well studied in Mitchell grasslands in the Northern Territory. While the system appears to be generally relatively resilient to grazing pressure, a number of species (16 vertebrate, 21 ant, 25 plant species) were identified as having a decreaser response, the majority of these species also being largely confined to this habitat.

There are a large number of significant wetlands within the zone (including 8 listed in the Directory of Important Wetlands in Australia), most notably the large seasonal lakes on the Barkly Tableland; permanent waterholes and riparian woodlands along major drainage channels; and mound springs in western Queensland.

The major threats to biodiversity in this GLMZ are:

- The ubiquity of pastoral land use and the widespread occurrence of artificial water points, which has ensured that virtually all areas are subject to significant levels of grazing by stock, and native and feral grazers. The small and declining area of water-remote land provides limited refuge for decreaser (grazing-sensitive) taxa. Decline in some species may be accelerated by further intensification of pastoral use.

- The concentration of grazing pressure on some sensitive and restricted ecosystems, notably natural waterholes, swamps, riparian frontages and alluvial plains.

- Some widespread environmental weeds, notably prickly acacia (*A. nilotica*), mesquite (*Prosopis glandulosa*) and parkinsonia (*Parkinsonia aculeata*), which are continuing to increase in distribution range and density.

- Feral predators (cats and foxes). Cats appear to occur in relatively high densities in the Mitchell grass downs, particularly following irruptions of the native long-haired rat (*Rattus villosissimus*) and have probably contributed to the decline of a number of threatened vertebrate species.

- Clearing of native vegetation and replacement of native pastures with exotic species in the south-east of the region.

- Localised impacts from feral herbivores (including cattle and horses), and possibly high densities of large macropods.

The implications for biodiversity of the general suppression of fire in pastoral areas is very poorly understood.

4.5.8. Previous projects and on-ground work

- A long history of research into pasture dynamics and grazing effects in Mitchell grasslands (focusing on dominant pasture species, rather than biodiversity more broadly).
- Detailed research on biogeography and effects of grazing on biodiversity in NT parts of the zone.
- Analysis of floristic variation in Queensland Mitchell grasslands.
- Repeated surveys of waterbirds and migratory waders in NT wetlands.
- Localised biodiversity inventories in parts of Queensland.
- Detailed studies of some threatened species, including bilby (*Macrotis lagotis*), Elizabeth Springs goby (*Chlamydogobius micropterus*), Julia Creek dunnart (*Sminthopsis douglasi*).
- Aerial surveys of feral animals and macropods in both NT and Queensland parts of zone, which are likely to continue periodically/intermittently.
- Uneven uptake of NHT funds for land management activities, including weed control and riparian fencing.
- Research into ecology and management of major weed species, such as prickly acacia.

4.5.9. Knowledge gaps

- There has been no broad-scale, systematic inventories of the biodiversity of the central and south-eastern regions of the Mitchell grass downs, and the impact of total grazing pressure on biodiversity in these areas is poorly known.
- While the biodiversity value of many wetland areas is well documented, the appropriate management to protect these values is poorly understood. While exclusion of stock through fencing may be a precautionary approach, it may not always offer the most cost-effective solution.
- The impact of changed fire regimes on biodiversity in this zone is very poorly understood. Fire is generally suppressed under pastoral management, and grazing by stock has replaced fire as a major disturbance. In areas where grazing pressure may be absent or greatly reduced, some disturbance by fire may be necessary to maintain (or enhance) plant and animal diversity.
- The impact of further pastoral intensification on biodiversity (particularly through the proliferation of water points) can be postulated, but has not been adequately demonstrated.

4.5.10. Opportunities to invest

- Basic biodiversity inventories in central and eastern parts of the zone, combined with research into the impact of grazing pressure and the proliferation of water points on biodiversity.

- Regional and property management plans that implement effective off-reserve conservation, particularly protection of sensitive habitats of high biodiversity value (e.g. wetlands, threatened species habitat) and maintenance of water-remote (or lightly grazed) parcels within each ecosystem.

- Incentives to limit proliferation of water points and implement off-reserve conservation provisions (listed above).

- Further research and development of best-practice guidelines for the use of fire in pastoral management.

- Strategic weed control to prevent further spread of critical species.

- Development and promotion of guidelines for maintaining biodiversity values in the context of pastoral intensification.

- Improved reservation in most of the zone.

4.6. Zone 4 – Einasleigh and Desert Uplands, North Queensland

Compiled by Jill Landsberg

Characterised by a diverse mosaic of mainly hilly tropical eucalypt woodlands, with small properties grazing beef and sometimes sheep at moderate to high densities.

4.6.1. Regional attributes

Area: 189,392 km^2

Bioregions: Einasleigh Uplands (all 6 subregions) and Desert Uplands (all 3 subregions)

NHT natural resource management regions: Most of the zone is in the Northern Gulf and the Burdekin Dry Tropics NRM regions, with smaller areas in the Wet Tropics, Southern Gulf and Desert Channels. The Desert Uplands regional implementation group, which overlaps the Burdekin Dry Tropics and Desert Channels NRM regions, takes primary responsibility for NRM in the Desert Uplands Bioregion.

4.6.2. Biophysical attributes

The GLMZ lies primarily within climate zones I (hot, seasonally wet/dry) in the north and H (hot, dry) in the south. Most of the northern subregions are in climate zone I3, which has cooler winters and a longer growing season (at least 6 months) than other classes in zone I, and is considered capable of some cropping. Climate zone H, which characterises most of the southern subregions, has a semi-arid climate, generally with some growth in the warm season, but too dry for cropping. The marked north–south decline in rainfall across the GLMZ coincides with decreasing distance from the east coast. Mean annual rainfall in the zone is between about 420 mm and 1500 mm.

Landscapes in the zone are diverse but generally hilly, with areas of plains and downs. Soils are often poor (e.g. lithosols, podzolics, sands) interspersed with areas of richer earths, clays and krasnosems. The vegetation is dominated by eucalypt woodlands (56%) and open woodlands (29%), with smaller areas of acacia forests and woodlands (6.7%), eucalypt tall open forests (2.6%) and tussock grasslands (2.6%). The ground layer is usually dominated by perennial tussock grasses, including speargrasses (*Heteropogon* spp.), bluegrasses (*Bothriochloa* spp., *Dichanthium* spp.), Mitchell grasses (*Astrebla* spp.), and wiregrasses (*Aristida* spp.). Spinifex is widespread on sandy soils and lithosols, particularly in the south. Restricted but biologically rich habitats within the zone include dry rainforests developed on limestone outcrops, basalts and granites; floristically rich woodlands on rock outcrops and sandstone ranges; limestone caves and lava tunnels; springs and spring-fed wetlands; seasonal and permanent lakes; and riparian corridors.

4.6.3. Socioeconomic attributes

The human population density in the zone is low, though not unduly so compared with other parts of the rangelands, with about 6.8 people per 1000 km^2.

The largest towns in the zone are Mareeba in the north-east, and Charters Towers in the south-east. There are also several smaller towns across the zone.

Most land is privately held leasehold (80.5%), with some (15.9%) freehold, mostly in the more humid areas nearer the coast. Conservation land occupies only 2.4% of the zone; Crown land, 1.6%, and Aboriginal land, a minuscule proportion (< 0.01%). The Conservation land is spread between a number of small–medium national parks, with the largest being Lumholtz, Undara, Bulleringa, White Mountains and Moorrinya.

Property sizes are very small by rangeland standards, averaging 34,200 ha. The smallest properties are those closest to the coast in the north, where the average property size is just over 12,000 ha. The largest property sizes occur furthest from the east coast, in the Georgetown–Croydon subregion, where they attain a maximum of 81,000 ha.

Most of the zone (91.6% overall) is used for grazing of native pastures, with some improved pastures (1.3%), dry cropping (0.07%) and irrigated cropping (0.04%). Cropping occurs mainly in the more humid north-eastern Einasleigh subregions, though there is also significant dryland cropping (0.2%) in the southernmost Desert Uplands subregion. The overall proportion of improved pastures (1.3%) is moderately high by rangeland standards. Their greatest extent is in the south, in the Alice Tableland subregion of the Desert Uplands and the Undara Basalts subregion of the Einasleigh. The Alice Tableland has the highest overall level of pasture improvement (3.5%) despite having the driest climate in the GLMZ.

The Desert Uplands subregions have also undergone the most clearing, ranging from 7.9% to 13.7% per subregion. This contrasts with clearing extents of 4.4% and 4.5% in the more humid north-eastern Einasleigh subregions.

Most other subregions are less than 1% cleared. The proportion of land cleared from the GLMZ overall is 5.4%.

Mining occurs throughout the zone, and has locally severe impacts on land condition.

4.6.4. Pastoral grazing systems

Cattle are the main livestock grazed, with an average overall density of 6 AE km^{-2}, which is moderate by rangelands standards. Sheep are also grazed at low densities in some subregions, with an average overall density of 3.5 DSE km^{-2}. There is, however, considerable variation in stocking densities and the level of infrastructure development across the zone. Highest livestock densities and smallest property sizes are concentrated in the southern subregions, particularly the Desert Uplands. Similar patterns are apparent in the development of livestock watering points. In the GLMZ overall, 19% of the landscape is more than 6 km from water, but only 2%, 3% and 15% of the Desert Uplands subregions are this water-remote. In contrast, proportions of the 6 Einasleigh subregions 6 km or more from water range from 15% to 39%. Patterns are similar for areas > 9 km from water, though, overall, only 9.5% of the landscape is this far from water. Most water is provided by dams and bores, though natural springs and rivers are also used where available.

4.6.5. Wild stock (including feral animals)

Densities of macropods are moderate by rangeland standards, averaging 4.6 animals km^{-2} overall. Their densities are highest in the Desert Uplands subregions, where the density of watering points is also highest. Though overall densities are lower in other subregions, there may be high grazing pressure from some species (e.g. agile wallabies) in localised areas, such as river frontage.

There are occasional feral goats in the Desert Uplands, but not elsewhere. Rabbits are reportedly common in all subregions. Feral pigs are widespread and moderately abundant in riparian and wetland areas. There are no feral buffalo. Feral cattle are common in some of the national parks.

4.6.6. Current management of TGP

At 5.93 AE km^{-2}, the combined density of cattle, sheep and macropods is moderate to high by rangeland standards. Within the subregions the pattern of TGP generally follows that of clearing and water development, with the highest total density of livestock and macropods in the three Desert Uplands subregions, and the lowest in the northernmost subregions of the Einasleigh Uplands. Parts of the Desert Uplands have undergone little development for grazing because of limited surface water and widespread poison bush (*Gastrolobium grandiflorum*).

Most grazing properties are boundary fenced, but the level of internal subdivision is highly variable across the zone. Properties are mostly stocked year round at densities determined by seasons and the individual mix of land types within paddocks. However, the mosaic of land types usually present makes it difficult to control localised impact due to preferential grazing. Decisions about stocking rates are often based on the condition of the cattle and the pastures at the end of the wet season; and stocking numbers may be reduced if there is not full ground cover. However, small property sizes limit the capacity of some landholders to reduce stocking rates to below the minimum needed to remain viable. Many properties have been able to increase stocking rates by providing a phosphorous supplement over the wet season, and urea-based licks during the dry season. Some properties aim to spell country regularly, though this is only possible if properties are large enough, and adequately fenced.

Dingoes and pigs are seen as the main problem animals by most landholders, with kangaroos and wallabies identified as problems only in some areas. Most properties have dingo baiting programs and many also control pigs by baiting, trapping and/or shooting. Few if any have regular programs for controlling kangaroo or wallaby populations.

4.6.7. Biodiversity issues

Because of its complex geology and wide range of altitudes and climate, the zone has a large number of diverse ecosystems, some of which are inherently vulnerable because of their small size, and others of which are considered threatened by current land use.

High indices of irreplacability (0.4 for flora only, 0.43 for flora and birds) indicate that many of the zone's flora and fauna may have conservation significance. Unfortunately, numbers of species listed as rare or threatened are also relatively high by rangeland standards. In 1999 there were 62 plant species and 38 animal species listed under state legislation in the Einasleigh Uplands, and 21 plant species and 33 animal species listed in the Desert Uplands. One animal species, the western quoll (*Dasyurus geoffroii*), is presumed extinct in both bioregions. Several previously widespread seed-eating birds (e.g. Gouldian finch [*Erythrura gouldiae*], star finch [*Neochmia ruficauda*], golden-shouldered parrot [*Psephotus chrysopterygius*], crimson finch [*Neochmia phaeton*]) are listed as threatened in both bioregions, presumably because of widespread changes to their habitats. Most of the other listed species of plants and animals are associated with specialised habitats of limited extent. Of these, the ones most threatened by current land use are the springs and riparian systems, because they are also foci of cattle grazing and weed invasion. Others, particularly the most rocky habitats, are naturally protected from grazing impacts by their inaccessibility. The most widespread processes causing threats to biodiversity are all related to management of pastoral enterprises. They are:

- Widespread land degradation (sheet and gully erosion, scalding, riverbank erosion, some dryland salting) caused by unsustainable grazing pressure, particularly in areas where holdings are small.
- Moderate levels of clearing and thinning of woody vegetation to improve pasture growth, often in association with planting and spread of buffel grass.
- Infestations of environmental weeds (especially rubber vine and lantana [*Lantana camara*]) in restricted habitat types, particularly dry rainforests, wetlands and riparian corridors.
- Changes in fire regimes (deliberate fire suppression to protect pastures coupled with infrequent but very extensive wildfires).

- Widespread woody thickening (partly due to fire suppression but also related to grazing pressure and seasonal preconditions), with unknown consequences for biodiversity.

Other processes that cause local threats to biodiversity include:

- Clearing for horticulture and cropping in the more humid parts of the zone.
- The impact of mining, particularly the development of access tracks and the management of contaminated tailings.

4.6.8. Previous research and on-ground work

- Devolved grants for riparian fencing in many parts of the GLMZ.
- Various projects funded by the Tropical Savannas CRC, including:
  - fauna surveys in the Desert Uplands
  - documentation of best-practice natural resource management by the beef industry
  - developing grazing management tools for determining and promoting long-term grazing carrying-capacity as a tool for sustainable management
  - biodiversity on grazing lands
  - FIREPLAN regional fire-management studies
  - bioregional planning in tropical savanna NRM regions.
- Various projects funded by the North Australian Program of Meat & Livestock Australia, including:
  - fire strategies to manage woody thickening for sustainable grazing
  - documentation of producer experience in beef property management.
- Various projects funded by Land & Water Australia, including: incorporating biodiversity monitoring into rangeland condition assessment.
- Various projects undertaken by the Environmental Protection Agency of Queensland, including:
  - mapping of regional ecosystems, and associated reconnaissance botanical survey
  - development of a conservation plan for biodiversity in the Desert Uplands.
- Various projects undertaken by the Australian Centre for Freshwater Research at James Cook University, including Dalrymple Shire Aquatic Habitat Study.

- Various projects funded under NHT2, including customisation of the Grazing Land Management education package for Queensland savanna regions.

4.6.9. Knowledge gaps

- The biodiversity of many areas is still very poorly known, particularly in Einasleigh Uplands, where very little of the bioregion has been systematically surveyed for fauna.
- There has been no systematic documentation or monitoring of the location and extent of woody thickening across most of the zone, nor of its effects on biodiversity.
- The effects of various land management regimes on biodiversity are poorly understood and often unknown. Common but poorly understood management strategies in this GLMZ include thinning of woody vegetation to increase pasture growth and/or reverse the effects of thickening; implementing fire regimes to control woody thickening; the use and location of livestock supplements; oversowing of native pastures with tropical legumes; and wet-season spelling of pastures.
- Because of the paucity of systematic surveys throughout the GLMZ, lists of threatened species include some species that are not actually threatened, and do not include other species that may be under threat.
- There are no data available on the density of feral pigs or rabbits across the zone, nor on the density of potentially problematic macropods, particularly agile wallabies.
- The impact of recent and ongoing proliferation of water points on biodiversity has not been documented.
- Land managers and regional planners generally lack appropriate broad- and fine-scale tools for monitoring biodiversity.
- There is a poor knowledge of biodiversity management issues among many land managers.

4.6.10. Opportunities to invest

- The Desert Uplands build-up program offers opportunities for planned intensification based on the development of new watering points, with areas deliberately set aside for nature conservation.
- Devolved grant schemes for fencing of biodiverse springs, wetlands and riparian corridors offer opportunities to invest in determining their efficacy in conserving species and ecosystems of conservation significance.
- Planned systematic surveys of flora and fauna in the Northern Gulf NRM region offer opportunities to invest in improving the strategic value of listed threatened species, and in providing regional conservation planning in poorly documented regions.

- Planned research aimed at documenting woody thickening offers opportunities to invest in determining its effects on biodiversity.

- Current management strategies aimed at improving land sustainability, including thinning of woody vegetation, wet-season spelling, and the use of fire to reduce woody thickening, offer opportunities to invest in testing their efficacy in conserving biodiversity.

- Current research on customisation of the Grazing Land Management education package for this zone offers opportunities to invest in developing and incorporating effective biodiversity monitoring tools in the package. In addition, the Einasleigh and Desert Uplands share many of the investment opportunities common to other rangeland regions including:

  - further basic biodiversity inventories to identify where management action is most urgently required (particularly clarifying fauna species distributions in the Einasleigh Uplands)

  - weed and feral animal control of targeted species in identified strategic areas (including monitoring of pest populations)

  - integration of property planning with regional conservation planning

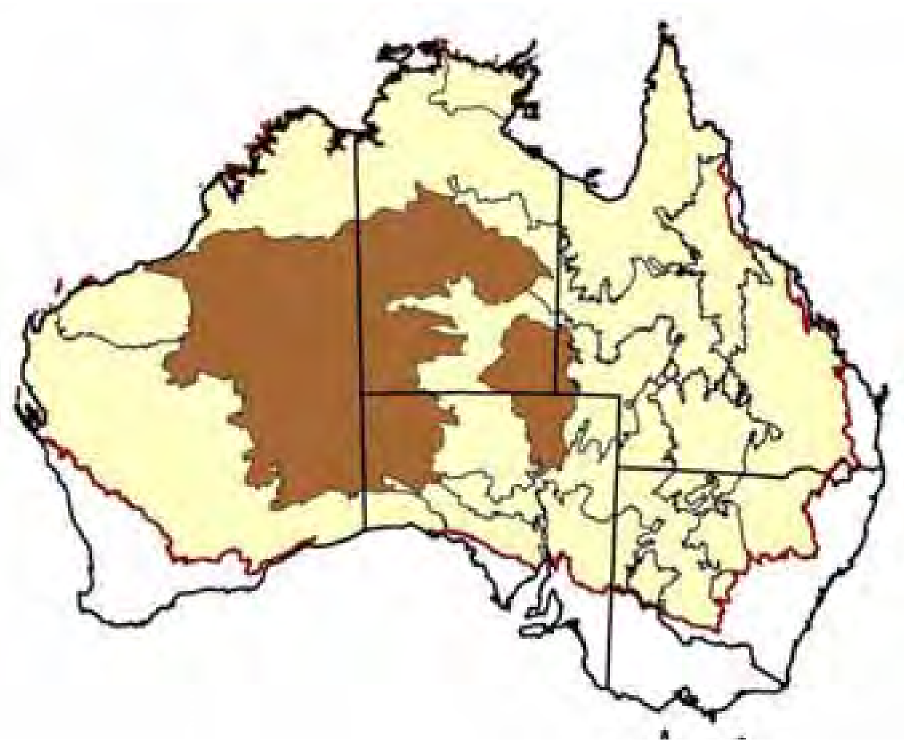
  - provision of meaningful incentives for public-good conservation, notably when conservation values are high, active management is needed, and other sources of income are foregone

  - provision of basic biodiversity and land management information in forms appropriate to a diversity of land managers.

4.7. Zone 5 – Arid Deserts

Compiled by Craig James and Leigh Hunt

Characterised by a hot, very dry climate; hummock grasslands (*Triodia* spp.) with a mixture of acacia woodlands and shrublands, chenopod shrublands and eucalypt woodlands; Aboriginal land and Crown land, with some areas of extensive pastoralism and conservation.



4.7.1. Regional attributes

Area: 1,661,505 km^2

Bioregions (subregions): Central Ranges (CR1–3), Davenport–Murchison Range (DMR1–3), GD12, Great Sandy Desert (GSD1–6), Great Victoria Desert (GVD2–4), LSD12, MacDonnell Ranges (MAC1,2), Nullarbor (NUL1), Simpson Strzelecki Dunefields (SSD2,3), Sturt Plateau (STU1), Tanami (TAN1–3)

NHT regions: Northern Territory, Desert Channels, Rangelands (South Australia), Aboriginal Lands, Rangelands (Western Australia)

4.7.2. Biophysical attributes

This zone is dominated by climate code G, with some of the zone experiencing climate E6. The former climate region is mostly hot, arid 'desert' areas and includes some of the driest parts of the continent, where there is little plant growth. Rainfall is unreliable and varies from winter-dominant in the south, to aseasonal in Central Australia, to more summer-dominant in the north. Climate E6 represents the southern margins of the arid interior. The climate is semi-arid but still too dry to support cropping. Median annual rainfall in the zone is between 100 mm and 300 mm.

Hummock grasslands (VG14) (dominated by *Triodia* spp.) is the major vegetation type, covering about 75% of the zone. Acacia open woodlands (VG10) and acacia forests and woodlands (VG4) each cover approximately 5% of the zone. Chenopod shrublands (VG16) occur on the southern margin of the zone. Eucalypt open woodlands (VG9) and mallee woodlands and shrublands (VG11) are minor vegetation types.

4.7.3. Socioeconomic attributes

Approximately 39% of the zone is Aboriginal land, which is principally used for cultural, domestic living and subsistence purposes (e.g. the Anangu Pitjantjatjara Aboriginal Lands of north-western South Australia, and others). Only about 14% is used for pastoral purposes, and this is held mostly as pastoral leasehold. The Woomera Prohibited Area (defence use) partly overlaps Aboriginal land and pastoral land in the zone in South Australia.

There is a moderate level of reservation in the zone overall (6.5%), although the level of reservation is highly variable between sub-bioregions. Major reserves dominate the area set aside for conservation (e.g. Witjara National Park, Gibson Desert Nature Reserve, Great Victoria Desert Nature Reserve and the Namungarintja Conservation Park). The majority of ecosystems are unreserved within most bioregions.

A large proportion (38%) of the zone is Crown land.

Tourism is an important land use in restricted parts; for example, the Uluru region south-west of Alice Springs.

Human population density is low throughout most of the zone (overall 1.4 per 1000 km^2), with few cities but several large regional centres, a very sparse rural population and scattered Aboriginal communities and small service centres.

4.7.4. Pastoral grazing systems

Very limited areas are used for pastoral purposes and these tend to be on the margins of the zone where it adjoins areas having greater water availability and/or greater rainfall and hence pasture growth. Sheep and cattle densities are very low (0.24 DSE km^{-2} and 0.81 AE km^{-2}), although locally densities can be higher. Surface water is scarce and much of the zone is greater than 9 km from water, although this distance does not account for the ability of camels (the principal [feral] grazing animal – see below) to travel greater distances from water. Pastoral management is generally set-stocking with adjustments according to seasonal conditions (due to changes in forage availability rather than water, which is mostly bore water). Some opportunistic stocking occurs in response to favourable seasonal conditions.

On Aboriginal land and pastoral areas some wild or semi-wild stock (cattle) as well as feral species (rabbits and cats) are harvested for subsistence. There is a nascent industry developing around the capture of feral camels for live export and meat.

4.7.5. Wild stock (including feral animals)

Camels and rabbits are the main wild stock species present. Camel numbers have been increasing in recent years and can occur in locally high numbers, depending on the region (especially adjacent to pastoral country). Rabbit densities are generally moderate to very low in the north of the zone. Mean macropod density is 0.9 kangaroos km^{-2}. Overall, TGP is low to moderate (0.79 AEs km^{-2}) because of the low rainfall and productivity of the region.

Goats are absent. Occasional donkeys occur in the northern reaches of the zone.

4.7.6. Current management of TGP

Most of the area has never been subject to pastoral use, and there is minimal development of pastoral infrastructure. No active management of grazing pressure occurs in this zone outside of the land used for pastoral purposes. Throughout the zone there are scattered bores that tap underground water supplies and these can become foci for substantial activity of water-dependent species (e.g. waterholes along the Canning Stock Route and Purni bore in the Simpson Desert which act as foci for water-dependent birds). Rabbit haemorrhagic disease (RHD) (and to a lesser extent myxomatosis) may occur in rabbit populations, with occasional outbreaks following favourable conditions.

Indigenous communities are the major settlements located in this zone and the residents constitute the major inhabitants in the zone. A history of no use by domestic stock across much of the zone offers an opportunity for long-term protection of unmodified or slightly modified habitat. However, low population densities and the lack of economic incentives will limit the capacity for extensive work in the zone. Activities will need to be targeted at restricted high value ecosystems.

4.7.7. Biodiversity issues

Much of the zone contains flora with a low to moderate endemicity index, but for certain regions the index is high (e.g. Central Ranges, parts of MacDonnell Ranges, Great Victoria and Gibson deserts). Several threatened bird, vascular plant and mammal species occur in the zone. Few ecosystems are protected in reserves, but few ecosystems are listed as threatened. Mammal extinctions have occurred in the past. Cats, foxes and rabbits are regarded as the prime causes of these extinctions.

Major threatening processes are changed fire regimes, feral camels and, in some land systems, rabbits. Overgrazing by domestic stock is an issue in the small areas used for pastoral purposes.

Approximately 90% of the area is greater than 6 km from water, and 82% is greater than 9 km from water, but camels may move substantially more than 9 km from water to forage.

Potentially there is tension between reducing feral cattle and camel numbers and retaining useful densities for subsistence and economic use by Aboriginal people.

Hunting of native mammals and reptiles by Aboriginal people may cause localised declines in some species near settlements.

4.7.8. Previous projects and on-ground work

- Intermittent control of camels.
- Control (by aerial shooting) of feral cattle and horses during the 1980s as part of the BTEC.
- Ethnographic surveys of mammal and reptile populations (past and present).
- Fauna surveys in Western Australia and South Australia desert regions.
- Indigenous Protected Area programs (e.g. black-footed rock wallaby [*Petrogale lateralis*] protection around Warburton).
- Fauna surveys and threatened species management plans for mulgara (*Dasycercus cristicauda*) in the Tanami Desert and Great Desert skink (*Egernia kingii*) around Uluru National Park and into the Gibson Desert.
- Fire pattern and process studies in the Tanami Desert, and around Warburton and Mutitjulu community (Uluru).

4.7.9. Knowledge gaps

- Priority areas for feral animal control.
- Environmental effects of dramatically increased camel population.
- Cost–benefit analyses for feral animal control, involving ecological, economic and social considerations.
- How to implement effective feral management given social, economic and logistic constraints.
- Optimum fire regimes for biodiversity management.
- Landscape-scale changes to fire regimes.

4.7.10. Opportunities to invest

Aboriginal communities and Indigenous Protected Area agreements offer the best opportunity for addressing specific biodiversity issues on communal lands. Specific opportunities include:

- Engaging Aboriginal communities in land management and monitoring for biodiversity (through the formation of ranger groups where they do not already exist).
- Resourcing Aboriginal people for land management.
- Research to determine cost–benefit analyses for feral animal control, and how to implement effective feral management across remote and arid country.
- Adaptive management experiments on landscape-scale fire regimes.

- For pastoral areas, the development and implementation of grazing management practices conducive to the protection of biodiversity, in conjunction with infrastructure planning to protect sensitive and/or important areas.

4.8. Zone 6 – Central Cattle Grazing

Compiled by Craig James

Characterised by hot, very dry climate; mixture of acacia woodlands, chenopod shrublands, spinifex and tussock grasslands; extensive grazing of cattle at relatively low density on very large leasehold properties.

4.8.1. Regional attributes

Area: 542,707 km^2

Bioregions (subregions): The Central Cattle Zone consists of 23 subregions: Burt Plain (BRT1–4), Channel Country (CHC1–7); Finke (FIN1–4), Great Victoria Desert (GVD5), MacDonnell Ranges (MAC3), Simpson Strzelecki Dunefields (SSD1,4), Stony Plains (STP1,2,4,5)

NHT regions: Rangelands (South Australia), Northern Territory, Desert Channels (Queensland)

4.8.2. Biophysical attributes

This zone lies entirely within climate zone G: warm to hot, very dry climate. Mean annual rainfall is low throughout the zone, with very high inter-year variability (annual coefficients of variation exceed 60%). Annual median rainfall increases slightly from north to south (c. 100 mm to 380 mm), with more seasonal (summer) rainfall in the north and north-east.

The variety of landforms in the zone include extensive gibber plains, sand plains, low rocky ranges, areas of dunefield, desert river floodplains and floodouts, and the braided floodplains of the Georgina and Diamantina river systems.

The major vegetation types within the zone are acacia woodlands (primarily mulga [*A. aneura*], and gidgee in the Channel Country), chenopod (*Atriplex* and *Maireana* spp.) shrublands (which are most common in the south of the zone), tussock grasslands (including Mitchell grasslands [*Astrebla* spp.] on stony plains, mixed species grassland on the Channel Country floodplains and canegrass on dunefields), and spinifex grasslands on sandplains and dunefields.

Significant habitats of restricted extent include riparian woodlands and waterholes along major watercourses, mound springs, ephemeral wetlands, relatively nutrient-rich floodout areas, and gorges in rocky ranges.

4.8.3. Socioeconomic attributes

Approximately 86% of the zone is under pastoral land use, almost entirely within pastoral leasehold. Pastoral land use covers 80–100% of each subregion, with the exception of the Great Victoria (GVD5) subregion, where only the eastern third is used for pastoralism. There are some areas of Aboriginal land (6% of the zone), particularly on the western margin of the zone.

Only 4.6% of the zone is within conservation reserves, and the level of reservation is highly variable between sub-bioregions (with virtually no reservation in the Burt Plain and Finke bioregions), and a very small proportion of regional ecosystems reserved in most sub-bioregions.

The population density (overall 1.5 per 1000 km^2) is lower than any other pastoral GLMZ, with a very sparse rural population primarily in widely spaced pastoral homesteads.

4.8.4. Pastoral grazing systems

The major pastoral system is extensive grazing of cattle on very large properties. Pastoral property sizes range from 121,200 to 979,600 ha (average 441,900 ha).

The mean cattle density (overall mean = 1.2 AE km^{-2}) is lower than other GLMZs where cattle predominate. Highest cattle densities are found in the Channel Country in the north-east of the zone. The Channel Country pastures are very productive following floods and they support relatively high densities of cattle during these periods.

Sheep are also grazed on some properties in the southern part of the zone (Channel Country, Finke and Stony Plains bioregions), but sheep density is relatively low (overall mean = 1.62 DSE km^{-2}).

Pastoral use throughout the zone is largely dependent on artificial water points (bores and dams) fed from underground water sources (i.e. the Great Artesian Basin in the eastern portion and local aquifers associated with riverine systems), although there may be concentrations of stock on permanent or intermittent natural waters. The estimated area of water-distant land is higher than most of the other GLMZs (apart from the ‘non-pastoral’ Zones 1 and 5), with 34.2% of the zone more than 6 km and 16% more than 9 km from water points. However, the proportion of water-distant land is considerably smaller in some sub-bioregions, notably in the general vicinity of Alice Springs and on the

Diamantina Plains, where less than 10% of the area of the subregions are remote from artificial sources of water.

A very small percentage of the zone has been cleared or is used for irrigated agriculture , notably in the Ti-tree Basin where table grapes are grown.

4.8.5. Wild stock (including feral animals)

Rabbits occur throughout the zone, with patchily high densities leading to substantial degradation. Rabbit populations have been reduced to 5% of their previous levels by calici virus and RHD. Feral horses and camels are also found throughout the zone, in sufficient numbers to cause at least localised damage to sensitive habitats. Goats and pigs are also found in the Channel Country bioregion but at low densities.

Red kangaroos (*Macropus rufus*) are sparse throughout the zone, ranging from 0.4 to 14 animals (25 kg body mass km^{-2}). This is due to a combination of low and variable rainfall and dingoes, which keep kangaroo numbers under control.

4.8.6. Current management of TGP

Grazing management is primarily set-stocking, but this is highly dependent on rated carrying capacities and seasonal conditions. The proliferation of artificial permanent water means that feed, rather than water, is now limiting. As a result, significant overgrazing may occur during dry periods if stock numbers are not reduced quickly enough.

Rabbits are actively controlled in the Alice Springs region by ripping warrens. The number of feral horses in the range country has been greatly reduced through an eradication campaign by the NT Government.

4.8.7. Biodiversity issues

There has been substantial loss of biodiversity from this zone since European settlement, most notably extinction of many medium-sized mammals. There had also been decline or regional extinction of a number of bird species. This loss has been attributed to a number of factors, including overgrazing by introduced herbivores (both stock and feral), particularly impacts on relatively fertile and restricted refugia during dry periods.

A number of threatened plants and animals still persist in the zone, most notably in the Sturt Stony Desert and Diamantina Plains; these regions also have a high number of threatened ecosystems. The Channel Country bioregion has been identified as having a very high value for relictual fauna.

There have been detailed studies of biodiversity along grazing gradients in mulga woodlands and chenopod shrublands within this zone, which have demonstrated that a proportion of all studied taxa (plants, birds, reptiles, ants) show a 'decreaser' response to grazing pressure.

The major threats to biodiversity in this zone are:

- Overgrazing by stock, particularly where concentrated in restricted and sensitive habitats (e.g. permanent natural waterholes and riparian habitats where impacts on aquatic and terrestrial biota occur).

- Proliferation of artificial water points and ubiquity of grazing pressure across extensive landscapes, leading to the decline and local extinction of grazing-sensitive species.
- Grazing by feral animals (particularly by rabbits but also by horses and camels), especially where concentrated on sensitive run-on habitats (e.g. camels on floodout of Dalhousie Springs complex).
- Predation by feral cats and foxes.
- Changes in fire regime. Attempted exclusion of fire under pastoral management and occasional extensive hot fires may be reducing environmental patchiness.
- Damage to mound springs from a combination of grazing impacts, weed invasion, water extraction from the Great Artesian Basin and recreational use.
- Weed infestation, notably athel pine (*Tamarix aphylla*), parkinsonia, Bathurst burr (*Xanthium spinosum*) and Noogoora burr (*Xanthium occidentale*).
- Spread of pasture grasses that may act as serious environmental weeds, particularly buffel grass and couch.

4.8.8. Previous research and on-ground work

- Detailed studies of response of biodiversity to grazing pressure in mulga woodlands and chenopod shrublands.
- 'Biograze' project examining options for biodiversity conservation at landscape scales, particularly through controlling the distribution of water points.
- Documentation of best-practice grazing land management practices in Channel Country (NHT and MLA funding).
- Systematic biodiversity inventories in some regions (e.g. Finke and Diamantina bioregions).
- Bioregional conservation planning in some regions (Finke bioregion – NHT funding; Burt Plain bioregion – under way).
- Aerial surveys for feral animals and macropods in eastern and southern parts of zone.

4.8.9. Knowledge gaps

- An understanding of the impact of alternate grazing systems (e.g. rotational grazing) on biodiversity and hence alternative land use planning strategies to achieve production and conservation.
- An understanding of the impact of camels on native biota.

- Documentation of the impact of cattle grazing on riparian and aquatic biodiversity.
- Implications of the invasion of habitats by buffel grass for native flora and fauna persistence.

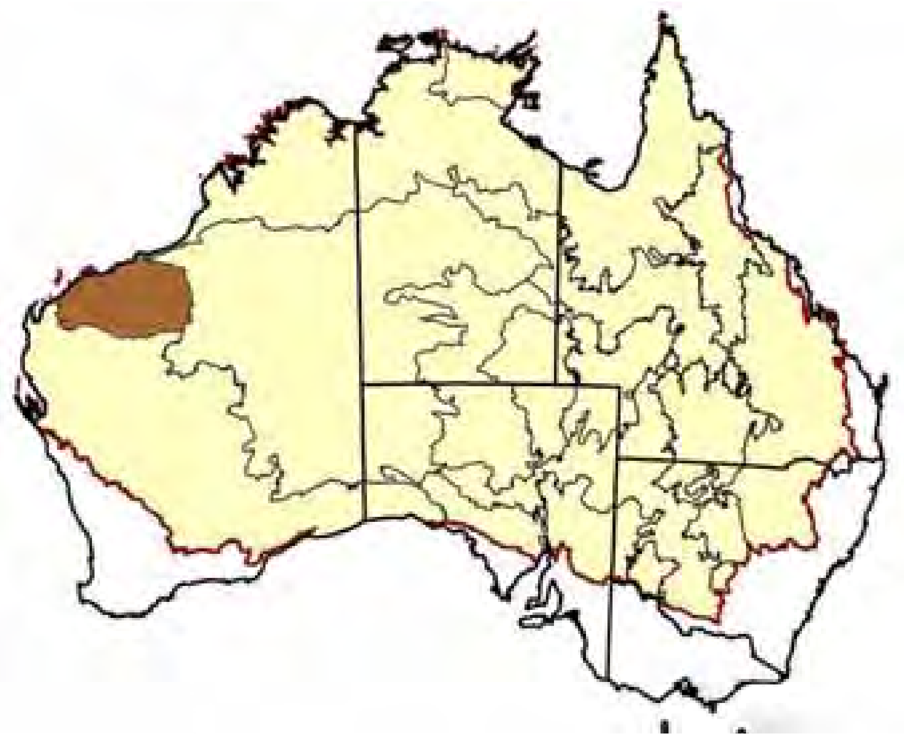
4.8.10. Opportunities to invest

- Development and implementation of proper framework for regional and property management plans that adequately incorporate biodiversity issues and promote off-reserve conservation management.
- Integration of property planning with regional conservation planning.
- Provision of meaningful incentives (for public-good conservation), notably in resource-poor areas.
- Feral animal control in identified strategic areas.
- Weed control (of targeted species) in identified strategic areas.

4.9. Zone 7 – Pilbara: Extensive Cattle Grazing in Tussock and Hummock Grasslands

Compiled by Ian Watson

This zone is characterised by a hot, arid climate; hummock grasslands on inland ranges and plateaus and acacia woodlands and tussock grasslands on plains; extensive grazing of cattle on very large leases.



4.9.1. Regional attributes

Area: 178,999 km^2

Bioregions (subregions): Pilbara (PIL1–4)

NHT regions: Rangelands (Western Australia)

4.9.2. Biophysical attributes

The Pilbara zone falls entirely within climate zone G: warm to hot, very dry. Mean annual rainfall is between 250 and 400 mm, falling predominantly in summer, although winter rainfall can be significant in about 20%–30% of years.

The major landforms of the zone are extensive coastal plains and ancient inland ranges and plateaus, with some areas of alluvial and basalt-derived plain.

The most extensive vegetation type is hummock grasslands, which dominates in the central Pilbara and makes up about three-quarters of the total area of the bioregion. However, there are also significant areas of tussock grasslands (including *Astrebla*, *Eragrostis*, *Eriachne* and *Chrysopogon* communities as well as introduced *Cenchrus* spp.) making up about 7% of the area, and acacia woodlands and open woodlands (primarily mulga) make up about 14%. There are small areas of chenopod shrublands and eucalypt woodlands, primarily on floodplains and along drainage lines. In the coastal areas, there are extensive stands of mangroves and a range of other mangal samphire communities.

Significant restricted habitats include *Themeda* grasslands in the central Pilbara, the summit flora of hilltops and gorge habitats of the Hamersley Range, the cracking-clay gilgai communities of the Chichester Tablelands, the samphire habitat associated with the Fortescue Marsh, spring-fed wetland habitats such as at Millstream and Weeli Wolli Spring, dunefields, and geographically restricted habitats such as greenstones east of Nullagine, containing at least one priority plant species.

4.9.3. Socioeconomic attributes

The majority of the zone is under pastoral leasehold tenure (58%) and there are also large areas of unallocated (note – 'vacant' is now a discredited term in Western Australia because it doesn't recognise prior Indigenous occupation) Crown land (20%). There are significant areas under Aboriginal ownership (10%) and within conservation reserves (6.5%). Recently, about 600,000 ha of pastoral lease has been bought to become part of the conservation estate and has reverted to unallocated Crown land (this probably occurred after the area figures quoted here were obtained). In due course, tenure will be changed to reflect its conservation status.

The overall population density in the zone is 9.6 per 1000 km^2, which is higher than most other GLMZs. However, the majority of the population is concentrated in towns serving the mining sector (notably Port Hedland, Karratha, Newman and Tom Price), and there is a very sparse rural population in homesteads and Aboriginal communities.

4.9.4. Pastoral grazing systems and other land uses

Pastoral land use is primarily based on extensive grazing of cattle. Pastoral leases are very large, with a mean property size of c. 250,000 ha (the second largest among all the GLMZs). Properties are smaller (c. 110,000 ha) near the coast, where rainfall is more reliable and the land has a higher carrying capacity.

Beef cattle carrying capacities range from about 6 km^{-2} to less than 1 km^{-2}. The mean cattle density (0.87 km^{-2}) is low compared to most other GLMZs, reflecting the low annual rainfall and low carrying capacity of most pastures. The low mean cattle density is also a reflection of the fact that only about 60% of the Pilbara is grazed by domestic livestock. The current mean sheep density (0.36 km^{-2}) is very low and there has been a steady decrease in sheep numbers (and increase in cattle) since the 1950s to the extent that the Pilbara is no longer considered a wool growing area.

There are no significant areas of land clearing or grazing on improved pasture. However, there has been a long history of active introduction of buffel and birdwood species that continues today. There are now considerable areas of buffel, especially along the coastal Pilbara and in alluvial riparian habitats along all the major watercourses in the Pilbara, and these species are a significant threat to biodiversity in the Pilbara. There are no significant areas of cropping.

The overall proportion of land that is water-distant (more than 6 km or 9 km from water) is moderate compared to other GLMZs, but varies considerably between subregions, depending on the level of pastoral development. Only 8% of the coastal Pilbara region is more than 6 km from water and only 2% is more than 9 km. In the inland Pilbara (subregion 3), 44% of land is more than 6 km from artificial water and 26% is more than 9 km.

The Pilbara's petroleum, gas and mining (principally iron ore) industries have extremely high value, far outweighing that produced by the pastoral industry. Turnover from tourism and commercial fishing is also probably higher than that from the pastoral industry.

4.9.5. Wild stock (including feral animals)

Feral grazers present in the zone include donkeys, camels, horses, cattle and goats. Pigs are present in localised areas such as the De Grey River delta. Across most of the Pilbara, donkey numbers are low, although in the lower east Pilbara, donkey numbers can be locally very high, leading to grazing pressure issues on a small number of pastoral leases. While donkey numbers are kept low on pastoral land, influx from the desert along the eastern and south-eastern margins of this zone can cause numbers to rise.

A similar situation exists for camels. Camel grazing pressure is low in the pastoral areas of this zone, although numbers can build through desert influx along the eastern margins in dry years. Anecdotal evidence suggests that camels number in the tens of thousands directly east of the Pilbara, in Zone 5. Of more concern to the management of grazing pressure is the damage that camels can do to pastoral fences. Damaged fences make it more difficult for pastoral managers to control grazing pressure from domestic cattle. That is, the grazing impact of camels is indirect, through their damage to fencing. Competition for water by influxes of desert camels can also present a problem. Feral horses are a localised problem on many leases and Indigenous-held lands, especially in the central Pilbara. On Indigenous lands there is low pressure to cull feral horses because of their cultural significance to local people. Feral goats are present in the region, particularly in the south, but at very low numbers and are not considered a major TGP issue. Feral cattle numbers are generally low, but can become an issue in rugged, inaccessible or desert areas.

Overall kangaroo density is very low (1.4 km^{-2}) compared to most other zones, with higher densities (3.7 km^{-2}) in the southernmost subregion. There has, however, been a substantial increase in the abundance of some large macropods, particularly euro (*Macropus robustus*) and red kangaroos, due to proliferation of artificial water and control of wild dingoes. There were broad-scale poisoning programs in the 1950s and 1960s to control euro numbers, which are now discontinued.

4.9.6. Current management of TGP

Historically, stock numbers were much higher and grazing was concentrated on the most fertile and productive areas, leading to overgrazing and land degradation. Most of the pastoral areas are now well fenced and the herds controlled. Mustering (especially aerial mustering) is more common than the trapping of animals on watering points. Anecdotal evidence also suggests that the switch from sheep to cattle grazing has meant that TGP has been reduced and some recovery has occurred.

Donkey numbers are kept low through cooperative culling programs between landholders and the state government. While donkey numbers are kept low on pastoral land, influx from the desert along the eastern and south-eastern margins of this zone can cause numbers to rise. Camel and feral horse numbers are also controlled through cooperative culling programs, although these are less frequent than for donkeys. All large feral herbivores are also culled on an opportunistic basis.

The control of all feral grazers on conservation land and unallocated Crown land presents an ongoing issue for management of TGP across the Pilbara. This is for several reasons; the resources that government is putting into feral animal control are declining, much of the unallocated Crown land and conservation estate is inaccessible by ground – requiring expensive helicopter shooting; the lack of infrastructure (roads, water, human habitation) within many of these areas makes on-ground control even more difficult; the sheer size of the areas means that current resources are spread very thinly.

A point to note is that donkey, camel and horse numbers are kept low through well-organised and cooperative culling programs, of considerable cost to the state government and the pastoral community. Evidence suggests that if this pressure is relaxed, feral grazers can build to significant numbers again very quickly.

Controlled baiting programs for wild dogs (generally aerial baiting) are conducted once a year across most of the Pilbara. In very small, mostly coastal areas, baiting (mostly for foxes) is more frequent and is designed to protect specific habitats such as beaches on which turtles lay their eggs.

A handful of licensed kangaroo shooters are active in the Pilbara.

4.9.7. Biodiversity issues

The following issues exist in the zone:

- Regional extinction of marsupial and rodent species but some species still persist on off-shore islands.
- Evidence of ongoing decline in some medium-sized (100-500 g) mammal species.
- Concentration of grazing pressure in some ecosystems, notably on river frontages, saltbush shrublands and tussock grasslands.
- Uncontrolled cattle grazing at natural water points (e.g. springs, soaks, ephemeral wetlands, and riparian areas).
- Poor representation of more productive habitat types in reserves.
- Foxes and cats are widespread.
- Changed fire regimes, with changes in frequency and hence intensity. An increase in hot fires leading to encroachment of spinifex grasslands into mulga woodlands.

- Very high mesquite density in localised areas.

Introduced *Cenchrus* species grasses (buffel grass and birdwood grass) now widespread throughout the Pilbara where their impact on coastal and alluvial/sandy parts of the Pilbara is substantial.

4.9.8. Previous projects and on-ground work

- Work by CSIRO in the 1950s and 1960s aimed at controlling macropod (especially euro) numbers.
- Pasture burning work by the Western Australia Department of Agriculture in the 1960s and 1970s aimed at improving fire management to enhance productive pastures.
- Much of what we know of the biology and control of the dingo in pastoral areas came from Agricultural Protection Board (now Western Australia Department of Agriculture) work in the Pilbara in the 1970s and 1980s.
- Ongoing aerial and ground baiting of wild dogs.
- Aerial shooting of feral horses, donkeys, camels and cattle continues.
- Research and operational use of Judas donkeys to aid culling of residual numbers.
- The BTEC had a major impact on providing infrastructure to control domestic cattle.
- Land system and resource condition mapping by the Departments of Agriculture and Land Administration (Ashburton catchment survey 1970s–1980s, Roebourne Plains survey 1980s–1990s and remainder of Pilbara surveyed 1990s–early 2000s).
- Ongoing pastoral estate monitoring through the Western Australian Rangeland Monitoring System (WARMS).
- Current research into the biological control of mesquite.
- Bioregional survey of biodiversity by the Western Australia Department of Conservation and Land Management (Western Australia DCALM).
- Ongoing habitat-specific biodiversity surveys by Western Australia DCALM.
- A range of fire and burning history research projects on conservation land held by Western Australia DCALM.
- Numerous Environmental Impact Statements and environmental surveys for the mining industry by a range of consultants.

4.9.9. Knowledge gaps

- Poor knowledge of biodiversity, and of the distribution and abundance of biogeographical patterns.

- Inadequate identification and mapping of 'special areas' for biodiversity (i.e. restricted ecosystems, hotspots).
- Poor understanding of consequences of changes in fire regime on biodiversity values of the region.
- Low level of understanding of the impact of grazing on biodiversity, except for gross degradation effects. This is particularly the case for grazing systems involving grazing rest.
- Low understanding of off-reserve conservation, both in terms of socioeconomic structures needed to foster it and in terms of the impact on biodiversity.
- Little knowledge of the effect of fire regimes on biodiversity.
- The means of tracking change in biodiversity are not available. This is both an institutional issue (i.e. funding, mandate, skills, staff availability) and a technical issue (i.e. how to monitor, what and where).
- Impact of buffel grass on biodiversity values in the rangelands and quantification of its value for pastoral grazing.

4.9.10. Opportunities to invest

- Regional patterns in the distribution and abundance of biodiversity.
- Identification of 'special areas' – restricted habitats, ephemeral wetlands, springs, soaks etc.
- Special management of these areas – probably within an off-reserve framework (e.g. Ecosystem Management Unit framework, memorandums of understanding [MoU]); restricted access of cattle to these areas.
- Improved grazing management systems that incorporate lengthy resting of paddocks.
- Better control of watering points and of grazers' access to them (i.e. trapping, shutting waters down, restricted access to natural waters).
- Better representation of high-productivity and under-represented areas in reserves.
- Continued control of feral donkeys, camels, horses, pigs and cattle.
- Integration of regional- and property-scale management planning, including an Environmental Management System (EMS)–type framework that clearly specifies what is expected of property managers, and sets achievable goals (rather than generic ones).
- Incentives for pastoralists to protect 'special areas'.
- Recognition of Indigenous knowledge of biodiversity and biodiversity management.

- Collation of existing work that has been done in a piecemeal fashion for mining industry purposes by private consultants (this is underway – see http://science.calm.wa.gov.au/projects/pilbaradb/).

- Working with pastoralists to improve biodiversity conservation and management, as an adjunct to improved grazing management.

4.10. Zone 8 – Southern Australia Sheep and Cattle Grazing in Shrublands

Compiled by Ian Watson and Leigh Hunt

This zone occurs in all the rangeland states and is highly variable. It contains arid and semi-arid areas, characterised by a hot, dry climate in northern areas and a more moderate climate in the south. Rainfall is winter-dominated throughout much of the west, but is bimodal or evenly distributed in the south and east of the zone. Feral goats, kangaroos and rabbits are the major components of TGP apart from domestic stock. Vegetation is predominantly chenopod and acacia shrublands and woodlands, but many vegetation types can be found.

4.10.1. Regional attributes

Area: 1,317,600 km^2

Bioregions (subregions): Broken Hill Complex (BHC2,3); Carnarvon (CAR1,2); Channel Country (CHC5,8,9,10,11); Coolgardie (COO1–3); Cobar Peneplain (CP1); Darling Riverine Plains (DRP6–9); Gascoyne (GAS1–3); Gawler (GAW4,5); Geraldton Sandplains (GS1); Great Victoria Desert (GVD1); Hampton (HAM); Murray Darling Depression (MDD6); Mulga Lands (MUL12–16); Murchison (MUR1,2); Nullarbor (NUL2,3); Riverina (RIV1,2); Simpson Strzelecki Dunefields (SSD5–7); Stony Plains (STP3); Yalgoo (YAL)

NHT regions: Western (New South Wales), Rangelands (Western Australia), Rangelands (South Australia), Aboriginal Lands (South Australia), Desert Channels (Queensland), South West NRM (Queensland)

4.10.2. Biophysical attributes

This is an extensive zone, with a corresponding diversity of climate, landforms and vegetation. It ranges from the hot, dry North West Cape through to the more temperate areas of the eastern Riverina. From west to east it includes the spinifex grasslands, chenopod shrublands and the mulga zone of the Gascoyne–Murchison, the dense chenopod shrublands of the Nullarbor and the more sparse chenopod shrublands and acacia open woodlands of the southern part of the North-west pastoral zone in South Australia. It also includes parts of the Stony Plains and Simpson Strzelecki Dunefields in South Australia, New South Wales and Queensland, as well as some of the Channel Country. In New South Wales it extends across a broad range of vegetation and landforms, including some of the Cobar Peneplain, Murray Darling Depression, Mulga Lands and the saltbush plains of the Riverina.

For most of this zone, particularly in the west and south, winter rainfall is more reliable than summer. Mean annual rainfall ranges from about 200 mm in parts of Western Australia and South Australia, through to about 400 mm in the south-eastern part of the zone in New South Wales.

In the west, the majority of this zone is described as desert (Code G), with very little plant growth, due to water limitation. The same classification is used for the channel country and dunefields included in this zone, which are centred around the junction of the New South Wales, Queensland and South Australian borders. The south-western margin is classified as climate code E2, i.e. 'Long hot summers and mild winters with significant moisture limits on growth. These include the Mediterranean climates and adjacent inland climates (where the dry season is in summer) and mid-latitude eastern continental climates with wetter summers and drier winters.' Along the southern parts of this zone, the climate is classified as E6, i.e. semi-arid – too dry to support field crops.

Vegetation is variable throughout the region. At least 15 of the 17 vegetation types are represented to some extent. Averaged across the entire zone, the vegetation consists of roughly equal amounts (c. 20%) of acacia forests and woodlands (VG4), acacia open woodlands (VG10) and chenopod and samphire shrublands and forblands (VG16). Around 10% of the area is hummock grasslands (VG14). The remainder (about 30%) is made up of small areas of eucalypt woodlands, open woodlands, tall open forests and mallee woodlands and shrublands (VG2,3,9&11), *Callitris* and casuarina forests and woodlands (VG5&6), mixed shrublands (VG12), tussock grasslands (VG13), mangroves and littoral vegetation (VG17) and 'other' vegetation types (VG8&15). There is also a large number of restricted vegetation types, too numerous to list in this summary. In areas with significant winter rainfall, annual and ephemeral vegetation is also important for production.

4.10.3. Socioeconomic attributes

Population density is low throughout the region, with an overall density of 5 people per 1000 km^2, ranging from 1 to 60. Large population centres are few, with many (e.g. Kalgoorlie) servicing mining interests rather than supporting pastoral land use.

This zone is dominated by pastoral land use, except on some of the margins. For most subregions in this zone, the proportion of land used for grazing native pastures is more than 80%. Marginal areas, not much used for pastoralism, are found in the west. These include the entire Coolgardie IBRA, parts of the Nullarbor and the Great Victoria Desert. The proportions of irrigated land and land used for dryland agriculture are very low, less than 1% (often zero), except in parts of the Riverina, where it is around 5% for both categories. The proportion of land in the conservation estate is very low (often zero) in the better grazing areas of this zone. In only 5 (of the 42) IBRA subregions does the proportion of land designated as conservation estate exceed 15%, although up to 70% of some western subregions are ungrazed Crown land. Aboriginal lands comprise very small proportions of this zone, with only one subregion (in the Great Victoria Desert) exceeding 10%. Overall, 70% is leasehold, 15% is Crown land, 7% is part of the conservation estate (5% reserved), 5% is freehold and 3% is Indigenous land. However, in such an extensive zone, the proportions of these land uses within each of the subregions is very varied.

Median property sizes range from less than 10,000 ha in 16 of the 42 subregions (almost entirely within New South Wales) to more than 200,000 ha in much of Western Australia, and parts of Queensland and South Australia.

4.10.4. Pastoral grazing systems and other land uses

In keeping with the broad range in attribute values in this zone, mean subregion beef cattle densities range from zero to 6.6 AE km^{-2}, although 34 of the 42 subregions contain less than 1.0 AE km^{-2}. Sheep densities similarly range from close to zero to more than 50 DSE km^{-2}, although in 24 of 42 subregions, sheep density is less than 10 DSE km^{-2}. In very broad terms, the northern areas of this zone are dominated by beef cattle grazing and the southern areas by sheep grazing. However, this is variable throughout the zone and many properties run both cattle and sheep. The ratio of cattle to sheep has increased over the last few decades.

Most of the pastoral stations are managed by individuals or families. However, there is a substantial number of large corporate properties in particular areas, such as the Nullarbor, the Riverina and the north-west and north-east parts of South Australia. Given the general absence of permanent natural water, almost all watering points are artificial and can be controlled to some extent. Most of the watering points are bores or wells, with supplementary piping around the station. Dams are used where groundwater is difficult to find, or is too expensive. The zone includes some of the Great Artesian Basin and artesian supplies in the Carnarvon Basin.

Many of the areas within this zone were settled early in the pastoral history of each state. Consequently, much of the zone has considerable infrastructure development. Almost all properties have boundary fences and there would be few without an extensive network of internal paddock fencing. However, in recent years, spending on infrastructure has declined and internal fencing on many properties has been allowed to deteriorate.

The majority of the area is within 6 km of permanent water and in 26 of 42 subregions, more than 90% is within 9 km of permanent water. However, there is considerable variation between subregions for this attribute. In some areas, such as the sheep enterprises of the Western Division of New South Wales, almost none of the land is beyond 6 km from permanent water. However, in the more extensive cattle producing areas, and in areas with a large proportion of non-pastoral land, the proportion is consistently higher, with 16 of 42 subregions having greater than 20% of land more than 6 km from water.

Management of goats is complicated by the fact that they can provide substantial economic return. Many pastoralists see goats as a ‘cash crop’, to be harvested when circumstances suit – but do not consider goat numbers when making stocking rate decisions for livestock. Management of livestock grazing in relation to kangaroos faces another problem. Many pastoralists are reluctant to spell paddocks from livestock grazing because of a belief that ‘the kangaroos will eat it all anyway’. That is, continuous stocking is maintained, without rest, because of potential grazing by kangaroos.

The patterns of land degradation, and presumably biodiversity loss, have been heavily influenced in this zone by severe degradation events during drought. These events include the 1890s and 1940s in western New South Wales, the 1920s/1930s in South Australia and the 1930s in Western Australia. In each of these droughts, high grazing pressure contributed to severe soil erosion, loss of perennial species and other changes to the land, which have permanently lowered carrying capacity. High rabbit numbers, particularly in the New South Wales part of this zone, contributed to much of the early damage (McKeon et al. 2004).

4.10.5. Wild stock (including feral animals)

Kangaroos are widespread and common throughout the region, reaching densities of more than 30 individuals km^{-2} in much of the New South Wales part of this zone. In many of the West Australian subregions, densities are below 1 km^{-2}, but these are still high in comparison to the density of domestic livestock. Goat densities are particularly high in the west and in parts of New South Wales, especially in comparison to livestock densities. Goat densities are also moderate to high in north-east South Australia and in the western parts of New South Wales. In parts of Western Australia at least, the combined grazing pressure from feral goats and kangaroos is considered to be about equal to that from domestic livestock, and similar proportions (especially when considering the additional contribution of rabbits) could be expected for much of this zone elsewhere. Soon after pastoral settlement, rabbits became common, particularly in southern and eastern areas and were considered a major TGP issue. However, since the introduction of the rabbit haemorrhagic disease, rabbit numbers throughout much of this zone are lower. While the disease remains effective, rabbit numbers will remain low, but the potential remains for rabbits to become a significant TGP issue again.

Camels, and possibly donkeys and feral horses, contribute to TGP on those lands adjacent to desert areas and unallocated Crown land. Feral pigs are present in small areas of this zone in Western Australia (in the Geraldton Sandplain subregion) and in much larger areas in New South Wales and Queensland (particularly in riparian and swampy areas of the Channel Country).

4.10.6. Current management of TGP

In most areas of this zone, pastoral land is managed on the basis of continuous stocking or set-stocking. More sophisticated grazing systems involving periodic rest are used in some areas, although the practice is not widespread. A major impediment to the use of grazing systems that involve destocking paddocks is the concern that uncontrolled grazing by kangaroos will destroy any potential gains of removing livestock.

In some areas (e.g. western New South Wales and the Gascoyne–Murchison) there has been a substantial change in the potential for conservation management on pastoral leases. This has occurred both on leases that have been bought for the purpose of nature conservation and on leases in which pastoral production remains the primary land use, because of changes in the attitude of pastoral managers.

Attempts at goat eradication have failed and management of goat densities is now closely linked to the economic return that can be gained from their sale. Goats are mustered or trapped for sale throughout the zone. Some goats are shot rather than sold, particularly where control is required in inaccessible areas. In Western Australia, goats have recently been declared 'authorised livestock' and are therefore no longer considered feral. However, while their technical status has altered, almost all goats are unmanaged and can be considered feral populations.

Kangaroos are essentially unmanaged across the region. Shooting by both licensed shooters and property managers occurs throughout much of the region but annual harvest rates would be less than 10% of the population. RHD has lowered rabbit numbers. However, warren ripping and targeted baiting is still used to control the potential for population increase.

The low numbers of camels, donkeys and feral horses are controlled within cooperative programs of landholders and the state government within Western Australia, but in South Australia they are uncontrolled or controlled only opportunistically by landholders.

4.10.7. Biodiversity issues

This zone is so diverse that almost all of the biodiversity issues found in other zones can be found here.

In particular, because much of the zone was settled early, extensive degradation was well recognised by at least the first few decades of the 20th century and in some cases (especially western New South Wales) widespread degradation was evident by the end of the 19th century. Fortunately, there are a few areas within this zone where pastoral land use is relatively recent. For example, much of the Nullarbor was not taken up for pastoralism until the 1960s. Subsequent pressure on biodiversity there has not been as intense as the earlier settled areas because large areas remain water remote and TGPs have been kept relatively low.

Indices of irreplacability for flora (0.26) and for flora and birds (0.35) are comparable with other zones dominated by extensive pastoral land use. Only 27% of identified ecosystems are in the reserve network and there is a relatively high number of threatened bird species (5.9), threatened mammals (3.2) and threatened vascular plants (4.2) per subregion. Medium (or 'critical') weight mammals have become extinct throughout much of this zone.

Because much of the zone has a low percentage of land in reserves, conservation of remaining biodiversity will depend on off-reserve management. In this zone, there are very few natural waters, so springs, soaks, ephemeral wetlands and river pools act as refuges and assume major biodiversity conservation importance.

Specific biodiversity threats include:

- Low capacity of landholders to adopt NRM interventions to manage for biodiversity due to poor availability of information and management tools, coupled with low financial capacity.

- The ubiquity of pastoral land use across much of the zone.

- Widespread degradation through sheet and gully erosion and loss of perennial plant cover.

- Damage to riparian areas and siltation/sedimentation of many river pools, causing them to dry up after only short periods.

- Uncontrolled grazing by high numbers of feral animals and macropods across much of the zone: goats in the west and the east, rabbits in the south and macropods everywhere.

- Lack of paddock spelling within the grazing systems and/or feral and native grazing of spelled areas.

- Feral pig damage of restricted habitats such as wetlands and riparian areas which are key areas for biodiversity and also act as refuges.

- Concentrated goat grazing on preferred, often restricted, habitats such as the tops of breakaways and ephemeral wetlands.

- Many of these restricted habitats tend to be poorly managed within a pastoral matrix because they are small or isolated areas and habitat-specific management is difficult.

- Many of these ‘special areas’ are poorly mapped or even identified.

- Excessive stocking rates in many areas, particularly associated with drought and its immediate aftermath.

- Increased density of woody weeds (acacias, *Dodonaea* spp, *Senna* spp, *Eremophila* spp and *Callitris spp*) across much of the zone.

- The spread of exotic pasture species such as buffel and birdwood grasses.

- Predation by other feral animals such as cats and foxes.

- The low proportions of many subregions that are water remote.

- Changed fire regimes: active fire suppression following very good years and increased opportunity for fires in some areas following decline in perennial shrub density and consequent increase in grass fuel loads.

4.10.8. Previous projects and on-ground work

The broad extent and diverse nature of this zone means that many projects and a large amount of on-ground work have occurred. This is summarised below:

- Various programs for aerial surveys of feral animals and macropods across much of the zone, continued on a regular basis in some areas.

- A large number of grazing trials, with a limited number of grazing systems trials.
- A long history of research into vegetation dynamics.
- Several trials aimed at controlling macropod grazing pressure through restricted access to water.
- Trials and on-ground work aimed at eradicating or controlling feral goats.
- Attempts to eradicate introduced predators (cats and foxes) from entire areas (e.g. in Shark Bay).
- Reintroduction of medium-sized native mammals.
- Major NHT, state government and community investment in regional strategies such as the South-West Strategy (Queensland), West-2000 (New South Wales) and the Gascoyne–Murchison Strategy (Western Australia) and the development of regional catchment plans in New South Wales.
- Attempts at regional planning through participatory processes and in South Australia the preparation of district plans under the Soil Conservation Act.
- Detailed biodiversity inventories and surveys across some of the zone, such as systematic flora and fauna surveys of the Carnarvon Basin and Nullarbor Plain in Western Australia, and much of rangeland South Australia, and systematic mapping of vegetation and regional ecosystems in Queensland).
- Grazing gradient assessments of the impact of distance from water on biodiversity.
- Land system and resource condition mapping across almost all of the zone.
- Pastoral monitoring across much of the zone.
- Regular pastoral lease inspections in South Australia and Western Australia.
- A few isolated examples of off-reserve conservation through participatory processes.
- Fire management for control of woody thickening, particularly in New South Wales and South Australia.
- Control programs for large feral animals such as camels, horses and donkeys on the desert margins.
- Pig baiting in the Queensland Channel Country.
- Research, development and extension of total grazing management systems, especially purpose-built trap yards.

4.10.9. Knowledge gaps

This zone is so diverse that almost all of the knowledge gaps found in other zones can be found here. Specifically:

- The biodiversity of many areas remains poorly known.
- The specific impact of grazing practices (other than the impact of gross degradation) on biodiversity remains poorly known.
- The locations of many restricted habitats and special areas are not known and/or not systematically identified and mapped.
- Effective means of obtaining long-term permanent control of introduced predators, especially cats and foxes.
- Better understanding of the relationship between biodiversity changes and the placement of new watering points.
- The means of nesting biodiversity conservation at the local scale with regional-scale biodiversity conservation.
- The need to settle on agreed objectives for biodiversity conservation and management across community and government so that adequate tools (i.e. identification and mapping, grazing management, feral animal control, monitoring etc) can be developed/adapted to meet the needs of those managing for biodiversity.
- Identification of areas that are a high priority for incorporation into the reserve system.
- The impact of grazing systems that include paddock rest on biodiversity (e.g. how long should a paddock be rested for, in good years or dry?; do kangaroos need to be controlled to achieve positive biodiversity outcomes?).
- The impact of increased climate variability and climate change on biodiversity in comparison to management impacts.

4.10.10. Opportunities to invest

This entire zone would benefit from a number of regional environmental management strategies. These would, by definition, be partnerships between government and rural and Indigenous communities. On-ground action would be supported with targeted information; for example, identification and mapping of threatened communities. Areas of particularly high conservation value would be acquired and added to the conservation estate, using appropriate resources for continued management. Much of the effort towards biodiversity conservation would occur off-reserve, within the pastoral matrix, and pastoralists would be supported to manage these areas. Efforts would be made to encourage more benign pastoral management, with better matching of livestock numbers to land capability and feed supply. This would occur within the context of an improved understanding of ecosystem and landscape function by all land managers (both government and industry). Pastoralists would be encouraged to demonstrate their environmental credentials through certified EMSs. Finally, institutional structures would be encouraged that fostered the above approach. These will need to be 'whole of government' and recognise a multiplicity of land uses and values for the rangelands. One model for such a strategy already supported by NHT is the Regional Environmental Management Program of the Gascoyne–Murchison Strategy (Pringle 2002).

Such a strategy would also encourage the development of a regional sustainability framework. This framework would both address themes (i.e. environmental, economic and socio-cultural) as well as scales – from enterprise to group to NRM subregion to region and state. The framework would need to be coherent across scales, and objectives and targets would be nested so that individuals managing biodiversity at the enterprise scale could be confident that they were contributing to biodiversity outcomes at broader scales. Many pastoralists are keen to make their pastoral management more benign for biodiversity but struggle to do so because of a perception that 'everything needs to be conserved everywhere' and because they have no framework within which to work. Such a framework has been proposed (and is being trialled) for the Gascoyne–Murchison Strategy area, supported by NHT (Pringle et al. 2002).

The diverse nature of this region allows a large number of opportunities to invest. Specifically:

- Better off-reserve management of threatened ecosystems and species, particularly through protection of restricted habitats. This can be achieved through a partnership approach such as the EMU project is demonstrating in Western Australia.
- Improved techniques for controlling feral animals and kangaroos through restricted access to water.
- Improved markets for kangaroo products and re-establishment of an international kangaroo products industry will make it more economic for licensed shooters to operate.
- Incentives to install trap yards at existing watering points. This is opportune because the recent decline in fencing infrastructure has meant that livestock control in the future will be based on access (restrictions) to water.
- Incentives to relocate watering points away from sensitive areas and restricted habitats.
- Improved grazing systems that allow paddocks to be spelled for lengthy periods, despite uncontrolled grazing pressure by feral grazers and kangaroos.
- Participatory and partnership approaches that encourage land managers to adopt more sophisticated grazing systems despite the constraints of uncontrolled grazing by feral animals and kangaroos.
- Engagement of individual pastoral managers to manage for biodiversity within their normal pastoral operations and the provision of tools to help them do so.
- Rabbit control targeted at specific, sensitive or important habitats.

- Better identification and mapping of restricted areas, species and ecosystems under threat.

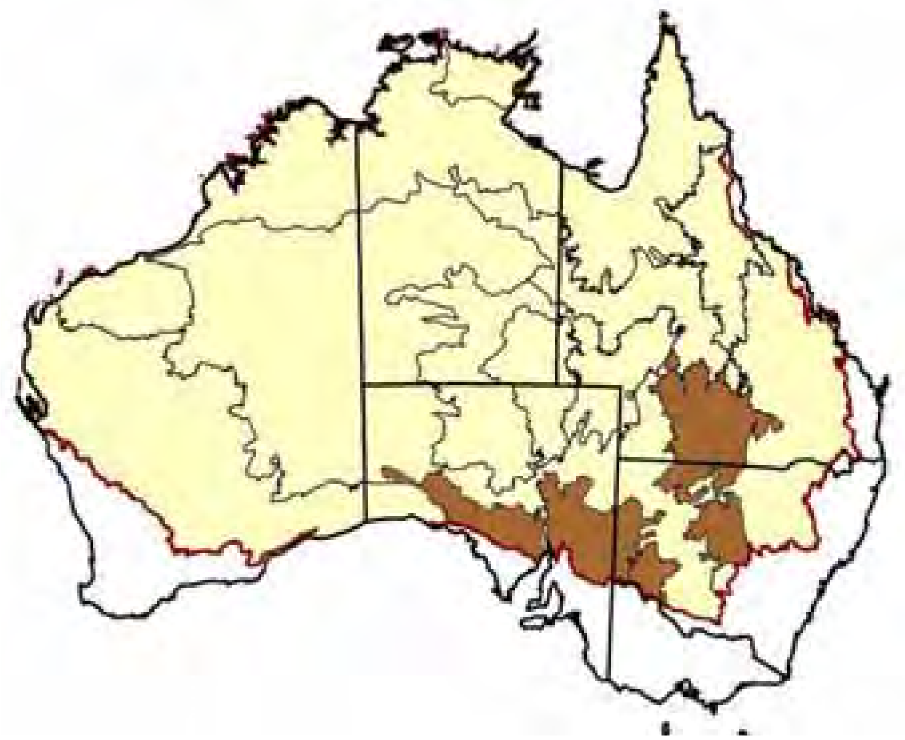
- Regional-scale environmental management plans that allow individual pastoral managers to work within a nested framework that conserves biodiversity at the regional scale. That is, a set of clearly defined and identified assets across the region and a set of targets and objectives for those assets that allows both government administrators and individual managers to work towards their conservation. This approach removes the perceived need to 'conserve everything everywhere' and allows the community to share the responsibility.

- Establishment of an industry for the use of invasive woody shrubs, or alternative land uses for areas where woody thickening has permanently diminished the value of the land for primary production.

4.11. Zone 9 – Extensive Sheep Grazing

Compiled by Leigh Hunt

Characterised by a warm to hot, semi-arid to arid climate; a mixture of chenopod shrublands, acacia (mainly mulga and myall) woodlands, and eucalypt and mallee woodlands; extensive sheep and some cattle pastoralism at low densities on small, mostly leasehold properties.



4.11.1. Regional attributes

Area: 538,240 km^2

Bioregions (subregions): BHC1,4, CP2–4, DRP10, FLB3–5, GAW1–3, GVD6, MDD1, MUL2–11

NHT regions: Rangelands (South Australia), Aboriginal Lands, River Murray, Lower Murray Darling, Western (New South Wales), South West NRM and Murray Darling (Queensland)

4.11.2. Biophysical attributes

Primarily within climate zone E6, with a small portion in climate zone G, described as warm to hot, dry to very dry climates. Summers are long and hot, but winters are mild. Rainfall is seasonal, and winter-dominant for southern parts. There is high inter-annual variability. Moisture availability is inadequate for cropping in these climates. Plant growth is limited by moisture rather than temperature. Median annual rainfall is between 150 and 500 mm.

Vegetation in this zone can be characterised as semi-arid shrublands and woodlands. Chenopod shrublands (VG16) occur predominantly in the southern parts (South Australia and New South Wales) and acacia open woodlands (VG10; mostly mulga), acacia forests and woodlands (VG4) and eucalypt woodlands (VG3) are found in New South Wales and Queensland, with minor areas of chenopod shrublands occurring in Queensland. Mallee woodlands and shrublands are the other major vegetation types (VG11), with mallee located mostly in subregion MDD1. The ground layer is usually a mix of ephemeral or short-lived perennial tussock grasses (*Austrostipa* and *Austrodanthonia* spp.) and forbs in the south and perennial tussock grasses in the northern parts. Common perennial grasses are *Thyridolepis*, *Eragrostis* and *Monachather* spp. Grazing is based on the short-lived ephemeral components when they are available and livestock switch to the more perennial species later.

Relatively restricted but important vegetation types are the *Callitris* forests and woodlands (VG5) and casuarina forests and woodlands (VG6).

4.11.3. Socioeconomic attributes

Approximately 80% of the zone is under pastoral land use, with the land mostly held as pastoral leasehold. There are small areas of Aboriginal land (overall 2.6%) scattered through western New South Wales and the northern Flinders Ranges.

There is a moderate level of reservation in the zone overall (5.2%), although the reservation is highly variable between sub-bioregions. High levels of reservation occur in the Flinders Ranges, where reserves are large (Flinders Ranges National Park, Gammon Ranges National Park), the mallee and casuarina woodlands north of the Murray River in South Australia (associated with Dangalli National Park), and with some smaller scattered areas in western New South Wales and the Mulga Lands of Queensland. However, the majority of ecosystems are unreserved within most bioregions.

Human population density is low throughout most of the zone (overall 6 people per 1000 km^2), with few cities but several large regional centres, a very sparse rural population and scattered Aboriginal communities and small service centres.

Property sizes are smaller than most other GLMZs (overall sub-bioregional mean = 27,700 ha), with mean property sizes tending to be smaller in New South Wales and Queensland than South Australia.

4.11.4. Pastoral grazing systems

Extensive sheep grazing is the dominant land use in the zone; sheep densities are low (average 13.2 DSE km^{-2}). Some cattle grazing also occurs (average cattle density 1.29 AE km^{-2}). Properties are generally intensively developed, with only 10% of the zone being more than 9 km from water. Exceptions are parts of the Gawler Ranges and Great Victoria Desert.

A moderate percentage of the area has been cleared, especially in the Queensland Mulga Lands, which have been nearly 20% cleared, mostly for pasture development. In contrast, only 0.5% of the New South Wales Mulga Lands have been cleared. There has also been some clearing for cropping in the marginal cropping areas in South Australia, which are usually cropped on an opportunistic basis depending on seasonal conditions. Clearing for cropping has also occurred in the eastern part of the zone in Queensland and along the Darling River in New South Wales. Some irrigation occurs in New South Wales but this is a very minor land use in the zone. Mining and tourism are minor land uses in the zone and are restricted to specific areas with high value for those uses.

4.11.5. Wild stock (including feral animals)

Feral goats, rabbits and kangaroos are the common species of wild stock in this region. All species are widespread across the zone and population densities are locally very high in some areas (e.g. goat densities are highest in the Flinders Ranges and Gawler Ranges, and in north-central New South Wales. Macropod densities are high (average 16.6 kangaroos km^{-2}). Feral pigs also occur in the New South Wales and Queensland sections of the zone, mostly along permanent waterways and wetlands.

Total grazing pressure in the zone is of the order of 3.1 AE or 31.1 DSE km^{-2}.

4.11.6. Current management of TGP

In most situations grazing of livestock occurs on a year-round, continuous basis (i.e. set-stocking). Stock numbers are usually set in relation to recommended (New South Wales and Queensland) or permitted (South Australia) maxima under lease conditions, with some adjustment down from this in poor seasonal conditions. For some areas that rely on surface waters, stock numbers are dictated more by the availability of water. Mostly, however, the availability of permanent water piped from bores and dams means that forage levels are the main control on stock numbers. There is little use of seasonal forecasts to reduce risk associated with drought.

It is feasible to control rabbits across much of this zone by destroying their warrens with tractor-mounted rippers, although on many properties no form of rabbit control is implemented. It is not always cost effective to do this, but for specific parts of the landscape that are important to pastoral use, conservation or tourism, the expense can be justified. Occasional epizootics of RHD and myxomatosis also play a role in suppressing rabbit numbers.

Feral goats are managed mostly by mustering, although trapping on waters occurs in some areas. Long-term suppression of goat numbers is jeopardised by the financial returns pastoralists receive from the sale of goats. Control tends to be opportunistic, and follow-up work (e.g. shooting) to remove the goats remaining after trapping or mustering is rarely implemented. The goat population is therefore able to grow again quite rapidly, especially under favourable seasonal conditions. Very high densities of goats, in conjunction with domestic livestock, have caused substantial degradation in New South Wales. Efforts to control woody weed populations using goats have generally proved to be unsuccessful.

Kangaroo management is regulated by the government in each state. Commercial shooting is the main form of control in Queensland, New South Wales and South Australia. This occurs under a strict quota system, based on aerial surveys of kangaroo numbers (concentrating on the four most common species).

Low human population densities, poor economic returns to the wool industry and the large size of properties all interact to limit the capacity for managers to implement ongoing suppression of goats and rabbits. Control is therefore opportunistic, and the monetary value of goats on the live market is a disincentive for managers to apply follow-up control to minimise the build up of numbers following control operations.

4.11.7. Biodiversity issues

The zone contains numerous IBRA subregions of high biodiversity value. These include the Flinders Block (high flora irreplacability index, and threatened vascular plants), South Olary Plain/Murray Basin (with 29 threatened bird species and 20 threatened mammal species), and the Great Victoria Desert subregion in South Australia. The Mulga Lands in New South Wales and Queensland also contain numerous threatened bird species. There are relatively few ecosystems listed as threatened in most parts of the zone. The highest number of threatened ecosystems is in the Mulga Lands (MUL2, 3,4,9) and the Cobar Peneplain (CP3,4).

Major threatening processes include:

- Feral animals (including goats and rabbits) which have broad impacts on the landscape, but goats can also have severe impacts on restricted and sensitive habitats.
- Other feral animals including pigs, which can have a serious impact in riparian habitats and other wetlands.
- Woody thickening (i.e. increased density and spread of woody plants) of native shrubs, including species of *Eremophila*, *Dodonaea*, *Senna* and acacia, especially in New South Wales and Queensland.
- Altered fire regimes, especially in the acacia woodlands and shrublands (which is a factor, together with overgrazing, in the thickening of woody weeds). This is generally a reduction or complete lack of fire.
- Overgrazing by domestic stock, particularly in periods of drought.

4.11.8. Previous research and on-ground work

Previous work in TGP has focused on paddock design (especially location of water points), documentation of densities and impacts of kangaroos and feral animals, rabbit and goat control, and rehabilitation of degraded land. Control and rehabilitation work has been restricted to relatively small areas showing a high level of modification due to grazing by pest species and domestic livestock. This has produced minimal benefits to biodiversity in the area of treatment, and no landscape-scale benefit. The impact of grazing pressure on biodiversity has been documented for some locations, but there has been no documentation of the impact of woody thickening on biodiversity. Education of land managers in improved management practices and the needs of specific native species has also occurred in some areas.

Other work includes:

- Aerial surveys of feral goats and macropods across most of the zone, which are likely to continue on a biennial basis.
- Shooting and mustering activities for feral goats in national parks in the Flinders Ranges. Subsidised helicopter mustering of feral goats on some

properties in the Olary Spur (supported by the South Australia Pastoral Management Branch).

- Property management planning programs implemented by the South Australia Government across the pastoral zone in South Australia.
- Best-practice management for pastoralists in certain areas of South Australia and New South Wales.
- Extensive rabbit control (by ripping) and woody weed clearing in parts of New South Wales.
- Operation Bounceback (a partnership between National Parks and Wildlife South Australia and NHT), which is a demonstration of environmental management that addresses threats to ecological integrity (goats, rabbits, euros in some areas, foxes, cats and weeds), long-term planning and monitoring and working with landholders adjacent to national parks.
- Rangeland condition assessment and land system description across pastoral leasehold land in South Australia, New South Wales and Queensland.
- Assessment of the impact of water point distribution on biodiversity at sites in all three jurisdictions.
- Research on methods of reducing shrub densities in thickened areas in New South Wales and Queensland.
- Research on the impact of TGP on perennial grass survival and landscape function.

4.11.9. Knowledge gaps

- Understanding the opportunities to improve grazing management; the needs of native species under grazing remain poorly understood.

Biodiversity of many areas is still poorly known, including the effects of various land management regimes and the identification of management ‘hotspots’.

- Inadequate and inconsistent listing of threatened species and ecosystems.
- Data on the density of feral animals are lacking in some areas.
- Appropriate broad- and fine-scale biodiversity monitoring tools.
- The efficacy of creating new areas for conserving biodiversity by manipulating water point location.

4.11.10. Opportunities to invest

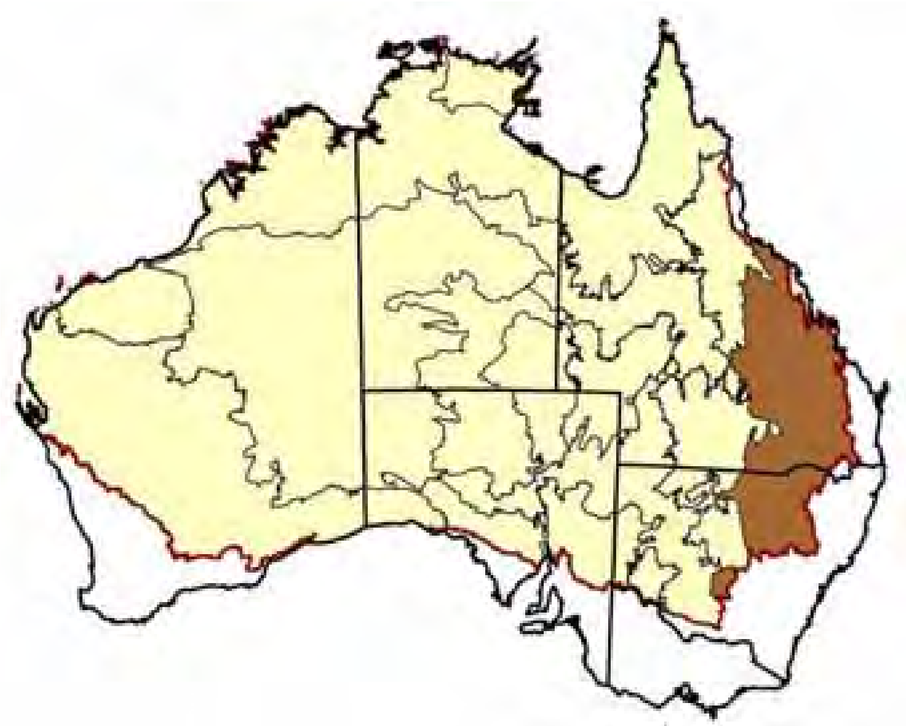
- Improvement in the options for grazing management at the broad scale on pastoral properties is required, to enable a move away from set-stocking.
- Development of grazing practices consistent with the needs of native species.

- Trap yards for feral goat and domestic stock control.
- Rabbit control in sensitive high value ecosystems, especially to take advantage of the suppression of rabbit numbers as a result of RHD (and thus limit increases as disease resistance builds in the rabbit population).
- Fencing of areas that are important for biodiversity, and fencing of degraded areas.
- Foregoing development of new water points, or decommissioning existing water points, to conserve regionally important biodiversity.
- Integration of property planning with regional conservation planning (especially an emphasis on on-property improvements in management in the context of regional conservation planning).
- Meaningful incentives for public-good conservation, notably in resource-poor areas.
- Improved reservation in some regions.

4.12. Zone 10 – Highly Modified Rangelands

Compiled by David Phelps and Alaric Fisher

Zone 10 is characterised by high fertility soils, hot to warm seasonal rainfall and large areas of cleared tree, shrub or grassland communities for dryland and irrigated cropping and comparatively intensive grazing systems. It also includes lower fertility soils supporting eucalypt forests and softwood scrub used primarily for extensive grazing. This zone represents a transition between coastal and cropping areas in the east and the 'true' (less modified) rangelands to the west. A diverse region has been included in the zone because many areas are being converted from rangelands. Management involves a variety of issues that are dominated by land use change rather than TGP.



4.12.1. Regional attributes

Area: 529,442 km^2

Bioregions (subregions): Zone 10 is dominated by the northern (BBN1–14) and southern (BBS1–24) Brigalow belts but includes MUL1 (West Balonne Plains), DRP 1–5 (Darling Riverine Plains) and CP5 (Lachlan Plains)

From the northern tip, the subregions are:

Townsville Plains (BBN1), Bogie River Hills (BBN2), Cape River Hills (BBN3), Beucazon Hills (BBN4), Wyarra Hills (BBN5), Northern Bowen Basin (BBN6), Belyando Downs (BBN7), Upper Belyando Floodout (BBN8), Anakie Inlier (BBN9), Basalt Downs (BBN10), Isaac – Comet Downs (BBN11), Nebo – Connors Ranges (BBN12), South Drummond Basin (BBN13), Marlborough Plains (BBN14), West Balonne Plains (MUL1), Claude River Downs (BBS1), Woorabinda (BBS2), Boomer Range (BBS3), Mount Morgan Ranges (BBS4), Callide Creek Downs (BBS5), Arcadia (BBS6), Dawson River Downs (BBS7), Banana – Auburn Ranges (BBS8), Buckland Basalts (BBS9), Carnarvon Ranges (BBS10), Taroom Downs (BBS11), Southern Downs (BBS12), Barakula (BBS13), Dulacca Downs (BBS14), Weribone High (BBS15), Tara Downs (BBS16), Eastern Darling Downs (BBS17), Inglewood Sandstones (BBS18), Moonie R. – Commoron Creek Floodout (BBS19), Moonie – Barwon Interfluve, Collarenebri Interfluve (BBS20), Northern Basalts (BBS21), Northern Outwash (BBS22), Pilliga Outwash (BBS23), Pilliga (BBS24), Liverpool Plains (BBS25), Liverpool Range (BBS26), Talbragar Valley (BBS27), Balonne – Culgoa Fan, Culgoa–Bokhara (DRP1), Narran – Lightning Ridge (DRP2), Warrambool–Moonie (DRP3), Macintyre – Weir Fan, Castlereagh–Barwon (DRP4), Bogan–Macquarie (DRP5), Lachlan Plains (CP5)

<u>NHT regions</u>: Lachlan, Central West, Namoi, Gwyder, Western New South Wales, Border Rivers (New South Wales), Border Rivers (Queensland), South-West Strategy, Maranoa–Balonne, Condamine Alliance, Fitzroy and Burdekin.

4.12.2. Biophysical attributes

Climate is dominated by seasonally wet/dry climates grading from hot 'tropical' conditions in the north to warm 'Mediterranean' conditions in the south. For instance, the Townsville plains and other northern areas are dominated by an I3 climate type with a growing season lasting at least six months. This grades into an E4 climate for most of the brigalow belt (e.g. Arcadia), which is unique to subtropical continental eastern Australia. Growth is relatively even through the year and is limited by moisture rather than temperature. E3 (summer growth limited by low soil moisture, with winter growth limited by temperature, e.g. Pilliga) and E2 ('Mediterranean', e.g. the Lachlan Plains) climate classes characterise the southernmost areas of Zone 10.

The original vegetation within Zone 10 was dominated by eucalypt forests and woodlands (55%), acacia forests and woodlands (19%) and grasslands (13%). Vegetation structure is now dominated by areas of remnant brigalow and softwood scrub, but includes standing eucalypt forests and woodlands, grasslands, dry rainforests, cypress pine woodlands and riparian communities. For instance, the Pilliga subregion is dominated by mixed eucalypt (especially hardwood species) and cypress pine forests, while the Collarenabri interfluvial plains are dominated by coolibah (*E. microtheca*) and open grasslands (e.g. *Astrebla* spp.). Zone 10 includes a portion of the Mulga Lands (MUL1), which is dominated by poplar box (*E. populnea*) and mulga communities, sections of the Darling Riverine Plains, dominated by coolibah and river red gum (*E. camaldulensis*) communities, and the Lachlan Plains, which is primarily comprised of eucalypt and acacia woodlands.

Where native vegetation persists, understorey vegetation is dominated by perennial grass species of the genera *Aristida*, *Bothriochloa*, *Heteropogon*, *Themeda*, *Dichanthium*, *Astrebla*, *Monachather* and *Thyridolepis*.

Complex geology in the north gives rise to ranges, breakaway country and alluvial deposits, following the Great Dividing Range down to the south and across towards the Warambungles and Nandewar ranges of New South Wales. There are large areas of flat to gently undulating clay soils west of the Great Dividing Range (e.g. the north-west slopes and plains of New South

Wales), often associated with large areas on alluvial deposits (e.g. the Darling Riverine Plains).

There are isolated remnant pockets of dry rainforest ('softwood scrub') and small areas of mound springs in the Dawson River system. Both are subjected to weed invasion and trampling by livestock (Fensham 1996, Fensham 1998).

Native grasslands in parts of the bioregion have been converted to cropping, and in other areas they are subjected to weed invasion (e.g. *Parthenium hysterophorus* – Fensham 1999).

4.12.3. Socioeconomic attributes

Approximately 90% of the zone is under pastoral and agricultural land use, with the land mostly held as freehold. Tenure is dominated by freehold in the central and southern portion of the zone, and by leasehold to the north and west. There is a low level of reservation in the zone overall (1.9%), with the greatest level of conservation in Queensland (e.g. 36.4% of the Buckland Basalt subregion is under reservation). An additional 5.5% is under state forest protection. Only 0.1% of tenure is Aboriginal land, the lowest for any GLMZ.

Population density is high throughout most of the zone (average of 57 people per 1000 km^2), with few cities but several large regional centres and a large rural population.

Property size is the smallest in the rangelands of Australia (overall sub-bioregional mean = 23,500 ha), with mean property sizes tending to be smallest to the east and south.

4.12.4. Pastoral grazing systems

European settlement commenced within this zone between the 1840s (in the south) and the 1860s (in the north), among the earliest in Australia's rangelands. This, coupled with fertile soils and favourable climate conditions, has resulted in substantial modification to the landscape for grazing, cropping and settlement. Zone 10 contains the highest levels of land clearing in the rangelands of Australia, often promoted through government schemes (e.g. Queensland's Brigalow scheme in the 1950s). The eastern and southern sections have been substantially cleared for cropping. The western and northern sections have been substantially cleared for grazing intensification, either to promote native grass species or (more commonly) to support introduced pasture species such as buffel grass (*Cenchrus ciliaris*) and legumes (e.g. stylo species and the leguminous tree leucaena). The widespread introduction of exotic species creates a less obvious alteration to the landscape compared with clearing, but potentially poses a greater threat to biodiversity by impacting upon a larger area and by being more difficult to control. Grazing is dominated by cattle in the north and by mixed sheep and cattle grazing to the west and south.

In excess of 50% of the original vegetation has been cleared, with clearing focusing on the most fertile soils with the greatest potential to increase productivity. Clearing methods have ranged from the broad-scale removal of trees and shrubs, leaving a few, if any, standing isolated trees, for cropping in the more fertile plains, through to well-considered clearing, retaining wildlife corridors and appropriate habitat. In general, areas of high slope have the lowest levels of clearing in recognition of the erosion risk, but also due to inaccessibility and low potential for increased productivity.

Much of the early clearing (pre-1940s) was by hand, with areas of standing dead timber retained during ringbarking. Other areas were clear felled, leaving no standing timber and no potential to provide habitat. Post World War II, mechanical and chemical clearing techniques have been dominant, generally severely limiting habitat values over large areas through broad-scale clearing and reduced connectivity. Despite strong tree clearing legislation in New South Wales since 1992 (SEP 46), the greatest levels of broad-scale clearing for conversion to cropping land in recent times has been within the Darling Plains, especially the Collarenebri inter-fluvial subregion and surrounding areas. This represents a strong western shift in the cropping belt.

Appropriate thinning techniques and compensation for lost production potential will be ongoing issues within remnant vegetation of Zone 10, with trade-offs for biodiversity and production values likely to dominate debates.

Cropping systems include dryland winter crops such as wheat, oats and barley and irrigated crops such as cotton in the south in cleared woodlands or grasslands (e.g. the Lachlan Plains), through to summer crops such as sorghum, millet and sunflowers within the southern brigalow belt and fodder crops such as sorghum to the north. Cropping is more prevalent in the western section of Zone 10 in New South Wales than in Queensland. The northern section of Zone 10 borders the irrigated sugar cane areas of the Mackay and Townsville areas. High levels of fertiliser and chemical inputs typify irrigated crops, and are becoming more highly used within dryland systems. Dryland cropping systems are starting to be dominated by conservation and precision farming practices which provide increased protection to the soil resource.

Sheep and cattle densities are high (13.94 DSE km^{-2} and 10.41 AE km^{-2} respectively), as are macropod densities (10.56 km^{-2}). Total grazing pressure is double the next highest zone (Zone 4), at 11.08 AE km^{-2} (99.72 DSE km^{-2}). Nearly 90% of the area is within 6 km of permanent water. The impact of grazing, however, is generally secondary in a landscape dominated by cropping and high levels of tree clearing.

4.12.5. Wild stock (including feral animals)

The most common feral species within Zone 10 are wild pigs, especially associated with riparian and cropping areas. There are limited numbers of goats and rabbits in isolated pockets, but generally low densities across the zone.

There are high densities of grey (*M. fuliginosus*) and red (*M. rufus*) kangaroos along the western margin of Zone 10, as well as to the south. Reid (1999) has cited declining emu populations in the wheat belt which covers Zone 10, but there appear to be localised high populations associated with cropping areas within less modified landscapes.

Overall, TGP is moderate to high because of the low rainfall and productivity of the region.

4.12.6. Current management of TGP

Grazing of livestock generally occurs on a year-round, continuous basis (i.e. set-stocking), with both feed substitution (e.g. on crop stubble or hay) and supplementation (e.g. molasses or lick blocks) commonplace. This has lead to wide-scale soil loss and vegetation degradation in some areas (e.g. the Burdekin).

On leasehold land, stock numbers are usually set in relation to recommended (New South Wales and Queensland) maxima under lease conditions. There are no restrictions on freehold land. For some areas that rely on surface waters, stock numbers are dictated more by the availability of water. Mostly, however, the availability of permanent water piped from bores and dams means that forage levels are the main control on stock numbers. There is some use of seasonal forecasts to reduce risk associated with drought, and feed budgeting in both the short and medium term is becoming more commonplace. There is also an increasing interest in the use of alternative grazing systems, such as short duration grazing.

The government in each state regulates kangaroo management. Commercial shooting is the main form of control in Queensland, New South Wales and South Australia. This occurs under a strict quota system, based on aerial surveys of kangaroo numbers (concentrating on the four most common species).

High human population densities and associated infrastructure, fluctuating economic returns, high capital costs and an expectation of high levels of production and return on investment place pressure on land management. The pressures include maximising available land for grazing, and maximising the utilisation of available pasture.

Zone 10 is generally outside the dingo exclusion fence separating the sheep pastoral areas of Queensland, New South Wales and South Australia from cattle, farming or desert country. As a result, dingo populations are relatively high, but there is cause for concern over the loss of purebred dingo genetics through inter-breeding with populations of wild dogs. This may have consequences not only for the dingo population, but also for dingo prey such as small marsupials, kangaroo joeys and (potentially) calves and sheep.

Eruptive invertebrates, such as the Australian plague locust (*Chorteceties terminifera*), generally arise in other areas (e.g. the Channel Country of Queensland) but arrive in plague proportions, devastating both native and exotic vegetation.

4.12.7. Biodiversity issues

Clearing of brigalow and softwood scrub areas, in particular, has led to loss of habitat and fragmentation of the landscape and has created additional risks to the movement and interaction of ground-dwelling species in particular. Sattler & Williams (1999) considered 27 of the 163 regional ecosystems identified for the brigalow belt in Queensland (17%) to be endangered and a further 43 (26%) to be ‘of concern’, mostly because of the direct impact of clearing and consequent fragmentation.

The introduction of exotic species also poses problems for maintaining biodiversity values. Exotic grasses, such as buffel grass, have been widely distributed in conjunction with pasture improvement programs. While productivity has been markedly increased as a result, concerns now relate to the loss of native vegetation and the potential loss of key ecosystem processes and biodiversity values. Control of grasses, in particular, is both difficult and controversial in a landscape dominated by high production grazing and cropping systems.

Broad-scale declines of many species of plants and animals have been reported across the region (Gordon 1984, Covacevich et al. 1996, Covacevich et al. 1998, Sattler & Williams 1999). Many of these species declined prior to the 1950s, including the extinction of the paradise parrot (*Psephotus pulcherrimus*), the only bird species known to have become extinct on the Australian mainland since European settlement. Many species with formerly extensive ranges, such as the bridled nailtail wallaby and northern hairy-nosed wombat, have become contracted to small populations at only one or a few sites. These losses have resulted from vegetation change, the spread of feral cats, hunting and poisoning and periods of prolonged drought.

In the southern areas of Zone 10, approximately 20 land bird species have declined, while 29 native and 7 introduced land birds have increased in abundance or range (Reid 1999). There have been major losses of native mammal species including the white-footed rabbit-rat (*Conilurus albipe*s), blue-grey mouse (*Pseudomys glaucus*), pale field-rat (*Rattus tunneyil*), bilby, brush-tailed bettong (*Bettongia penicillata*), eastern hare-wallaby (*Lagorchestes leporides*) and bridled nailtail wallaby (Southgate 1990, Dickman et al. 1993, Dickman 1993).

Altered fire regimes are likely to have resulted in changed vegetation structure. In some areas fire has become a favoured management tool, increasing fire frequency but probably reducing pre-European fire intensity.

The impact of localised grazing is causing degradation of small patches of remnant vegetation, and of mound springs.

4.12.8. Previous projects and on-ground work

In Queensland, the government has invested heavily in research within Zone 10 through the Department of Primary Industries and Fisheries (DPIF), Natural Resources, Mines and Energy (NRME) and the Environment Protection Agency (EPA). While projects initially tended to focus on increasing the grazing potential through introduced plant species, both sustainability and biodiversity have been addressed in recent years. DPIF and NRME have, for instance, established networks of long-term woody and understorey monitoring sites (e.g., Q-Graze sites), and have conducted projects to determine sustainable levels of grazing (e.g. studies into the impact of grazing in *Aristida–Bothriochloa* pasture communities). Biodiversity studies have been conducted throughout the brigalow belt in particular, as has specific research into the northern hairy-nosed wombat and spectacled hare-wallaby.

4.12.9. Knowledge gaps

Despite the level of research to date, knowledge gaps still exist for both site-specific and landscape-level biodiversity issues. For example, the northern hairy-nosed wombat has adapted to eating buffel grass (Low 1997) and the spectacled hare-wallaby seems largely unaffected by pastoralism (Filet et al. 1997), but the long-term impacts of landscape fragmentation and diet switching are not necessarily well understood.

The density of many plant species in particular areas has changed due to pastoral development on agricultural tenures (Hannah 2000), but the extent of the change has not been quantified for most species. While no plant species appear endangered by clearing (Johnson 1997), many existing regional ecosystems are endangered due to loss of integrity. The full extent of the impact of pastoral development is yet to be fully understood.

4.12.10. Opportunities to invest

The most immediate and obvious on-ground opportunities to invest are the protection of mound springs and small fragmented areas of remnant vegetation.

Other opportunities include:

- The control of weed species, especially those that have impacts at multiple levels (economic, environmental, human health), such as parthenium weed.
- The continued protection of isolated colonies of mammals (e.g. the northern hairy-nosed wombat).
- Re-establishing connectivity across the landscape based on sound science and compensation/incentive packages.
- Investigation of more flexible vegetation management policies (e.g. the introduction of vegetation-clearing trading rights to allow for the re-establishment of softwood scrub, while allowing for the sustainable development of 'of-concern' regional ecosystems).
- Research into economically viable thinning within thickened vegetation.
- Thorough investigation of the potential for current vegetation management policies to protect rare and threatened species and encourage a return to functional ecosystems.
- A detailed review of the current rare and threatened species lists.
- Strong incentives for collaboration between Queensland and New South Wales in recognition of the fact that biodiversity and vegetation management issues are ignorant of state boundaries.

5. REVIEW OF PREVIOUS PROJECTS

5.1. Introduction

One requirement for this study was to provide a review of past (and current) research and management projects relating to TGP and biodiversity conservation in the rangelands. In particular, this would focus on projects funded through the Natural Heritage Trust, although the scope included other funding bodies and programs such as National Reserve System Cooperative Program; Land and Water Australia; Meat and Livestock Australia and various state-based programs. The purpose of the project review was:

- To provide a readily accessible summary of past projects funded through NHT (and other relevant projects) in a searchable form (e.g. with relevant keywords).
- To assess the transferability of the outputs and insights from past projects to other areas of the rangelands.
- To assist in identifying knowledge gaps and priorities for future investment.

An indicative list of relevant NHT projects was supplied by the Department of the Environment and Heritage, based on a keywords search within their databases. Progress and final reports were provided for review from DEH files.

Unfortunately, the indicative list contained only 37 NHT1 projects (Table 5.1) and our existing knowledge and experience indicated that many relevant NHT projects were not included on this list. Furthermore, file information could only be provided for 14 of these projects. In most cases, this information did not include final reports and/or the information in the reports was manifestly inadequate for providing useful information for this review.

During the description of the GLMZs, the project expert group provided an indicative list of other past and current research relevant to TGP management and biodiversity conservation (see Chapter 4). A process is now under way to make this list as comprehensive as possible, and to provide useful summary information in a searchable database.

5.2. Project review database

To provide summary information about relevant projects, an Excel table was created (with linked Word documents for larger blocks of text). The table structure was developed to allow simple indexing or searching by locality, theme or keyword. Fields within the table are listed in Table 5.2.

Table 5.1. Preliminary list of NHT1 projects relating to TGP and biodiversity in rangelands. This is a summary of a database provided by DEH, with projects attributed to GLMZ.

GLMZ	State	Project name	Proponent	Summary objectives
5,6	NT	Demonstration of Ecologically Sustainable Management of Camels on Aboriginal and Pastoral Land	Central Australian Camel Industry Association Inc.	Australia has a population of more than 200,000 feral camels with numbers increasing dramatically – estimated to be doubling every six to eight years. This project will provide the methodology for effective and continuous control of camels, and at the same time offer Aboriginal communities and pastoralists the potential for diverse income. It will describe the impact of camels on native vegetation and recommend ecologically sustainable stocking rates. The project will provide training programs for land managers in managing camels and rangelands. The Northern Territory Government sees feral camel management as a high priority due to the potential major impact of uncontrolled feral camel numbers upon both the pastoral industry and the environment in the rangelands. This project could alleviate the need for inefficient and costly control programs which will be required in the future.
5,6	NT	Develop Centre Land Watch, a Pastoralists' Natural Resource Monitoring Program	Centralian Land Management Association	Develop and promote among a growing group of pastoral land managers (which will include managers of Aboriginal land), a land condition assessment and monitoring scheme to provide landholders with an improved tool for managing natural resources. It will embrace historic records. Complementing the Northern Territory Government programs, it will develop photographic and descriptive guides to land condition states. An advisory/consultative group of stakeholders will be established with an independent chair.
2	NT	Grazing Regimes to Maintain Biodiversity in the Mitchell Grasslands	Department of Primary Industries and Fisheries – NT	The impact of livestock grazing pressure, both total and spatially throughout the landscape, on plant and bird biodiversity will be assessed on an existing long-term research site located on 60 sq km of Mitchell grasslands at Mt Sanford. Information from indicator species of flora and fauna will be used to enhance land managers' knowledge and understanding, and the implementation of management for conservation of biodiversity within sustainable production systems.
5,6	NT	Indigenous Land Management Facilitator – Parks and Wildlife Commission NT (South)	Parks and Wildlife Commission of the Northern Territory	1 Promote commitment to, and participation in, sustainable land management and nature conservation by managers of Indigenous land. Foster involvement of Indigenous people in national, regional and local activities for achieving ecologically sustainable development. 2. Act as a practical two-way link between Indigenous land managers, and other individuals and organisations involved in promoting sustainable land management and nature conservation. 3. Assist Indigenous land managers with access to financial and technical assistance from the Natural Heritage Trust and other sources. 4. Provide input into the consideration of Indigenous land management issues by Departments of Environment and Heritage and Agriculture Fisheries and Forestry. 5. Assist in the provision of cross-cultural awareness training, especially in relation to Indigenous land management practices. 6. Assist in the representation and promotion of Indigenous values, aspirations and capacity in land management through local and regional, and national meetings, including through Regional and State Assessment Panels.

GLMZ	State	Project name	Proponent	Summary objectives
2	NT	Integrated Rangeland Management in the Victoria River District	Victoria River District Conservation Association Inc.	This project seeks funding for a regionally applied and devolved grants scheme that will complement the efforts of regional landholders to reduce TGP and improve the quality and extent of native vegetation cover in the Victoria River District. The project is integrated to include native grass revegetation, fencing environmentally significant areas, strategic feral animal control and monitoring. Funding requests will be assessed on the basis of a site inspection by the proponent and the completion of an application form which will describe the nature and extent of the proposed actions and landholder's commitment to ongoing management. Two levels of management agreement will be available to landholders participating in the project to increase incentives and long-term security of works undertaken.
6	NT	Land Restoration on Ingkerreke Communities	Institute for Aboriginal Development	Provide skills development for on-ground action tackling a range of environmental problems on 12 pastoral excision communities on areas of former stock route within a 200 km radius of Alice Springs. The project aims to assist the organisation and implementation of on-ground activities and promote planning, knowledge and skills development of community members in sustainable land use. The communities are affiliated through Ingkerreke Outstation Resource Centre. On-ground activities will address the root causes of existing land degradation on each excision, and rehabilitation and restoration work will reduce erosion, control dust and improve general environmental health by fencing to reduce livestock intrusion into residential areas, planting and soil conservation programs to reduce erosion and dust problems, and development of bush food production activities to increase self sufficiency.
6	NT	Post-RCD Rabbit Control to Benefit Threatened Species in the Finke Bioregion	Centralian Land Management Association	To remove rabbits from a portion of the Finke bioregion to allow for regeneration of important habitat in the area (containing marsupial mole and mulgara). Identify key habitat for conservation-dependent species and monitor population trends of native fauna, particularly threatened species. A fox control program will be conducted in association with the rabbit control activities to avoid the risk of heightened predation pressure on native species. A second section of the Finke bioregion (the Finke floodout) will be assessed to determine the feasibility of rabbit control activities and the likely benefits for threatened species. A monitoring program will be recommenced at two sites in Central Australia to determine the impact of RCD. Rabbits in peri-urban areas will be included in the project, with advice provided on recommended treatments.
6	NT	Rangelands Rehabilitation – Paddy's Plain	Pantharpilenhe Community	Paddy's Plain is part of the Loves Creek Pastoral Lease, which has been extensively overgrazed by cattle and feral horses. Consequently there are large areas of sheet and gully erosion. As part of the Central Land Council's continuing land management program, a workshop held with the Pantharpilenhe community and other stakeholders identified the need to focus on the rehabilitation of Paddy's Plain. This project represents the next step in a holistic land management plan to rehabilitate part of Australia's rangelands. The plan aims to reduce the TGP from cattle and feral horses, remediate soil erosion and restore the balance of native herbivores. In the long term these actions will be complemented by the development of an appropriate fire regime.

GLMZ	State	Project name	Proponent	Summary objectives
5,6	NT	The Impact of Wild Dog Control on Cattle, Native and Introduced Herbivores and Introduced Predators	Parks and Wildlife Commission	This project will investigate the effect of wild dog control on macropods and rabbits and resulting grazing impact, and on feral cats and foxes. The cost–benefits of wild dog control will also be examined. This project will coincide with the release of national wild dog management guidelines by the Bureau of Resource Science – both should lead to better management of wild dogs in Australia's rangelands.
3,6,8, 9	QLD	Appraising Safe Grazing for All Properties in South West Queensland	Queensland Department of Primary Industries and Queensland Beef Industry Institute	Objective assessment of the long-term grazing capacity of each property in South West Queensland.
2,3,4, 6,8,9, 10	QLD	Demonstrating Stocking Rates for Sustainable Productivity	Queensland Department of Primary Industries	This project aims to demonstrate and incorporate improved management techniques for producers, as inappropriate grazing management is a major cause of land degradation associated with, but not confined to, drought.
4	QLD	Ecologically Sustainable Management of the Birdbush Basalt Environment and Grazing Industry	Dalrymple Landcare Committee Inc.	The Birdbush Basalt district is one of the most viable beef-producing areas in the Burdekin Rangelands. It has a unique blend of basaltic soils, geological formations, including the Great Basalt Wall National Park, and spring-fed streams. Although the natural resources of the area are in good condition, there are some threats that Natural Heritage Trust funding can help to overcome. They include declining pasture condition, overgrazed/weedy stream frontages, scalded land and declining water quality. This project aims to use fencing to regulate grazing pressures on stream frontages and other favoured areas, so that vegetation in riparian areas can regenerate and water quality can improve.
10	QLD	Implementing Best Practice Land Management in Fitzroy Basin Grazing Lands	Parthenium Action Group Inc.	Develop a land management strategy incorporating action plans which provide landholders with a range of practices that integrate pest management for sustainable agriculture. Develop appropriate resource management systems at the property and industry sector level, e.g. grazing, cropping, mining and local government, and through collective cooperation expand these to a regional level suitable for incorporating into regional strategies such as the Central Queensland Strategy for Sustainability.
3,8,9	QLD	Management of Grazing Pressure for Sustainable Land Use	Queensland Department of Primary Industries and Queensland Beef Industry Institute	Management of TGP in the Mulga Lands and adjacent Mitchell grass downs in South West Queensland.
4	QLD	Practical Grazing Management Guidelines for Dalrymple Shire	Grazing and Land Management Unit	Practical guidelines to help producers determine pasture condition; safe levels of pasture use; increased awareness of, and on-ground adoption of, sustainable grazing management practices.

GLMZ	State	Project name	Proponent	Summary objectives
4	QLD	Review of Resource Management Issues – Eastern Desert, Central Queensland	Department of Natural Resources	Review natural resource management issues in the Desert Uplands.
6	QLD	Sustainable Grazing on the Channel Country Floodplains	Department of Primary Industries – Queensland	This project will explore the sustainability of cattle grazing on Channel Country floodplains.
4	QLD	Sustainable Rangeland Management in the Upper Catchments of Lolworth Creek, Clarke, Basalt and Flinders Rivers	Headwaters Landcare Group	The Headwaters Landcare Group consists of nine cattle properties covering an area of 333,000 ha of extensive grazing land. Through the strategic use of fencing and the location of watering points, and the adoption of key grazing management practices to improve the habitat value and grazing value in the district, this project will address the following issues on seven of these properties: the increasing density of wood plants in the savanna; decline in native pasture condition on riparian and black soils areas; preventing exotic woody weeds from invading these areas; soil erosion on riparian and sloping black soil areas; overgrazed areas in large paddocks due to inadequate stock water distribution. Long-term objectives are: to adopt land and grazing management practices that are economically viable and will have positive outcomes for biodiversity and conservation in the Headwaters area, and to enhance the habitat in the area between two important but vastly different protected areas – the Great Basalt Wall and White Mountains national parks.
9	SA	Aroona Catchment Biodiversity Enhancement Project	Northern Flinders Soil Conservation Board	A best-practice program will be designed and implemented in an effort to enhance the biodiversity of the project area by reducing soil erosion, enhancing sustainable pasture, controlling feral species, securing habitat for rare species, and promoting community awareness.
5,6,8, 9	SA	Education – A Vital Key to Sustainable Rangeland Management	Arid Areas Water Resources Committee	To develop information kits that will assist future resource managers and decision makers to make the best-informed judgments and decisions in relation to rangeland natural resource management. The project will result in the development of innovative, quality educational resource kits focusing on sustainable rangeland management. These will be compatible with National Curriculum Statements and Profiles for Australian Schools.
6,8,9	SA	Long Term Change in Rangelands Using Historic Photographs	Department of Environment, Heritage and Aboriginal Affairs	Provide rangeland managers and administrators with descriptions of long-term change in vegetation and condition of rangelands to assist interpretation of information in contemporary rangeland assessment and monitoring systems and contribute to development of sustainable rangeland use. Develop increased appreciation by the general community of arid zone ecosystems and how they change. Rangeland managers can interpret information collected in their own monitoring systems over shorter time spans. Environmental scientists and administrators will have greater understanding of the dynamics of arid ecosystems to assist assessment of land condition.

GLMZ	State	Project name	Proponent	Summary objectives
5,6,8, 9	SA	Rangeland Action Project	Combined Rangeland Soil Boards Inc. (SA)	The project aims to alleviate the decline in habitat/biodiversity and to improve the current status of pastoral production in the rangelands of South Australia by implementing a range of work programs. The project addresses high priority issues from the national, state and regional rangelands strategies, including achieving the conservation of biodiversity; adoption of ecologically sustainable pastoral practices; pest animal and weed management; monitoring rangeland condition.
6	SA	Towards Best Practice Management for Kowari Country	Marree Soil Conservation Board	The project aims to develop and implement best management practices for Kowari habitat in the gibber country of north-east South Australia and south-west Queensland. In consultation with the broader community, the local Kowari Country Management Group will develop and implement best-practice guidelines addressing issues such as remnant vegetation protection, grazing management, and feral animal control.
8	WA	Accredited Ecologically Sustainable Pastoralism (NLP)	Gascoyne–Murchison Strategy	Establishment of linkages between regional environment and industry needs in rangeland Western Australia. Review of benchmark management standards. Statement of baseline (current) regional management standards. Establishment of objectives for regional management. Development and integration of mechanisms for achieving objectives. Implementation and monitoring of regional objectives.
5,8	WA	Aerial Survey Techniques for Feral Goats	Agriculture Western Australia	This project will determine the accuracy of aerial counting of feral goats, taking into account seasonal distribution, vegetation and goat colour. An accurate census method will allow property management to be based on TGP rather than just livestock numbers.
5,7,8	WA	Developing Total Grazing Control Strategies in WA Rangelands	Agriculture Western Australia	The project aims to integrate the work done in feral goat eradication into programs that will develop and implement strategies, tactics and methodologies to achieve total grazing control in the rangelands.
2,5,7, 8	WA	Development of Information Products for Reporting Rangeland Changes	Agriculture Western Australia	To develop useful information products for the reporting of changes in rangeland ecosystems to land managers, state and federal governments and the corporate sector.
8	WA	Gascoyne River Floodplain Native Vegetation Regeneration Project	Gascoyne Ashburton Headwaters Land Conservation District Committee Inc.	The main aim is to provide a demonstration of natural diversity and ground cover, and evaluate outcomes of such restoration through the establishment of a pasture and rehabilitation monitoring program. Activities associated with the project will be both on the ground (fencing, ripping, reseeding, monitoring) and of a promotional nature (field days, etc). The four main outcomes will be increased biodiversity through regeneration, rehabilitation of scalded hardpan; monitoring skills development within the group; and an awareness of the project within the wider community.

GLMZ	State	Project name	Proponent	Summary objectives
8	WA	Gascoyne–Murchison Strategy	Gascoyne–Murchison Strategy	This project is a key component of the Gascoyne–Murchison Rangeland Strategy (a recognised regional initiative). This project was developed to contribute to achieving the following strategy objectives: to ensure land management, based on multiple land use, that preserves the rangeland resource through the recognition of seasonal variation and the inherent values of the land; and to ensure management of the Gascoyne–Murchison rangelands so as to enhance biodiversity and ecological sustainability through the use and development of best-practice total grazing management techniques.
8	WA	Implementing Best Practice Total Grazing Management	Agriculture Western Australia	The project aims to coordinate the implementation of total grazing management systems across the Southern Rangelands based on landholder groups.
2	WA	Kimberley Aboriginal Pastoral Association – Fitzroy Valley Integrated Rangeland Management Project	Kimberley Aboriginal Pastoralists Association	The 24 pastoral properties that are members of the Kimberley Aboriginal Pastoralists Association cover an area of 4,927,779 ha and are located in every part of the Kimberley region. Twenty permanent Aboriginal communities on the properties have a combined population of more than 2000. Land tenure of properties is either pastoral leasehold (90%) or Aboriginal reserve (10%). The project will protect and maintain biodiversity, enhance sustainable production, revegetate community living areas, achieve Aboriginal community ownership and participation in ecologically sustainable management, utilise the human resources of the 24 stations and related communities to achieve project objectives, and integrate with other regional projects.
8	WA	Promoting Awareness and Education of Good Pastoral Practices	Kalgoorlie Land Conservation District Committee Inc.	To promote good rangeland management by pastoralists through self education. To educate other land users of rangelands about pastoral management, and the need to respect pastoral management and pastoral infrastructure (fences and water points) for the sake of the stock and for the maintenance of the condition of the rangelands. To provide educational materials to schools.
8	WA	Sustainable Rangeland Productivity Through Planned Landuse Diversification	Agriculture Western Australia	The project is designed to improve the environmental, economic and social sustainability of rangeland enterprises in the Gascoyne and Meekatharra regions of WA through land use and business planning at an individual station level.
8	WA	Vegetation Monitoring as a Tactical Tool in Grazing Management	Agriculture Western Australia	This project was designed to improve pastoralist stocking decision-making by employing former pastoralists for each of the agency's regional offices in the Southern Rangelands.

Table 5.2. Fields in project review database

Project ID	
NHT code	
NHT program	
Project name	
Proponent organisation	
Contacts:	Other participants
	Project leader
	Address
	Phone
	Email
	Funding amount
	Start date
	Finish date
Location:	State
	Text description
	NHT region
	IBRA
	GLMZ
	Latitude
	Longitude
	Extent
Keywords:	
Grazing animals	
Biodiversity elements	
Habitat	
Project type	
Land management type	
Project objectives	
Project summary	
Project outcomes	
Project recommendations	
Project evaluation	
Priorities for GLMZ	
Transferability	
Report adequacy	
Reviewer	

6. TGP: MANAGEMENT ISSUES AND TECHNIQUES FOR THE RANGELANDS

6.1. Introduction

Total grazing pressure in the rangelands has two distinct components – that which is managed, and that which is unmanaged. Domestic livestock (predominantly cattle and sheep, but also goats in a few areas) constitute the component that is considered to be under management control, although the degree of control exercised varies between geographical regions and animal species. In more extensive areas less control of livestock occurs. These are typically areas where cattle are run in central and northern Australia. Wild stock are essentially unmanaged, although some control of numbers occurs for some species in particular areas. On occasions in some areas the grazing pressure exerted by certain species of wild stock exceeds that exerted by domestic stock. Nevertheless there are examples of considerable success in managing total grazing pressure in the rangelands.

The number of domestic livestock on the landscape is to a large extent managed and monitored (in comparison to feral species), and in some states is subject to legislatively imposed maxima, and sometimes minima. Because paddocks are typically large, there is often little control over where (and when) animals graze in the landscape. A common consequence of this is uneven use of the landscape, with some parts being heavily utilised and other parts hardly used at all. Notwithstanding this uneven distribution, almost all the area of most properties is subject to grazing by domestic stock (Landsberg & Gillieson 1996).

There are some characteristic differences between cattle and sheep enterprises in the rangelands, which can have a bearing on the application and effectiveness of total grazing management. Sheep are generally more common in the south and are found on smaller properties where control of waters is high, the use of fire and dietary supplements is limited (or, in the case of fire, actively excluded) and set-stocking is a common management practice. Intensity of use is high, with high domestic stocking rates and generally high numbers of rabbits, feral goats and kangaroos. These areas have suffered many extinctions of native mammals. In contrast, cattle are more common in the north, and are run on large properties where both fire and supplements are commonly used management tools. Control over water availability is variable, and set utilisation is a common grazing management practice. Wild stock include horses, donkeys, camels and pigs, and the intensity of use by domestic stock is low but increasing. Many native mammals are in decline in these areas.

Control over where animals graze in the landscape has improved markedly in cattle-grazing regions since the Brucellosis and Tuberculosis Eradication Campaign of the 1980s–1990s, which involved fencing programs to facilitate disease testing and control of livestock. In more settled areas (often where sheep are the dominant livestock type) paddocks are smaller and more control can be exercised over animals. In these areas, it is more common to find paddocks being spelled and the class of livestock assigned to paddocks differing depending on the biophysical characteristics of the land and animal needs. Variation also occurs over time depending on water availability (in both more and less extensive regions).

Despite the availability of methods for the management of population numbers, grazing by wild stock (both native and introduced) can be considered to be uncontrolled. There is no general day-to-day control of numbers, or of where in the landscape the animals graze. The abundance of wild stock species is chiefly determined by seasonal conditions, although control operations will have some impact where implemented. Disease and predation play little role in regulating wild stock numbers, except in the case of rabbits (see later) and possibly kangaroos (Newsome et al. 2001). Predation can help limit the distribution of some species of wild stock, however (such as the influence dingoes have on feral goat distribution).

Preferred habitat types and mobility influence the extent of the grazing impact of wild stock. Some species are sedentary and are restricted to certain parts of the landscape (e.g. rabbits are usually found on soil types conducive to burrowing), while others are more mobile but have reasonably fixed homes ranges that may extend over several paddocks (e.g. feral goats). The movements of many of the larger species are not constrained by the types of fencing usually used to control domestic stock. Other species can be more migratory (e.g. camels, to some extent). Movements of all these animals and the locations where grazing is most concentrated are largely influenced by the availability of water, and by the availability of preferred feed. For example, red kangaroos move to areas where local thunderstorms have produced a growth of green feed (although still within a restricted home range area). Camels are less restricted in their movements by the need to drink water, whereas buffalo and feral pigs are strongly dependent on water. The fidelity of animals to particular parts of the landscape and the extent of their home range (i.e. limits of their normal daily movements) have important implications for the feasibility, design and success of control activities.

This chapter focuses on managing total grazing pressure in the rangelands. It begins with a discussion of general issues relating to managing domestic livestock and wild stock, and some factors affecting pastoralists' perceptions of wild stock species. Specific management practices for domestic livestock, and associated issues, will then be discussed. The management of wild stock follows next, including a summary of appropriate control techniques for the main species of wild stock found in the rangelands. Insights for total grazing management in the rangelands that arise from experiences in intensively used areas of south-eastern Australia are also presented.

6.2. Issues in the management of the natural resource base

It is evident from the preceding discussion that the options for managing total grazing pressure in the rangelands are limited compared with the intensive use zone. The scale of enterprises and management units, the variable and unpredictable climate, the magnitude of pest populations, the limited availability of labour and the limited control that can be achieved over animals and their movements all contribute to this difference. Economic circumstances for grazing enterprises and the low financial returns that are generally achieved per land area in the rangelands have a strong influence too. A discussion of several of the important issues in total grazing management follows.

6.2.1. Acknowledging all grazers in estimating and managing grazing pressure

For many years land managers and administrators disregarded the grazing pressure exerted by wild stock in the rangelands. Stocking rates (and carrying capacities) for domestic livestock were set with little consideration of the abundance of non-domestic herbivores. In addition, the most commonly used approach for managing grazing by domestic stock was simple continuous grazing at a constant stocking rate (apart from destocking usually enforced by low forage yields or lack of water during severe drought). To some extent the pressures applied by uncontrolled wild stock were ignored because it was seen as beyond the capacity of land managers to do anything about them. Furthermore, because wild stock could not be adequately controlled, managers frequently have been reluctant to reduce domestic stock numbers during periods of feed shortages, since wild herbivores would simply continue to utilise the remaining forage. Instead it was seen as sensible to ensure domestic stock maximised the use of the available forage before destocking. What, in fact, is required is for the number of wild-stock animals on a lease or in a paddock to be taken into account when calculating stocking rates for domestic livestock.

In recent years land managers and administrators have acknowledged and accepted the need to factor in non-domestic grazing pressure when setting carrying capacities and stocking rates. This provides an additional incentive for wild-stock populations to be effectively controlled. The need for occasional resting of paddocks to ensure the persistence of preferred perennial plants is also becoming increasingly recognised, and to achieve this wild stock numbers must also be reduced. Land managers have often complained that attempts to spell paddocks have been thwarted by increases in the numbers of kangaroos following the destocking of paddocks. Evidence to support this observation has come from Western Australia, where it was concluded that the migration of kangaroos into destocked areas from neighbouring areas could limit rehabilitation programs (Norbury et al. 1993). Similarly, it makes no sense to control wild stock and then fail to maintain adequate control of domestic grazing, or to simply replace wild stock with domestic stock. To be effective for the benefit of animal production and the protection of biodiversity, management must include all grazing species and effective control should be exercised over all.

6.2.2. Feral animals – pest or economic resource?

For some feral species an apparent conflict exists between the need to control feral animals because of the uncontrolled grazing pressure they exert, the damage they cause to the land and vegetation, and competition with domestic livestock, and the market value of the pest animals when caught and sold. This conflict applies particularly to feral goats, but also to feral horses, pigs and camels, where opportunistic harvesting of animals has been the norm. Indigenous people also frequently rely on feral species as an economic resource. On pastoral properties, rigorous attempts to keep numbers of feral species as low as possible by following mustering or trapping with shooting have rarely been made, because managers have been willing for numbers to build up to provide additional income at a later stage, especially in poor seasons. Many managers have failed to recognise that feral species in fact compete with domestic livestock, and can reduce livestock productivity, so total grazing pressure on the land has often been excessive. Henzell (1989), in an analysis of the implications of feral goats on pastoral properties in South Australia, showed that even allowing for the financial returns from mustering and selling feral goats, the overall economic position of the pastoral enterprise was negatively affected by the presence of feral goats. Obviously changes in the prices received for wool, sheep, cattle and feral goats will affect this conclusion. In recent years the value of feral goats on export markets has increased and some properties have made good money from their sale.

Minimising the abundance of feral pest species at all times is vital for the maintenance of biodiversity and the sustainability of pastoral enterprises. Because management control over pest species is limited, such as where in the landscape they graze, the capacity for limiting adverse impacts from them is constrained. It is therefore important for managers to be clear about the true role of feral species in the rangelands, which generally should be seen as a threat rather than as an economic resource. In an attempt to resolve this conflict, policies have been instituted in Western Australia that allow pastoralists to run goat enterprises by domesticating and breeding feral goats (see feral goat section later). However, the value and effectiveness of this in achieving improved resource management is unproven.

6.2.3. The issue of dietary choice

It is sometimes argued that differences in dietary choice between herbivore species means there is little competition between them when grazed together on the same land. This results in the perception that there is less pressure on vegetation resources than if all herbivores were the same species because defoliation pressure is spread across a greater range of plant species. Recommendations for the co-grazing of camels and cattle in Central Australia are based on this idea. A related argument is that herbivore species with a more eclectic diet also have less potential for causing damage to vegetation because they more readily switch between plant species. This is one of the arguments behind the promotion of the domestication of feral goats on rangeland sheep enterprises.

Although it is true that herbivores do differ in dietary breadth and willingness to switch to less preferred plant species, there is still the potential for competition to occur and environmental damage to result because of similar dietary consumption. Most herbivore species will select the best, most nutritious feed. When available, this will usually be the green material of grasses and forbs. Thus grazing pressure on resources is higher when domestic stock and wild stock are both present. One consequence can be the earlier depletion of good quality feed so that stock are forced onto poorer feed sooner than would be the case without other herbivores present. There will also be increased pressure on all vegetation resources during poor seasonal conditions, but particularly in refuge areas, with adverse consequences for biodiversity. Production from domestic livestock can be adversely affected. Issues of trampling of plants and soils, and the potential for increased soil erosion also arise with increased herbivore numbers, which can affect habitat quality for native species (i.e. biodiversity values). As a result, the argument that the co-grazing of different herbivore species can occur without additional environmental risk should be questioned. It is also inconsistent with the accepted view that pest animals compete with livestock and cause environmental damage. Finally, the presence of herbivores with a more diverse diet can still result in declines in rangeland condition if they are not managed carefully because of their preference for higher quality plant species.

6.2.4. Soil impacts

Of course, the impact of grazing animals is not limited to the direct effects of grazing on plants. Much of the impact occurs through the effect of the soil being trampled and greater exposure of the soil to the erosive effects of rainfall and wind because of reduced vegetative cover. These effects are exacerbated by the animals creating tracks radiating out from water points, walking along drainage lines, and by causing the dispersion of bush mounds in chenopod shrublands when stocking rates are too high and the shrubs are removed by grazing. The result is an alteration of landscape function through a modification in surface hydrology, nutrient dynamics and plant growth potential. Clearly, the management and monitoring of the impact on soils is as critical as managing and monitoring the impact on plants. Both domestic livestock and introduced wild stock contribute to these effects.

6.2.5. Transferability between GLMZs

The transferability of management options between GLMZs is influenced by factors such as vegetation type, scale of enterprises and management units, the productivity and economic circumstances of pastoral operations, the intensity of land use, and, for wild stock, the species of concern and the extent and density of the population. Grazing management systems for domestic stock are often not readily transferable because of differences in livestock type, water availability, vegetation resources and season of growth. For example, grazing management based on the estimated seasonal growth and known safe utilisation rates is appropriate for perennial grass-dominated tropical savanna systems but is completely unsuitable for shrub-dominated systems such as the chenopod shrublands. Legislation affecting the use of the land for domestic stock production can also influence transferability by limiting or preventing pastoral enterprises from increasing domestic stock numbers in response to pest control. However, in the context of the protection of biodiversity it is not likely to be desirable to increase stock numbers.

6.3. Management of domestic livestock

The generally accepted (but often unstated) aim of managing the natural resources in pastoral lands is the retention of sufficient vegetative cover to protect the soil from erosion, and thus maintain its productive capacity. However, natural resource management occurs within the context of achieving adequate levels of animal production (and income) to meet short-term economic needs. In practice, these two demands do not always converge.

Management needs for sustainability are in fact more demanding than simply maintaining adequate levels of cover. Maintenance of perennial plant species (grasses and sub-shrubs, depending on the rangeland type) is a high priority where they occur, but it is widely assumed that maintaining an adequate level of cover will be sufficient to maintain perennial species. This is not necessarily the case, and more exacting management is probably required because of subtle changes that can occur in plants and their populations which have long-term implications for persistence. In addition, although maintaining desirable species in the pasture is recognised as an important management goal, management activities specifically targeted at maintaining plant species composition are rare in Australia’s rangelands.

In many arid and temperate areas of the southern rangelands annual species or short-lived facultative perennials dominate pastures rather than long-lived perennial species. These short-lived species are subject to considerable fluctuation in abundance because of the tight coupling between rainfall, temperature and pasture growth. Normally in such situations management has little influence on species composition and primary production, and maintaining adequate cover for the protection of the soil should be the prime focus of management.

Many jurisdictions offer recommended carrying capacities for land systems as a basis for long-term stocking decisions (e.g. Western Australia). Specified carrying capacities should not be viewed as a safe carrying capacity for all seasonal conditions, or as a target in the implementation of a continuous stocking system on a property. Some state administrations (e.g. South Australia) also specify maximum allowable stock numbers for each lease, although how the animals are distributed on a lease is the concern of the manager.

6.3.1. Common grazing management issues

There is a range of specific issues that management should consider when choosing and implementing grazing management practices to achieve an acceptable balance between animal production, long-term sustainability and the protection of biodiversity. These issues have general application and relevance across the rangelands. A brief discussion of the key points and the associated best-practice recommendations follows.

6.3.1.1. Stocking rates, utilisation rates and carrying capacities

As mentioned above, some state jurisdictions have recommended carrying capacities (in terms of the number of animals per unit area) for different land systems, based on rangeland assessment surveys and historical carrying capacities. Carrying capacities are most often specified for the southern rangelands which are dominated by shrubby vegetation types or annual pastures. In tropical grassland systems, safe utilisation rates are normally used instead of carrying capacities.

Recommended carrying capacities are generally based on what is considered to be a safe level in the long term, and are used in determining stocking rates appropriate for most but the driest years, i.e. the number that can be carried without forced destocking in about eight or nine years out of ten. In some states maximum allowable stock numbers are specified rather than carrying capacities.

Stocking rates (i.e. the actual number of livestock on the land at a particular time) should be based on the capacity of land to carry stock. Long-term carrying capacities are often provided by state agencies, but the manager must make short-term decisions in response to seasonal conditions. Stocking rates should be conservative to provide a buffer against declining seasonal conditions and forage availability (ideally they should be set at a level that avoids forced destocking in all but the worst drought, i.e. a one in ten year drought).

It is inappropriate and impractical to set stock numbers based on shrub utilisation rates in the chenopod shrublands. In these vegetation types it is the grasses and forbs that grow between the shrubs that provide the bulk of the feed in most years, and these have a fair degree of resilience to grazing. When recommended stocking rates are used, the shrubs are heavily grazed only in years of low rainfall when few grasses and forbs grow. The critical point in the management of these systems is deciding when to destock in drought so that the perennial shrub populations are not seriously affected in the long term.

For the tropical and subtropical savanna grasslands and Mitchell grasslands, optimum utilisation rates are usually specified and these dictate the stocking rates that should be used at any particular time. These utilisation rates represent the percentage of the perennial grass forage present at the end of the growing season that it is safe to use as forage. These rates are usually in the order of 15–30%, the specific value being defined according to different ecosystems and management contexts. Pasture growth models (e.g. GRASP – Littleboy and McKeon 1997) should be used to estimate pasture availability based on rainfall received during the growing season.

6.3.1.2. Drought and risk management

Managing drought is a critical part of successful overall grazing management. It is during droughts that the potential for substantial long-term damage to natural resources can arise because of the decreasing ratio of forage availability to livestock numbers and the moisture stress that plants are under at these times. There can also be a tendency for livestock to use parts of the landscape that are usually avoided or used only minimally. This grazing pressure may compromise the natural resource values of these areas, which might otherwise have good biodiversity values.

Prompt decision-making in times of drought is critical to achieving sustainability. An early reduction in stock numbers decreases the risk of land degradation and the need for forced selling of stock when prices are poor. The use of critical indicators of pasture condition (e.g. photostandards or minimum stubble height measures) protects perennial plants from overuse. Being prepared for drought (having a drought plan) increases the chances of the business and the rangelands surviving a drought in reasonable condition. Having wild stock numbers effectively controlled prior to the onset of drought also increases the capacity for successfully managing drought.

The use of seasonal forecasting and pasture growth models to make more timely decisions about stock numbers is recommended, especially in areas strongly influenced by El Niño – Southern Oscillation (i.e. northern and eastern regions). This can provide an early warning for the need to make stocking rate adjustments. Comparison of current pasture conditions with similar conditions on an earlier occasion using pasture models such as Aussie GRASS (short for Australian Grassland and Rangeland Assessment by Spatial Simulation; see Carter et al. 2000 and www.cvap.gov.au/newfsHall.htm) enables more informed decision-making. However, not all regions have well-developed and appropriate tools for use in this context.

Supplementary feeding of livestock during drought is generally not recommended (because of the cost and potential for damage to pasture resources), although maintaining a breeding nucleus of stock is considered an exception. Artificially maintaining livestock on the land creates the potential for overgrazing of perennial plants during times of high stress.

Vegetation should be allowed to recover for some months following the breaking of a drought before restocking. Rapid restocking after drought may assist the enterprise financially but could compromise the recovery of the vegetation, or cause the death of plants if they are heavily grazed at an early stage of regrowth. The same applies to grazing soon after a fire, or early in the wet season following the breaking of dormancy in perennial grasses.

6.3.1.3. Managing spatial impact

For the purpose of sustainable and reliable animal production, a wide-spread view holds that grazing pressure should be spread over the landscape as evenly as possible. Uneven distribution of grazing within paddocks leads to localised patches of degradation because of animals' preferences for particular forage types. This is a common concern for managers of pastoral enterprises, and it is difficult to prevent. A more even distribution of grazing pressure can be achieved by subdividing the landscape with fencing and by locating watering points strategically. Smaller paddocks and shorter return distances to water for drink result in a more even utilisation of the landscape as a whole and of the area within a paddock. The relative benefits and costs of these alternatives, both economically and environmentally, are not clear. More even grazing may also have detrimental consequences for biodiversity values because little of the landscape is unaffected by grazing; therefore, additional strategies must be adopted to protect these values (see biodiversity recommendations below).

Land types with different grazing values and different responses to grazing and seasons should not usually occur within the one paddock (see Ash & Stafford Smith 1996); where possible, fences should be positioned so as to enclose only similar vegetation types in the one paddock to minimise the risk of animals concentrating on preferred vegetation or land types. The use of fire to remove grazed patches (which are favoured and repeatedly visited by livestock who are attracted by the palatable regrowth) in tropical and subtropical grassland pastures can result in the more even use of a paddock. At this stage, though, the effectiveness of using sophisticated grazing systems that subdivide the landscape and rotate animals between paddocks, such as cell grazing, to achieve more even paddock and landscape use remains unproven.

Opposed to the widely accepted belief in the need for grazing to be spread evenly across the landscape and for different land types to be segregated, there is a growing view that paddocks that contain a diversity of land types may offer production benefits for domestic stock. This is because areas that are remote from water or usual grazing areas, or are less preferred land types, can provide quality forage during less favourable seasonal periods and thus may buffer declining productivity. However, because such resource reserves can maintain animals on the landscape during resource shortages, damage to more preferred land types, or those closer to water points, may result (e.g. Illius & O'Connor 1999). This might be less of a problem for resilient land types, but careful management is nevertheless essential in this situation.

Preferred parts of the landscape and foci of animal activity such as water points will be the first to exhibit signs of excessive grazing pressure. While these areas become heavily grazed, a small and stable area of disturbance is tolerable. These focal areas should be monitored for signs of expansion or increasing erosion because these indicators will point to broader scale, long-term consequences that may be occurring in the landscape.

6.3.1.4. Riparian management

Riparian management is an important part of managing grazing because of the sensitivity of riparian habitats to the impact of grazing, and the high biodiversity values usually associated with riparian zones. Livestock also tend to congregate in riparian zones, if given the opportunity, creating the potential for substantial impacts. The fencing of riparian zones to exclude domestic stock or to provide greater control over their use of riparian zones is recommended practice, although it can prove costly and anticipated benefits are not always achieved (e.g. weeds can increase). Installing off-stream water points and placing supplements away from watercourses are other techniques for minimising the impact of grazing by domestic stock in riparian zones.

6.3.1.5. Use of fire

Fire is a useful management tool in some rangeland types (generally grassy rangeland types), although all regions should include fire management as a part of normal pasture management. Fire can be used to manage pasture composition (shifting it to a more productive balance), improve pasture vigour and quality, manage woody vegetation structure, and remove heavily grazed patches from the pasture. The development of extensive stands of dense woody vegetation in the absence of fire is likely to reduce habitat value for many native species.

Patch mosaic burning can be used to promote biodiversity by increasing the diversity of habitat types or post-fire successional stages in the landscape. Achieving an appropriate frequency of burning is important for promoting this diversity. It is not known how the frequency of burning for pasture management compares with burning for the promotion of biodiversity. However, for pasture management purposes, tropical tall-grass pastures may need to be burnt every two years and other grass pastures every four to six years. Annual short-grass pastures should not be burnt at all.

For rangeland types not adapted to fire (e.g. the chenopod shrublands), appropriate amelioration and contingency planning should be in place to minimise the adverse effects of wildfire.

For a thorough review of fire and its effects on rangeland biodiversity, see Myers et al. (2004)

6.3.1.6. Biodiversity

Studies have shown that the abundance of native species of flora and fauna may decline, be unaffected or increase in response to grazing. James et al. (1999) reported that about 15–38% of species showed declines in response to grazing. Negative effects on abundance are particularly apparent in areas surrounding water points where the landscape experiences moderate to heavy grazing. Strategies to achieve more even grazing of the landscape, as desired for pastoral activities, are likely to have detrimental effects on biodiversity at the paddock level. Protecting some land from grazing at property and regional scales is therefore important, and this is a key strategy for maintaining grazing-sensitive species in pastoral lands. Approximately 10% of the landscape should remain ungrazed or only lightly grazed. This can be achieved by ensuring some areas remain distant from water points (more than 4 km from water for sheep or 8 km for cattle) or by fencing off areas. It is also recommended that 10% of all types of country on a lease be lightly grazed or ungrazed. Feral animals and weeds should be controlled in these areas.

At present there are no grazing systems that are acknowledged as being suitable for the maintenance of all species. There is a need to investigate alternatives to simply excluding areas from grazing since only a small fraction of the landscape can be protected in this way. Another issue that arises in protecting sections of the landscape from grazing is that resource-rich areas (e.g. riparian zones, local sinks for run-off and nutrients, breakaways) are of value for domestic stock production as well as being areas of biodiversity value (e.g., as refuge areas – Morton 1990). Because of their productive grazing value, pastoralists may not be willing to exclude such areas from grazing. Restricting stock access to these areas may be the only feasible method of protecting biodiversity. However, the development of grazing systems that are conducive to the persistence of species that may otherwise be disadvantaged by continuous grazing (e.g., through rotational grazing) may offer an alternative solution. The development of such grazing systems should take a mechanistic approach to understanding why certain effects arise from particular grazing systems and to identifying their impact on the biology of native taxa, rather than simply trying a range of different grazing systems.

6.3.2. Grazing management systems

Surprisingly, given the diversity of rangeland types across Australia, the variety of grazing management systems in use for domestic livestock in the rangelands is relatively limited. Those that are commonly used have usually developed through practical experience over many years rather than as a result of scientific investigation and assessment. In many regions the incorporation of insights from scientific studies into grazing management is rare. A discussion of the most commonly used grazing management practices follows.

6.3.2.1. Continuous grazing

Continuous grazing is the most widely used grazing system. Most grazing management in the rangelands is some kind of continuous grazing, although there are variations on the theme, such as set-stocking, seasonal tracking and set utilisation.

6.3.2.2. Set-stocking

Continuous grazing in southern areas most commonly involves set-stocking, often at conservative stocking rates that are set at a level where forced destocking is only rarely required (say once every ten years). Set-stocking tends to be the grazing system most widely used in the chenopod shrublands and mulga woodlands/shrublands of South Australia and Western Australia (GLMZs 8 and 9) where ephemeral and annual species provide the bulk of the forage when sufficient rain has been received, and the perennial shrubs are relied upon to provide feed at other times. Recent work, however, has suggested that variations in the availability of forage combined with spatial patterns of grazing can cause declines in range condition under continuous grazing over the long-term and that some destocking is necessary. Knowing the best time to destock or reduce numbers in worsening seasonal conditions is a major challenge for managers who use this system. Leaving stock on too long when going into drought is a common problem, and is a cause of declines in perennial shrub density (Hunt 2001). A consequence can be an expansion of the piosphere surrounding water points that is irreversible in practical terms. Simple plant-based indicators and recommendations for spatial monitoring have been proposed to alleviate this problem (Hunt 1994). This approach is in effect a 'tactical grazing' system, where the aim is to adjust grazing pressure in accordance with plant needs (see section on tactical grazing later).

6.3.2.3. Seasonal tracking

An alternative continuous grazing approach is one where some tracking of seasonal conditions is practised, and livestock numbers are varied in accordance with seasonal conditions and forage availability. When applied to a moderate extent, this can have short- and long-term financial benefits for pastoral enterprises, as very conservative stocking rates may not provide satisfactory economic returns in the short term. However, this approach is associated with higher economic and ecological risks (Stafford Smith 1996). A higher level of managerial skill is required to implement this approach properly and thus minimise these risks. In practice, most enterprises using this tracking system maintain some livestock on properties even in the worst years. Continuous grazing with some degree of seasonal tracking is commonly used in the semi-arid woodland areas of New South Wales and South Australia.

6.3.2.4. Set utilisation

Another form of continuous grazing practised in tropical and subtropical savanna systems is set utilisation. In these regions there is a distinct summer-growing season and perennial grasses dominate pastures. Here stock numbers are set on the basis of the forage available at the end of the growing season and the defined safe utilisation levels for this forage. Utilisation rates of between 10% and 30% of standing forage at the end of the growing season are recommended, with the actual rate depending on the ecosystem and management context. Once livestock have been allocated to paddocks at the end of the growing season, they usually remain in place until the end of the next growing season. Computer-based models of pasture growth based on rainfall received during the growth season are sometimes used to estimate the appropriate livestock number to achieve the specified safe utilisation level. It should be pointed out here that while this system is a form of continuous grazing, it is 'set utilisation' rather than set-stocking.

6.3.2.5. Rotational grazing and spelling

Recently, interest in rotational grazing systems has been increasing among pastoralists and state agency personnel. In part this is a recognition that most native pasture species are not well adapted to continuous grazing, and that some form of pasture resting/spelling is desirable. This is to allow plants to recover from grazing and complete their life cycle processes. But little objective information currently exists to support or challenge the claimed benefits of rotational grazing, or the pros and cons of alternative rotational grazing schemes, so their value remains unproven. In the past, scientific studies comparing continuous grazing with various forms of rotational grazing have concluded that rotational systems have nothing to offer in terms of higher animal production and better range condition. Norton (1998) argues that such findings arise from the use of inappropriate scientific designs that fail to take into account the spatial component inherent in commercial grazing systems.

Rotational grazing and spelling systems take many forms but they usually involve multiple paddock systems. Numerous systems have been devised and are in use in rangelands in the United States (e.g. short-duration, deferred short-duration, high-density short-duration grazing), but few have been tested in Australian rangelands. Many of these systems were devised specifically to suit the ecology of perennial pasture species in the US, but some of the principles might have relevance in Australia. A common characteristic of many rotational grazing systems is regular spelling (or grazing) on a calendar basis or on the basis of the number of days of grazing or spelling. In systems where rainfall and plant growth are unreliable and unpredictable it is not certain that this approach offers any benefits. In such situations opportunistic spelling is sometimes practised.

Some recommendations for rotational grazing in the rangelands include the use of very high stock densities, often well above usually accepted limits. Cell grazing (or time-control grazing) is one such novel grazing system that usually involves high stocking densities. The argument is that high stocking densities break up soil surface crusts and thus promote water infiltration and the burial of seeds. Another stated aim is to maintain plants in the most productive growth phase by moderate to heavy defoliation. In a system that includes many small paddocks, there is rapid rotation and each paddock is provided with an extensive rest period following grazing to allow recovery. It is important to stress that these recommendations are contrary to normal accepted practice for the protection of the soil surface and for limiting the extent of plant defoliation. However, we do not have much scientific evidence to explicitly refute the grazing management principles espoused by the proponents of cell grazing.

6.3.2.6. Opportunistic spelling

Other less formal spelling or rotational grazing systems can sometimes offer benefits in terms of natural resource condition. These can include opportunistic spelling (often in association with forced destocking due to drought and/or deferring the build-up of stock numbers following drought-breaking rains), or rotation of stock between water points in a paddock (especially where forced to do this due to seasonal waters drying up). Resting can also involve taking advantage of exceptionally good seasonal conditions to rest a few paddocks at a time. One of the problems with resting as it is currently often practised by pastoralists is that it occurs for insufficient time. Resting should occur for long enough to allow plant responses to reduced grazing. One difficulty in applying resting is a lack of indicators and rules for resting strategies.

In some situations where a variety of range types with differing plant communities and growth habits is available within a single property, it can be useful to devise rotational systems that take advantage of seasonal differences in growth, forage availability or resistance to defoliation (e.g. lake country in West Australian rangelands is more productive and so is used for lambing ewes, while less productive country is used as a drought reserve [Morrisey & O'Connor 1988]).

Early wet season spelling is currently recommended for tropical and subtropical savanna pastures to maintain palatable, perennial and productive native grasses (i.e. the '3P' grasses) (Ash et al. 2002). This can be incorporated into various rotational grazing configurations that can be applied on commercial properties. The biological basis of early wet season spelling is that it protects palatable perennial grasses from defoliation during the sensitive period when the plants are just beginning to regrow following the start of the wet season. The Ecograze studies showed that adopting wet-season spelling also allowed an increase in utilisation rates and animal production that compensated for having some land 'out of production' during the spelling period. At this stage wet-season spelling is not widely applied on commercial properties but is an appropriate management practice in GLMZs 2 and 4.

6.3.2.7. Tactical grazing

For regions where the climate (and rainfall in particular) is erratic and unreliable, tactical grazing is recommended (e.g. GLMZs 6, 8 and 9). Tactical grazing involves adjusting stock numbers in accordance with changes in seasonal and climatic conditions and plant growth. The key principle underpinning tactical grazing is the need for grazing to be managed in a way that recognises the paramount importance of perennial plants. These species must be able to complete all life cycle stages to ensure the persistence of plant populations. Tactical grazing acknowledges the potential for plants to be killed by grazing and for recruitment to be limited because grazing can limit growth, flowering, and seed production. Regions with an erratic and unreliable climate are most likely to benefit from tactical grazing since many plants do not complete life cycle processes on a regular or annual basis.

It follows that under tactical grazing, at critical times, based on plant condition scores, decisions to alter stock numbers or destock should be taken. For example, in the semi-arid woodlands of New South Wales a minimum stubble height (grazing residue) for perennial grasses is 10 cm (Hodgkinson 1996). The mortality of the grasses increases dramatically during drought by grazing beyond this limit. The minimal stubble height is recommended for New South Wales rangelands but is relevant to all rangelands where seasonal conditions are unpredictable. The New South Wales authorities, however, do not consider tactical grazing to be a grazing method but rather a decision-making framework (R. Hacker pers. comm.). An important part of applying tactical grazing is the identification and definition of objectives and strategies on a paddock-by-paddock basis (Campbell & Hacker 2000).

6.3.3. General recommendations for grazing systems

In conclusion, a few general recommendations can be made for the appropriate grazing system in particular rangeland areas with particular vegetation types. Tactical grazing should be used for systems based on perennials where climate is unpredictable. Annual systems should use a feed-budgeting approach. More reliable tropical savannas can use safe utilisation rates in conjunction with pasture growth models (and local knowledge), or early wet season spelling (acknowledging that utilisation rates can be higher with the latter). Continuous grazing is okay for resilient systems if stocking rates are constantly monitored and reviewed. Seasonal forecasting should be used in all areas to manage risk, although in some regions this is more accurate and reliable than others.

6.3.4. Grazing management lessons from the intensive use zone

Differences in enterprise types, level of productivity and extensiveness of properties all have a bearing on the transferability of total grazing management techniques from the more intensively used landscapes in south-eastern Australia to the rangelands. Wild stock problems also differ between the intensive use zone (IUZ) and the rangelands, with some species not presenting a problem in the IUZ because they are absent, or the populations are markedly smaller in the areas of intensive use. These factors affect the practicality and cost of implementing grazing management practices or, for pest animals, control methods. Despite this, some principles and practices from the IUZ have relevance in the more extensively used and managed rangelands.

With respect to domestic stock management for biodiversity protection, McIntyre (2001) developed a series of management principles based on a landscape planning approach for the grassy eucalypt woodlands of south-east Queensland. These areas are grazed predominantly by cattle. The principles are:

- Property planning and management should include a long-term vision that considers the whole of the property and its place in the catchment.
- Soils should be managed to prevent erosion and to maintain productive capacity and water quality.
- Pastures should be managed for production and to maintain the variety of plants and animals.
- Local native trees should be maintained for the long-term ecological health of the property and catchment.
- All properties require an environmental reserve for species that are sensitive to agricultural land uses.
- Watercourses are particularly important to the ecosystem and grazing enterprise, and require special management.

McIntyre (2001) developed this further by identifying practical measures to conserve biodiversity that managers can incorporate into sustainable management practices. Indicators for monitoring results and improving management were also described. These indicators are based on land use and the proportion of a property in particular land use classes. The principle is that certain proportions of each property should be allocated to land uses that are favourable to biodiversity conservation. Three key recommendations are:

- Only 30% of the land should be used for high intensity land use.
- The remaining 70% should include uses that have a range of intensities of use with varying levels of impact on biodiversity.
- Within this 70%, about 10% should be allocated as environmental reserve.

It was acknowledged that in many cases the achievement of these ideals is limited by the degree of landscape modification already having occurred. Other indicators for the location and extent of woodlands were proposed, and relate to the proportion of each land type retained, the extent of woodlands on recharge zones and riparian zones. In addition there should be 60–70% of pasture with tall and medium tussock grasses dominant and less than 30–40% bare ground. Fencing of riparian areas is recommended, although it is widely regarded as being impractical.

McIntyre et al. (2001) specifically considered the question of the generality of their results to other ecosystems in northern Australia. They considered the question in relation to three issues: the source of evidence, the relevance of the land uses, and existing landscape condition. They concluded that their principles were relevant to all grassy eucalypt woodlands across Australia and that the principles were directly applicable. In drawing these conclusions they considered that the thresholds had fundamental biological meaning in all ecosystems. However, the precise thresholds for different land uses do need modification for other landscape types with different vegetation communities. Thus, the overall principles have relevance to the rangelands but the specific indicators and thresholds are probably of limited relevance. Of significance to the present report are the thresholds recommended for semi-arid rangelands (which are considered to be essentially intact landscapes with few areas of intensive use, at least in comparison with more temperate areas). Because of the importance of water sources as a controlling influence on the distribution and activity of livestock in rangelands, the thresholds are linked to distance from water. The recommended areas of land in different distance-from-water classes are: no more than 10% close to water points and therefore heavily grazed; 40% grazed at intermediate distance from water; 40% grazed but at greater distance from water; and, 10% far from water, beyond the reach of livestock and very infrequently grazed.

Despite the view that fencing riparian zones to exclude stock and feral animals is impractical, some large pastoral companies in the rangelands of northern Australia have fenced many of the main waterways on their properties and keep them destocked. Nevertheless, the effectiveness of this in protecting biodiversity is sometimes reduced by an increase in weed abundance that often follows destocking.

The approach to biodiversity conservation that McIntyre (2001) adopts is strongly based on a landscape planning approach and does not consider specific management practices for grazing (domestic or feral) that are targeted at protecting biodiversity. A knowledge of appropriate practices that can be applied within paddocks and as circumstances change should also be a part of management for biodiversity protection.

6.4. Management methods for wild stock

6.4.1. Issues in the management of wild stock

It is self evident that uncontrolled herbivores present a risk to sustainable management and livestock production in the rangelands. Managers should strive for effective control of feral animals, and, where appropriate, native herbivores, at all times, not just when poor seasonal conditions make their impact more obvious.

Managing grazing pressure from wild stock (including native herbivores such as kangaroos) is generally more challenging than for domestic stock. The reasons for this difficulty include the size and extent of wild-stock populations, the mobility of some species, the need for ongoing follow-up control, the expense of control activities, and the lack of immediately apparent economic and ecological benefits (due to hysteresis in the response of vegetation to reduced grazing pressure). Rabbit control is an example of these problems – there are only a limited number of GLMZs where rabbit control is feasible using conventional control methods, and then only in limited areas (e.g. parts of GLMZ 9). Effective and practical control methods do not exist for all species of wild stock.

Legislation influences control methods and approaches. Most states and territories have statutory authorities responsible for overseeing the management of pest species. Legislative requirements usually exist for the control of declared pest species, although associated policies often do not require enforcement (in the case of rabbits, for example). Education of land managers is seen as the key to effective control. Access to poisons is also strictly regulated. Animal welfare legislation places obligations for the humane treatment and destruction of pest animals. Options for the management of native species such as kangaroos are more restricted than for feral species because, as native species, their management is regulated by state and Commonwealth legislation.

Management of wild stock generally involves removal or destruction of the animals. Moving wild stock to another part of the landscape is not an option, as it is in the case of domestic stock. Fencing is not usually feasible for extensive control of wild stock because specialised fence designs are usually necessary. The expense of such fences is prohibitive for broad-scale use, although they might be justified for the protection of specific biodiversity or landscape resources.

Regional coordination of management activities is an important consideration for some species of wild stock, particularly those that are highly mobile or have large home ranges (see below). The timing of control operations should also be considered, so that advantage is taken of natural declines in abundance due to poor seasonal conditions or disease outbreaks (rabbit haemorrhagic disease in rabbits, for example). Control of feral animals is sometimes easier in dry periods, when they tend to congregate near waters, although ideally control should be ongoing and not left to dry periods, when environmental damage from excessive numbers of animals is more likely.

A vital part of wild stock control is ongoing and follow-up control of pest species. This maximises the long-term effectiveness of management activities. Monitoring of populations of wild stock and their impact is also essential, as it is for domestic stock.

6.4.1.1. Motivation for management

Land managers implement practices for the control of wild stock for numerous reasons. A key reason is probably to reduce competition with domestic livestock, which can produce increases in animal production, improved management flexibility and options, and a better capacity for coping with drought (especially more flexibility in management of livestock and less need for destocking during poor seasons). However, sometimes these benefits are not acknowledged, or are not clearly obvious to managers. Control may not actually be cost effective for some species of animals in some GLMZs (e.g. rabbits in GLMZ 5), with the consequence that wild-stock populations are controlled only by the availability of feed and water. Drought can therefore be a period of extreme grazing pressure on natural resources before increased mortality in response to deteriorating conditions causes a decline in wild stock abundance. Sometimes control is implemented to generate income, as is often the case with feral goats.

Land managers sometimes implement control measures for reasons other than productivity benefits. Altruism (it’s good for the land), reduced risk of soil erosion, aesthetics (the country looks better, especially in areas readily seen by the public or tourists) and legislative obligation are other common reasons for implementing control. Legislation is rarely effective at encouraging people to control feral animals due to issues of cost and the availability of appropriate methods of control, hence it is not usually enforced. Disease control has also been an important reason in the past for considerable effort to be directed to wild stock control. The BTEC program in the 1980s and 1990s was responsible for considerable efforts to control horses, feral cattle, donkeys and buffalo. While feral animals continue to pose a risk in the spread of exotic disease – should one be introduced to Australia – rarely is this a factor that motivates pastoral land managers to control wild stock.

Pastoral land managers rarely initiate wild stock management for the specific protection of biodiversity. In cases where biodiversity is cited as a reason for managing total grazing pressure it is seen as a spin-off rather than as the prime reason for control. Protection of specific natural features or rare species also only occurs where some form of financial assistance is available from a government-sponsored scheme. This will often also involve excising a parcel of land from grazing use, the erection of protective fencing, and some form of management agreement between the government and land manager. Of course, in reserves and national parks the situation is different, with biodiversity protection the chief reason for the control of wild stock.

6.4.1.2. Monitoring effectiveness of management/control

The effectiveness of wild stock control should always be assessed in terms of the reduction in damage to the environment or agricultural production, not in the number of animals killed or removed. In this way emphasis is always placed on the remaining animals that can continue to cause damage and provide the potential for numbers to build up to pre-control levels.

The ecological benefits should also be measured through monitoring of the resource base (especially vegetation and soil conditions). As mentioned before, there is little point in controlling wild stock if domestic stock management is not also controlled. In many situations, the wild stock removed from an area should not simply be replaced by additional domestic stock. Changes in livestock management or grazing management practices might also be warranted. In the longer term some increase in domestic stock may be possible, but evidence of improved rangeland condition should be obtained first.

For further information on future and current threats to biodiversity from introduced mammals and a proposed framework for monitoring the impact of introduced mammals in the rangelands the reader is referred to Edwards et al. (2004).

6.4.1.3. Spatial issues

Spatial issues in relation to pest animals are of a different nature to those associated with domestic livestock. Some species are constrained to areas relatively near water (e.g. pigs: although some species do seem to be able to roam further and often aren't constrained by fences designed to contain livestock). Other species are restricted to certain landscape types (e.g. at a regional level as opposed to a broad national level, rabbits are generally found where soils are suitable for burrowing). Thus, control programs may not need to be as extensive as might be imagined, and effective control can be achieved by quite targeted control activities. For some species, their normal home range extends over several paddocks or properties (e.g. feral goats). This means that for effective control, management actions should be coordinated across neighbouring properties. Otherwise control will prove ineffective and/or a rapid build up of numbers soon after control is likely.

6.4.2. Management of wild stock and control techniques

6.4.2.1. Rabbits

Broad-scale rabbit control in much of the extensive arid and semi-arid rangelands is problematic because of the cost of control, the usually extensive nature of rabbit infestations and the lack of clear economic benefits. As a result there has been heavy reliance on biological control agents to keep rabbit numbers in check, and in fact in many areas no other form of control is implemented. Myxomatosis and, more recently, rabbit haemorrhagic disease have had substantial impacts on rabbit populations, and occasional epizootics continue to regulate numbers when seasonal conditions are favourable for an outbreak. Myxomatosis has had less effect in more arid regions because of the lack of suitable insect vectors, and the introduction of Spanish rabbit fleas in the 1980s was aimed at addressing this limitation. RHD has proved very effective in arid areas, although less effective in more mesic agricultural regions.

Biological control is not a panacea for rabbit problems in the rangelands. The rabbit population has developed a resistance to both myxomatosis and RHD, reducing their effectiveness. Recently rabbit numbers have begun to increase since the initial impact of RHD following its release in the mid to late 1990s. Two messages arise from this for land managers: one is that, where feasible, conventional methods of control should be adopted as the primary means of rabbit management; the other is that to maximise the benefits of biological control there is a need to take advantage of rabbit population reductions that occur due to disease outbreaks by destroying rabbit habitat (i.e. warren ripping). Habitat destruction following an epizootic is advocated to limit the survival of resistant animals, which may slow the development of disease resistance in the population.

For some rangeland areas (e.g. parts of GLMZs 8 and 9) rabbit control is a realistic option because the extent of the problem is of manageable size and positive economic returns are likely to be achieved from an investment in rabbit control. Characteristics that suggest rabbit control might be worthwhile for pastoralists include a high density of rabbits (or warrens), relatively small property size, productive pastures, accessible country, and lease conditions that permit increases in stock numbers in response to higher feed availability following rabbit control. Obviously where biodiversity values are of high priority these will impinge on any perceived need for, and benefits of, rabbit control. Of course, increasing stock numbers following rabbit control may not be consistent with protecting biodiversity values. Where this is a priority, consideration should be given to the wisdom of increasing stock numbers.

A key principle of rabbit control is the integration of several techniques. In the intensive use zone, the recommended control method encompass poisoning with 1080 baits, followed by warren destruction by ripping, and finally fumigation of any warrens that reopen after ripping (or that are inaccessible to the tractor-mounted ripper). Poisoning is intended to reduce rabbit numbers, and warren destruction kills remaining rabbits and removes the protection that is vital to rabbit survival in the arid zone. However, Cooke and Hunt (1987) showed that in the rangelands poisoning adds little to the overall effectiveness of control if control occurs in autumn when rabbit numbers have usually declined due to seasonal stresses (although in some areas such as the subtropics where rabbits live and shelter above the ground, poisoning may be necessary). The most cost-effective form of conventional control for rabbits in the rangelands is warren destruction using rippers mounted on a large tractor or bulldozer (Cooke & Hunt 1987). This is best done in late summer to autumn when rabbit populations are under stress due to declining feed availability. Any warrens that reopen after ripping should be ripped again, or alternatively fumigated, although the former is likely to be the most effective and convenient.

Focusing rabbit control activities on specific parts of a property will maximise the benefits of control. Areas such as holding paddocks, highly productive areas and favourable refuge areas where rabbit populations can persist during droughts (e.g. adjacent to floodout plains [e.g. Mutze 1991]) are potential priority areas for control. Rabbits are generally strongly territorial animals and rarely venture more than 300 m from their warren. Control operations should take this into account, providing a buffer zone of 300 m around control areas to minimise reinfestation. However, the sedentary nature of rabbits means that reinfestation of treated areas is slow as long as the buffer zone is regularly monitored and opened warrens are re-ripped. This facilitates an orderly and planned progression of rabbit control across a paddock or property. Similarly, in Central Australia rabbits are generally confined to certain types of landscapes. They are most commonly found in areas with calcareous soils, on fringing dunes and on creek frontages (Phillips 1998).

Fencing is rarely used as a form of rabbit control because of the expense, although it can be effective when used to protect high value resources such as specific vegetation communities or habitat, or rare or threatened plant species. An example where this has been used successfully is the Arid Recovery Project at Roxby Downs in northern South Australia. Shooting and trapping are not considered to be effective means of rabbit control.

6.4.2.2. Goats

Feral goats cause significant problems including direct grazing and trampling of plants, disrupting the habitat of native fauna, and soil erosion. As generalist herbivores, goats graze and browse a wide range of plant species. They also browse trees and tall shrubs to a considerable height by rearing up on their hind legs. Despite being generalists, they are still very selective in their choice of diet, preferring high quality forage when it is available. This can result in preferred plant species being subjected to considerable grazing pressure from goats, causing their reduction in the plant community (Queensland Land Protection 2001). This is in contrast to the widely held belief that an eclectic dietary choice spreads grazing pressure over a wider cross-section of the plant community. Their hardiness in drought is partly a reflection of this broad diet and the result is that goats are considered to have the potential to have a more serious negative impact on plant and soil resources in the rangelands than sheep.

Eradication of feral goats is very difficult to achieve in the rangelands due to the high mobility of goats, their abundance and widespread distribution, their hardiness and high reproduction rates, and their preference for rugged country. Effective control is therefore a reasonable and realistic management objective. In general the widespread practice adopted by managers of opportunistically harvesting feral goats is not effective at achieving long-term suppression of numbers. Because of the commercial value of goats, managers often fail to implement mopping up activities, preferring to leave a remnant population of goats that will provide breeding capacity for the build up of numbers and future harvesting opportunities. More effective long-term control is achieved by implementing mopping up such as ground shooting on an ongoing basis. State legislation generally requires feral goats to be controlled, but in effect this requirement is seen as being keeping numbers down to a level that minimises environmental damage. Approximately 35% of a feral goat population needs to be removed each year to prevent numbers increasing.

The primary control techniques for feral goats are mustering and trapping on water points. Shooting from a helicopter is also used in some situations.

Trapping is perhaps the easiest and most cost-effective way of managing feral goat populations. Traps are constructed around water points and consist of heavy-duty fences (using steel mesh to about 1.5 m in height) with one-way spear gates or swinging gates, or jump-down ramps. For most of the time the trap remains open so that goats and domestic livestock can move freely to and from water. This accustoms the goats to using the water point despite it being fenced in, and familiarises them with the entry and exit areas of the trap yard. This 'training' is an important part of the trapping process and usually takes three to four weeks. When animals are to be trapped, the one-way entry gate is set and exit gates are shut.

Designs for trap yards for use with feral goats, sheep and cattle are presented in Underwood (2002). Experience suggests that some trial and error is often involved in perfecting the design, dimensions and settings for the one-way entry gate on trap yards. Often trap yards are dual purpose in that they are also used for trapping domestic stock, to reduce the need for mustering. They can also be used for concentrating kangaroo numbers to assist harvesting (see later).

A key requirement for successful trapping is restricting access to other water sources in the vicinity of the trap yard. This can be achieved by the use of electric fencing around alternative water sources. Conducting trapping during the dry and/or the hot part of the year is most effective, as goats will need to water daily and water is less likely to be available in creeks and natural waterholes.

Both aerial mustering by helicopter and mustering on the ground by motorbike (sometimes with the help of dogs) are widely used for reducing feral goat numbers. A single muster only removes about 30–40% of the population in an area, so follow-up work is necessary (Parkes et al. 1996). Further musters will result in additional reductions, but mustering becomes increasingly difficult with fewer numbers and as goats learn to evade musterers. Follow-up shooting should be carried out to remove as many of the remaining goats as possible. Helicopter mustering can achieve higher mustering rates than ground mustering alone.

Shooting has been used in specific areas such as national parks (e.g. the Flinders Ranges in South Australia), and an aerial shooting program was conducted in the North-East Goldfields region of Western Australia for a number of years. Helicopter shooting is particularly useful in areas with inaccessible terrain, although it is costly. Goats also quickly learn to hide under trees or rock ledges to avoid detection from above. The use of Judas goats (fitted with radio transmitters) to locate mobs of goats in aerial and ground shooting programs has been tested especially in the context of controlling exotic disease outbreaks. A regional control effort is essential when shooting of goats is used as a control measure.

Fencing is generally ineffective with feral goats as they are able to penetrate most commonly used fence designs, or alternatively they can cause substantial damage to fences. Fences can be made to be goat-proof but costs are high. Electric fencing is sometimes used to contain goats but this requires goats to have had experience with electric fences, and damage to fences or twisted wires needs to be promptly rectified. In practice, feral goats do penetrate electric fences, at least when they first encounter them.

Management of the supply of water at artificial water points (including complete closure of water points) can be used to manage goat populations because of the dependence of goats on water during dry periods, especially in the semi-arid and arid rangelands. Restricting the availability of water can force goats to move elsewhere, and also reduce the capacity of large numbers of goats to persist in the region. Prior to closing water points, goat numbers should be reduced by mustering or trapping to minimise the risk of animals perishing.

Local and regional planning and coordination of goat control programs is recommended to maximise the efficacy of control and provide long-term suppression of numbers. This is because of the mobility of goats and the typical size of their home range. Feral goats are not usually confined to one property, but may move between adjacent properties as part of their regular movements. For example, goats may water on one property and utilise areas of preferred feed on a neighbouring property because their movements are not constrained by conventional stock fences. While feral goats are generally sedentary animals, there are reports of goats promptly moving into control areas from adjacent uncontrolled areas following control operations.

In an attempt to resolve the conflict between feral goats as a pest and their economic value in export markets, the Western Australian Government has permitted the farming of goats in the rangelands. In a legislative sense, there are now no feral goats in the pastoral rangelands of Western Australia; there are only managed and unmanaged rangeland goats. Specific requirements for the identification and management of the animals have been put in place, including the need for electric fencing of paddocks to contain the goats, and trap yards for mustering. There are also requirements for identification of domestic herds and effective control of feral goat herds. The reasoning behind this approach is that pastoralists will exercise more effective control over feral goats because of the risk they present to their domestic goat operation, and that the domestic goats will be managed effectively. In addition, as previously discussed, there is the perception that because goats have a broader dietary intake than sheep, in particular selecting a greater number of browse species, they have a less damaging impact on the vegetation. However, this is not the case, and careful management of the impact of goats is needed, especially as feed becomes scarce in dry periods. Additional problems encountered include the less-than-100% effectiveness of electric fences and trap yards in controlling the movement of goats and in preventing their escape (to potentially join the feral population), the ease with which electric fences can be put out of service and the limited control of feral goats. A large investment in infrastructure is also required. The policy to declare feral goats on pastoral leases as ‘approved livestock’ does not, of course, alter their status on conservation reserves and other non-pastoral rangelands.

6.4.2.3. Camels

Camels are highly mobile and can survive for long periods without drinking. They are thus not confined to areas near water, although if it is available they will drink most days during summer. They prefer a diet of herbage and grass species when available but will browse shrub and tree species at other times (Phillips et al. 2001). Control of camels is usually by trapping or mustering using helicopters, motorbikes or vehicles (generally opportunistic mustering for the live-export market). Aerial shooting can also be effective. Camels can be excluded from certain areas through the use of electric fences, although they must be properly designed and easily visible to the camels or there is the risk of substantial damage to the fences. Recommendations for electric fence design and construction for camel control are available from some state agencies (e.g. Bertram 1996).

Recently there has been interest in the potential for camels to be run as domestic stock in conjunction with cattle (Phillips et al. 2001). It is thought that the broad dietary selection exercised by camels and their tendency to consume browse species make them a suitable companion species for cattle. It is expected that camels will not compete with cattle and they will have less impact on desirable and/or sensitive plant species. However, this is yet to be conclusively demonstrated and, as indicated above, camels will consume herbage and grass species when available, as do cattle.

6.4.2.4. Horses and donkeys

Widespread eradication of horses is considered impractical and prohibitively expensive, although in some circumstances it may be possible on a local scale. However, the risk of reinfestation must be considered before investing in attempts at local eradication. In most situations a high level of control is a more realistic aim of feral horse control operations. Reducing horse numbers to a level that can be sustained during drought without causing serious land damage (approximately 0.1 horses km^{-2} in Central Australia) is considered to be an appropriate target level of control (Dobbie et al. 1993). Given that eradication is usually not feasible, ongoing control is essential. To achieve effective suppression of horse populations at the recommended level requires approximately 30% of the population to be removed each year. Strategic planning of control is essential to maximise efficiency and effectiveness and limit migration into areas where satisfactory control has been achieved.

The main methods of control for horses are mustering (often using helicopters, supported on the ground with motorbikes or horses), trapping (around water points using one-way spear gates) and shooting from helicopters or from the ground (Dobbie et al. 1993). Codes of practice for control operations to ensure work is conducted in a humane way have been developed (e.g. Standing Committee on Agriculture 1996).

Assuming moderate densities of feral horses, the first stage of a horse control program should be commercial harvesting (for use as pet meat, human consumption or as live horses) by trapping and helicopter mustering. This can be followed up with the other more intensive control methods such as helicopter shooting. As effective control is achieved in a management area, helicopter mustering and shooting become too expensive and impractical and ground shooting and trapping are the best option for mopping up remaining animals. Periods of drought offer an ideal opportunity to remove horses remaining after other intensive control operations because of the tendency of horses to concentrate around water sources.

Using exclusion fencing to protect specific sensitive or important areas from feral horses is recommended, even where there is adequate control by other methods. Ordinary stock fences are generally adequate for this purpose. However, electric fences have also been used successfully in Central Australia. The advantages include being lightweight, cheap and easy to install. When trapping on waters, fencing off other waters where traps have not been installed is necessary to force horses to use waters with traps.

Donkeys are more difficult to control than horses because attempts to trap around water points produce variable results and donkeys are difficult to muster. Consequently, shooting from a helicopter is the most effective form of control, particularly in rugged country. The use of Judas donkeys (with radio collars for tracking) is strongly recommended to maximise the effectiveness of helicopter shooting. Feral donkeys' home ranges vary between approximately 32 km^2 in arid areas to just 3 km^2 in productive grassland areas. Thus, control programs must be scaled to an appropriate regional coverage for the area, to ensure reinfestation is kept to a minimum.

6.4.2.5. Kangaroos

Kangaroos have benefited from the installation of water sources for domestic stock. Numbers are considered to be higher now than at the time of European settlement, particularly in the sheep rangelands, where dingo numbers are low due to exclusion fencing or intensive control activities (Pople & Grigg 1999). Kangaroos are recognised as having the potential to negate the benefits of destocking for rehabilitation purposes in areas where their numbers are high, and to compete with domestic stock for palatable grasses and forbs. Often when destocking of domestic stock takes place, kangaroo numbers can increase (as can feral numbers) as a result, and this can mean that there is little or no net reduction in total grazing pressure. While dietary preferences do differ among herbivore species, there can still be a negative impact on biodiversity (especially native plant diversity) through increased kangaroo numbers. Hence, it is sometimes necessary for kangaroo numbers to be controlled in national parks also. Ideally an integrated approach should be adopted in reducing total grazing pressure on pastoral lands, where domestic, feral and native herbivores are all reduced simultaneously.

The situation for managing grazing pressure from kangaroos is different to that for introduced species because the control of kangaroos is regulated by legislation that also protects them as native species. However, most states have some form of kangaroo culling program in place to manage their impact on native vegetation and competition with domestic livestock. Government administered and regulated harvesting by commercial shooters is therefore the main method of managing common species of kangaroos. The number harvested is strictly controlled in most states, with annual quotas being issued on a regional basis for the four most abundant species (the euro, red kangaroo, western grey (*Macropus fuliginosus*) and eastern grey (*M. giganteus*) kangaroo. In some situations non-lethal control is attempted by controlling access to water points by strategically placing electric wires around watering troughs.

Commonwealth and state legislation requires that management plans be developed and adopted where the harvesting of native species is to be carried out. For example, in South Australia a management plan applies to three species of kangaroo (red kangaroo, western grey kangaroo and euro). The underlying principles of the plan are the protection of biological diversity and ensuring viable kangaroo populations in the long term. In applying these principles a precautionary approach to management is adopted to make certain there are no unintended adverse outcomes for kangaroo populations. Provision is also made for non-commercial destruction of kangaroos to minimise their deleterious impact on other land uses.

Kangaroo numbers are managed at the property level through the allocation of a commercial harvest quota (up to 20% of the estimated population size for reds and 15% for western greys and euros) by the South Australia National Parks and Wildlife Service. Licensed professional shooters usually fill the quota. The management plan also includes initiating research into the contribution of kangaroos to total grazing pressure and their impact on biodiversity in the rangelands. Regional kangaroo management strategies are also in place for South Australia. These provide the basis for management of kangaroos in particular regions, reflecting the priorities, directions and objectives for those regions. In South Australia the quota contains a special land management component as well as the sustainable harvest component. The former is only allocated once the commercial quota has been filled. Non-commercial destruction can also occur where a successful case has been made that high numbers of kangaroos are causing damage to native vegetation, soil or other resources. This option is available for areas where commercial harvesting is not possible for reasons of economics or logistics.

Similar kangaroo harvesting and management plans are in effect in most other states, although some details differ. In New South Wales a kangaroo management plan is in effect for the management of four species: the red kangaroo, the western grey kangaroo, the eastern grey kangaroo and the euro (or wallaroo). The New South Wales National Parks and Wildlife Service administers this plan. It has similar objectives to the South Australian plan but non-commercial destruction of kangaroos is more readily available as a management option for land managers, although a permit and tags are still required. Also, the kangaroos are able to be shot by the landholder or one other nominated person. Biennial aerial surveys are carried out in South Australia and New South Wales to provide a basis for setting culling quotas.

In Queensland commercial harvesting of macropods occurs under the Nature Conservation (Macropod Harvesting) Conservation Plan 1994, and culling by pastoral managers, where the carcases are left in the paddock, is also permitted under damage mitigation permits (issued by the Queensland Parks and Wildlife Service). Three species can be harvested: eastern grey kangaroo, red kangaroo and wallaroo). Macropods are generally not a significant problem in the tropical savannas, although wallabies can cause localised high impacts in riparian zones.

No control of macropods occurs in the Northern Territory. Macropod numbers are substantially lower in the Northern Territory in comparison to southern rangeland regions and they are generally not considered to be sufficiently abundant to present a problem to pastoral activities or to threaten rangeland condition. Approximately every five years counts of macropods are made in several areas of the Northern Territory (including the Gulf, VRD, Barkly, Arnhem and Central Australian regions) in conjunction with aerial surveys of feral animal populations. Commercial harvesting occurs in some areas of the rangelands in Western Australia (e.g. GLMZs 7 and 8).

One potential method for non-lethal control of kangaroo grazing is the Finlayson 'electrified' trough (Norbury 1992). This involves the use of strategically placed electric wires to deter kangaroos from drinking from troughs fitted with this device. The intention is to force the kangaroos to move to another area. King et al. (1997) tested the efficacy of electrified troughs as a means of managing kangaroo grazing in the rangelands of Western Australia. They reported that the troughs were effective at moving kangaroos to other non-electrified water sources, but where all waters in a large area (100,000 ha) had the electric deterrent fitted the majority of kangaroos learnt within about two weeks how to drink without receiving an electric shock. Kangaroos lifted their tails clear of the electric wire while drinking or approached the trough from the side and positioned their body parallel to the trough (and electric wire) so their feet and tail failed to contact the wire. The troughs thus proved ineffective at preventing kangaroos from drinking and altering the distribution of their grazing. Hacker and Freudenberger (1997) reported that moving the electric wire closer to the trough (at 0.5 m rather than 1 m) made it more difficult for kangaroos to avoid receiving an electric shock. Weather conditions (specifically warmer ambient temperatures and dry conditions) were important in determining the effectiveness of electrified troughs in reducing concentrations of kangaroos around water troughs.

The use of electrified troughs alone to manage kangaroos should be viewed as a technique that can potentially facilitate rest from grazing by kangaroos and allow a degree of pasture spelling, rather than as a way to reduce kangaroo numbers permanently. Studies have provided little evidence of a significant change in kangaroo density and grazing pressure as a result of using electric troughs. However, some reduction in kangaroo grazing intensity can be expected, and this is most likely to be achieved in the case of dry seasonal conditions when kangaroos are more dependent on water (Freudenberger & Hacker 1997). Lighter grazing during dry periods is often critical to the persistence of perennial plant species, although rest during the active growing season of plants can also be important; it is not likely to be achieved with these devices, however. Electrified watering trough devices can also be used to concentrate kangaroos to facilitate commercial harvesting by shooting.

Excluding kangaroos from watering troughs can potentially have a wider regional impact, such as causing an increase in kangaroo abundance on neighbouring properties where electrified troughs are not in use. Care is also needed to avoid any possible animal welfare issues if animals are denied water and they fail to move to alternative water supplies.

Electrified troughs can be fitted with timers so the wire is only energised during the night, which is when most kangaroos drink. This helps to minimise the risk of sheep receiving a shock, since they water predominantly during daylight hours. These devices need special modifications for use where cattle are present as cattle can damage the electric wire installation and cause it to malfunction. More robust alternative designs have been suggested for waters where cattle drink but they have not been tested for their effectiveness in excluding kangaroos (see Hacker & Freudenberger 1997).

6.4.2.6. Pigs

Feral pigs are declared pest animals in all state jurisdictions. They are a major pest in areas with higher rainfall or where pigs have year-round access to water. Pigs are absent from most of the arid and semi-arid interior of the continent, although some areas in western New South Wales do have significant pig populations. Feral pigs not only present a risk to biodiversity through damage to habitat; they also have an adverse effect on pastoral productivity, carry diseases and would pose a major problem as a host for many exotic animal diseases should they be introduced.

Trapping, poisoning and shooting (both aerial and ground-based shooting, the latter often in conjunction with dogs) are the principal methods used for managing feral pig populations (Choquenot et al. 1996). Extermination is generally not achievable except in special circumstances, so ongoing effective control should be the objective of management. Fencing of specific high-value habitats to exclude feral pigs is also an option, albeit an expensive one. Pigs have a large home range (up to about 30 km^2) that can incorporate more than one property, so control activities must be spatially extensive and coordinated among neighbouring properties for best effect. As with most control programs for pest animals, a systematic and integrated control strategy should be developed and implemented for pigs. Ongoing follow-up control is essential to prevent a return to high numbers following control operations. Due to their high fecundity, pig populations can double in size within a year, so ongoing control is essential. A reduction in population size of 70% is regarded as necessary to suppress the population for one year (Caley 1999).

Poisoning with sodium monofluoroacetate (1080) is the most effective technique for the control of large numbers of feral pigs, and is the recommended method where suitable bait material is available. The choice of bait material is critical, not just for trapping success but to avoid the poisoning of off-target species. Fermented grain is often the best choice as it is attractive to pigs but not to many native species. If there is a risk of damage to non-target native species from baiting then it should not be chosen as the control method.

Trapping is a highly effective method, but for maximum success operators need to have a degree of skill and experience. Various trap designs are successful, but advice should be sought from local state agencies for the most suitable trap design and choice of bait material for the circumstances. A pig-specific gate trigger should be used to minimise the capture of non-target species. Trapping is most effective in the dry season when food and water supplies are less abundant. Cost effectiveness also improves in the dry. Cost estimates from trapping programs in the Douglas Daly region of the Northern Territory put early dry season trapping at $72 per head and late dry season trapping at $20 per head (Caley 1999).

Shooting is not considered to be an effective means of achieving long-term control of feral pigs in the wet tropics or in other areas with dense vegetation cover. Pigs tend to move out of an area once shooting begins and they also are adept at seeking refuge in thick vegetation where visibility for shooters is poor. However, ground-based shooting, especially with the aid of dogs, can be helpful as a follow-up method after other control activities such as trapping. Helicopter shooting is effective where pigs inhabit open areas with only light vegetation cover, such as floodplains.

6.4.2.7. Buffalo

Buffalo are confined to wet tropical areas in the north of the continent. In the past, buffalo were a major problem in Kakadu National Park and Arnhem Land, where they did substantial damage to wetlands and floodplains. Their numbers are much reduced now compared to the late 1970s, although they still cause problems in eastern Arnhem Land. This reduction is a result of extensive control operations during the 1980s and 1990s as part of the BTEC. Remnant populations do persist elsewhere in the Top End.

The options for controlling buffalo populations are limited. The size of the animals, and the abundance of water and forage in the regions they inhabit preclude trapping as an effective means of control. Aerial shooting from a helicopter is the most effective means of control. Feral species such as buffalo can be important within Indigenous economies and this should be a consideration in planning and implementing control activities.

7. SYNTHESIS

7.1. Summary of issues and priorities from GLMZ descriptions

In describing each of the GLMZs (Chapter 4), we drew together published information and expert knowledge of the major issues relating to TGP and biodiversity conservation in each zone, and suggested significant opportunities for investment for research and management in these zones. In the section below, we synthesis the information from the GLMZ descriptions.

7.1.1. Biodiversity issues

- Widespread land degradation due to high TGP across entire landscapes was noted as an issue in a few regions (due to both stock, goats and rabbits).
- Concentration of grazing pressure on restricted, sensitive and/or high-biodiversity-value habitats is a significant issue across all GLMZs. This is most notably the case in wetland, riparian and run-on habitats, but also some other habitats in particular regions (e.g. breakaways, monsoon rainforests, restricted vegetation communities in arid ranges). Both stock and feral grazers contribute to this pressure, the relative importance of these pressures varying between zones.
- Proliferation of water points and the ubiquity of grazing pressure across broad landscapes is a significant issue in many zones. Studies have demonstrated that there is a significant ‘decreaser’ component in the biota in a range of rangeland ecosystems.
- Threatened species management is primarily an issue in the southern GLMZs, but there are significant declines of at least mammals and birds in the northern GLMZs (and ongoing declines in the southern ones). TGP is implicated in these declines, but the specific causes are unclear.
- There are major noxious weed issues in a number of zones, with at least the potential for major biodiversity impact. In many cases, weed management is inextricably linked with grazing management, and the removal of grazing does not necessarily produce an improvement in the weed problem.
- The spread of exotic pasture grasses to become environmental weeds is a significant issue in many zones (central and northern GLMZs).
- Changed fire regimes are a significant biodiversity issue in most zones, although the precise nature of the impact on biodiversity is usually unclear. Outside the tropical savannas, this is generally related to suppression of fire by pastoral managers, often combined with occasional hot and extensive fires. Again, fire management is usually inextricably linked with grazing management.
- The low level of reservation, or a high bias in reservation, is a significant issue in many zones.

- Changes in vegetation structure are a significant issue in most of the more intensively used zones. This includes clearing, loss of perennial pasture species (grasses and shrubs) or shifts in perennial composition, and vegetation thickening (woody weeds), which has a complex relationship with grazing and fire management.

- Predation by cats and/or foxes is a serious issue across all the zones.

7.1.2. Knowledge gaps

- Poor knowledge of biodiversity is a serious issue in a number of zones. This has a number of aspects, which are more or less important in different zones:

  - basic knowledge of species distribution

  - inability to delineate management 'hotspots' (important in most zones)

  - inadequate or inaccurate listings of, for example, threatened or priority species and ecosystems.

- There is still a poor understanding of the impact of pastoral use on biodiversity in many zones, particularly the details which may be important for good management. This includes:

  - impact of alternate grazing strategies (e.g. rotational, tactical grazing)

  - impact on riparian / aquatic biodiversity

  - impact of environmental weeds (notably pasture grasses)

  - impact of changed fire regimes.

- Similarly, for many ecosystems there is still a poor understanding of the benefits for biodiversity that different grazing strategies may offer.

- An extension of the above points is that while there may be a 'scientific' understanding of biodiversity values and the impact of TGP, these are generally poorly understood by land managers.

- While the impact of feral animals may be recognised, there is often a poor understanding of the location of priority areas for feral control, and/or the most cost-effective means of feral control.

- The lack of effective tools for monitoring biodiversity is an issue across all the zones.

- Even where there is a willingness to implement off-reserve conservation actions, there may still be an inadequate understanding of the best ways of achieving this (e.g. what is the most appropriate management in ungrazed areas).

7.1.3. Priorities / investment opportunities

- The need for basic biodiversity inventories was noted as a priority in a number of zones.
- The delineation of management 'hotspots', where improved management of TGP will have maximum benefit, was a more focused priority in most zones.
- The development and effective integration of regional and property NRM plans to provide the framework for TGP management and biodiversity conservation was a priority across the zones.
- One important aspect of developing and integrating regional and property NRM plans was to clarify the expectations placed on individual land managers and to provide realistic, specific (rather than generic) goals.
- A second priority across all the zones was the implementation of off-reserve conservation initiatives, notably:
  - protection of 'special areas', particularly through fencing to exclude stock and/or ferals
  - management of water points (or fencing, in some zones) to ensure the retention of significant areas of all major ecosystems that have very low TGP
  - the need to provide meaningful incentives for off-reserve conservation initiatives was noted for most zones
  - improved or continued control of feral grazers was a priority in most zones, and it was generally noted that this must be done in a strategic, targeted fashion; in some zones, this would include giving land managers better information or access to management technologies
  - the need to provide biodiversity and management information to land managers in appropriate, accessible forms was a priority in many regions.
- The importance of improved reservation in formal reserves was noted for many zones.
- The implementation of strategies for increasing the sustainability of land use was a priority in many zones. This would include adoption of best-practice GLM (e.g. wet-season spelling).
- Large-scale adaptive management experiments on achieving better grazing management for improved biodiversity outcomes was another priority.
- Support for Aboriginal ranger groups was noted as being one of the most effective ways of improving land management for biodiversity conservation in zones with a high percentage of Aboriginal land.

7.1.4. Other TGP issues

- The problems posed by low population densities, poor socioeconomic status, poor economic returns were noted for several zones.

- In some areas of Aboriginal land, there is a tension between the control of feral grazers (or uncontrolled stock) and the desire to retain populations for utilisation.

7.2. Management issues and actions

In the following section, we discuss each of the major management issues relating to TGP and biodiversity that were identified during this project. In particular, we describe management actions that are most likely to yield positive biodiversity conservation outcomes, and where future investment is most likely to be cost effective.

The issues can be grouped into three broad categories:

- Direct management of grazing pressure (e.g. water points, feral grazers, management hotspots).

- Other land management issues that have a significant (and often complex) interrelationship with TGP (e.g. clearing, fire, weeds).

- Issues related to integrated land management planning and implementation (e.g. integration of regional and property planning, biodiversity inventories, monitoring tools).

It is important to note that, in most regions and ecosystems, addressing the second and third group of issues is as important (and in some cases more likely to result in satisfactory long-term outcomes) as investment in the direct management of TGP.

7.2.1. Direct management of TGP

7.2.1.1. Water points

Water points are a major factor controlling the distribution of grazing animals both spatially and over time. They are therefore a powerful tool for managing TGP. The effectiveness of water points as a TGP management tool is greatest in more arid parts of the rangelands where stock and feral animals are reliant on artificial sources of water daily during the summer months and every few days in winter months. Animals escape the restriction of returning to water to drink during cooler and wetter periods. Hence the effectiveness of their use in the management of TGP is limited in zones where surface waters are relatively more natural. In these zones, other approaches are necessary to help control TGP; for example, fencing, fire, and nutrient and mineral supplements.

Water-point and fence management of TGP for biodiversity implicitly involves an investment trade-off with conservation: if new water points are added in undeveloped country, more animal production can be achieved but at the loss of areas where grazing-sensitive species may be taking refuge. Hence, there is an opportunity cost to not developing, and a real lost-production cost if water points are removed. A cost–benefit analysis of strategies should be undertaken with land managers, and incentives for stewardship considered.

Issue	Management approaches	Relevant GLMZs
Planning for new infrastructure (includes fences and water points)	Planning to have areas that remain lightly grazed by virtue of water-remoteness and/or fencing by including specific targets of representation of different land types for 'undeveloped' or water-distant country in INRM plans. May include discussions of appropriate stewardship payments for opportunity cost of not developing country and/or management for fire, weeds, feral animals etc.	1, 2, 3, 4, 6, 8
	May include strategic decommissioning of existing waters, notably within conservation reserves or other areas with high biodiversity values.	6, 8, 9
Placement and management of infrastructure (includes fences and water points)	Protection of riparian zones and natural water points by fencing to prevent excessive disturbance.	all
	Protection of fragile land types (either because of susceptibility to soil erosion, or sensitivity of native species, etc) by careful placement of water points. In some situations it may be worth encouraging the installation of new water points to allow smaller flocks/herds of stock to graze country more lightly and evenly as a trade-off against soil erosion.	all
	May include strategically moving water points to achieve targets (i.e. negligible loss of productive potential while achieving conservation outcomes). This would be done especially where infrastructure is in disrepair and the location of a new water point could be guided.	6, 8, 9
	Possibility of turning waters off and on to spell country. This needs to be done on a sufficiently large scale (e.g. several paddocks) to ensure that areas remote from any free water are created and feral animals (especially kangaroos) do not then reduce potential benefits of spelling.	4, 6, 7, 8
	Using trap yards to trap stock and feral animals, especially in combination with the approach outlined in the previous point, where a rapidly imposed large-scale relative scarcity of water can increase the effectiveness of the selective availability of a water point.	4, 6, 7, 8, 9, 10

7.2.1.2. Application of 'best-practice' grazing land management

There is general inertia to changing grazing land management practices. This is particularly so when the recommended change is to achieve better biodiversity outcomes but there is no (or negative) outcomes for economic returns.

Few studies have been done on the effects of different grazing strategies on biodiversity. The most comprehensively studied strategy has been that of the effect of decades of set-stocking (i.e. keeping roughly the same grazing pressure in a paddock all the time, depending on environmental conditions) through the Biograze project (Biograze 2000). Ecological theory indicates that widespread homogeneous 'disturbance' is likely to favour a few species adapted to that disturbance regime, over a variety of species. As a broad generalisation, the majority of pastoralists in most regions use the traditional strategy of set-stocking. The trend to have more water points evenly spaced leads to a more effective use of forage but reinforces the homogenisation of the landscape with respect to grazing pressure. At the same time, the suppression of fire on pastoral lands takes away a factor that used to introduce spatial diversity.

Ecological theory implies that grazing land management that encourages spatial and temporal variation in the disturbance regime will create situations were different sorts of species are advantaged at some time, or in some place – that is, a diversity of species will persist. Some grazing land management strategies that are likely to be biodiversity-friendly, because they encourage this variability are: wet-season spelling; tactical grazing; variable stocking; and rotational grazing (see Chapter 6).

7.2.1.3. Feral grazers

Apart from domestic stock, grazing animals that contribute to TGP include feral stock, goats, rabbits, horses, donkeys, camels and pigs. Different management options are needed for the different species and sometimes different techniques are needed for the same species in different regions. Detailed discussion of issues for each group of wild stock species is covered in section 6.4.2.

Issue	Management approach	Relevant GLMZs
Goats (and wild sheep)	Goats can contribute substantially to the TGP in sheep-grazed regions (i.e. where dingoes are absent) and they are not constrained by fencelines, so areas remote from water in a paddock may be accessible by goats from adjoining paddocks. Most pastoralists consider them to be an informal cash resource (except in WA, where they are a formal cash ‘crop’), so pastoralists resist controlling their numbers. This is especially true during drought: goats eat a wider range of plants and can maintain condition longer than sheep. They thus become a harvestable resource during drought when sheep are in poor condition. However, one study has suggested that the net cash effect of goats on a pastoral property is negative and so this attitude should be discouraged unless these findings are proven to be incorrect in other regions. Goats are difficult to muster from the air or on the ground because they frequent shrubby areas (especially where woody shrubs have increased due to pastoralism) and rocky habitats (e.g. Flinders and Gawler ranges). In most areas, populations can be managed effectively by trapping animals at artificial water points except when there are numerous natural water points (e.g. along creeks and in claypans after rain). In rocky habitats, populations are best controlled by aerial shooting. The management of goat populations could, in some circumstances, be achieved by the reintroduction of dingoes, although pastoralists may fiercely contest this. In some special situations where a pastoral property is purchased for a conservation reserve, it may be simpler and less expensive over the medium to long term to control goats (and other wild stock) by fencing the perimeter to dog-proof standard (e.g. with netting), and introducing a few dingoes. This approach is untested but may have greater biodiversity benefits than traditional approaches. Given the likely resentment from neighbours towards this approach, it would almost certainly have to be accompanied by an agreement to generously compensate	7, 8, 9

	for any stock that could be proven to be killed by dingoes from the enclosure. Careful economic analysis and community consultation would be needed to determine if a trial of this approach would be possible.	
Rabbits	The most effective broad-scale management of rabbit populations has been through the use of diseases (myxomatosis and rabbit haemorrhagic disease). Rabbits do not need to drink except under exceptional circumstances and so cannot be managed by water point techniques. Local-scale management includes ripping, blasting, and fumigating warrens. These techniques are effective at keeping rabbit populations low on a local scale since calici virus lowered them by up to 95% in 1995.	4, 5, 6, 7, 8, 9, 10
Horses, donkeys	Horses and donkeys generally occur in low numbers on the margins of pastoral land, except in rocky habitats where their population size can be substantial and damaging. They are typically controlled by aerial shooting; however, there can be resistance to control in some areas where horses are seen as a resource.	2, 6, 7, 8,
Camels	The main barrier to camel population management is sparse populations in remote areas. They are actively shot where populations encroach onto pastoral land because they damage fences. Their ability to go long periods without drinking, and to cover large distances in this time, means that water point–focused control has limited effect, except perhaps during extremely dry periods. The most likely form of control is through the development of a flourishing camel meat industry based on mustering and processing wild camels *in situ* with mobile facilities.	5
Pigs	Although found in a wide variety of GLMZs, pigs are generally only abundant in mesic habitats (marshes, watercourses, floodplains etc). Control is difficult due to the dispersed nature of populations and the rate of increase. Regionally coordinated control and persistence is necessary to keep numbers in check.	1, 2, 3, 4, 8, 9, 10

7.2.1.4. Management 'hotspots'

Management hotspots are the 'special areas' where there is an intersection of high biodiversity value and susceptibility to damage by TGP. These locations typically harbour relatively large numbers of species, threatened, endemic and restricted-range species and they are associated with habitats such as wetlands; stony or elevated country; rainforests and vine thickets; and regionally restricted habitats.

Wetlands, stony country, rainforests and vine thickets and regionally restricted habitats can often be identified in most zones through existing maps, and can therefore be taken as candidate sites of importance. The first step for all of these categories of hotspot areas is to identify them, and to identify their significance. Not all areas will have the same value for biodiversity, and not all areas will need to be managed in special ways for biodiversity (i.e. existing TGP pressures are acceptable).

Areas of specific significance are best revealed through a process of evaluating the regional context with respect to TGP as a threatening process (e.g. following the first four steps in biodiversity target-setting proposed by James & Saunders [2001]). A second step, if it has not already been done, and the analysis of regional significance suggests that it might be highly important, is to conduct basic biodiversity inventories to determine the level of irreplacability of the candidate hotspot sites in terms of the species present. The amount of resources that are targeted at such sites will reflect the outcome of this analysis.

As many of the hotspots are unrecognised, there is a need to compile or refine the current 'lists' used to identify these hotspots. Property and regional NRM plans must identify management hotspots and provide evidence of a credible approach to management as outlined below.

Issue	Management approach	Relevant GLMZs
Wetlands	These include directory wetlands, mound springs, permanent natural waterholes, swamps, waterbird breeding sites, and generally mesic refugia in otherwise dry landscapes (Morton et al. 1995).	all
	Naturally occurring wetlands and waterholes are still regarded as a free resource in terms of pastoral land use (i.e. water provided without the cost of tanks and troughs). There is little evidence to indicate one way or another whether trampling fringing vegetation and fouling waterholes has a significant impact on the native species (especially fish that are often endemic or highly restricted in range) that inhabit these water bodies.	most
Stony or elevated country	This country type is often synonymous with threatened, endemic and restricted-range species because of specific geological characteristics (e.g. greenstone belt in Goldfields region of WA) and because of relictual species distributions that are maintained because of microclimatic conditions (e.g. plants in rocky gorges in Central Australian ranges). They may also function as refuges because they are difficult for grazing animals to get to (i.e. broken terrain) or because water points are located far from stony rises (down the catenary gradient).	all
Rainforests and vine thickets	They are hotspots because of the relatively high number of species that persist there and because some of the species are likely to be regionally restricted-range species.	1, 2, 3, 4, 7, 10
Regionally restricted habitats	As the name implies, these are habitats that are special because they are: small in total area; patchy across the region (fragmented); or represent pristine vestiges of otherwise modified habitats (e.g. water-remote lightly grazed patches in an extensively grazed landscape).	all
Management approaches	Property and regional plans to include analysis of context and threats for habitats in the region. This process requires skilled NRM facilitators or processes such as EMU being used in the Gascoyne–Murchison (Pringle 2002).	all
	Fencing off areas to protect riparian and fringing aquatic habitats, and piping water to tanks remote from the wetland.	all
	Fencing off small stony rises and other refuge habitats.	all
	Implementing stewardship agreements for the management of paddocks that contain hotspots, so that TGP is managed	all

in specified ways under certain conditions – this may often not be known, so some resources should be directed at understanding the appropriate times and actions for intervention.

7.2.2. Other land management issues interrelated with TGP

7.2.2.1. Weeds (exotic plants species)

Weeds establish and become problems for biodiversity on landscape scales through deliberate and non-deliberate introduction. Deliberate introductions (e.g. buffel grass in pastoral lands) are obviously those that are desired (by the industry) to improve the productive potential of the landscape. In some zones exotic pasture species are an important component of the grazing system. The establishment of limited areas of introduced pasture may help reduce TGP on other parts of the property because of the additional productivity gained from introduced pastures. However, there is a potential that introduced pasture species may spread beyond managed pasture areas and become environmental weeds. Appropriate screening and management of species is necessary to limit this potential.

The non-deliberate introduction of weeds is facilitated by disturbance of native species and soils. Areas of heavy grazing pressure, where the soil surface is broken and native plants are thinned, are therefore good locations from which weed species establish and spread. Weed infestations occur because they are not kept under control by domestic stock, a native grazing species (vertebrate or invertebrate), or a pathogen. Thus weed infestations lead to a loss of land area from which production is derived, or to a general lowering of production from a given land area (or both), and this is likely to increase grazing pressure on other parts of the landscape. Early intervention is always more effective than delayed action when it comes to controlling the population and spread of weed species. Part of regional planning should be to identify nascent weed infestations and alert land managers in the region to the need for timely and concerted action to protect their lands from potential degradation.

7.2.2.2. Fire

In the rangelands as elsewhere in Australia, biodiversity is generally sensitive to fire regimes, because most environments are highly flammable. The pre-pastoral fire regimes under which the biota evolved were largely those prescribed by Aboriginal people for a variety of cultural and environmental purposes, within constraints imposed by the fire/climate region. Though these regimes are seldom known in detail, they are believed to have generally involved fine-grain spatial and temporal patterns of burning. Fire regimes in pastoral rangelands are still circumscribed by climate and region, but within that they are now prescribed by pastoral managers for a variety of purposes related to the pastoral resource. These include protecting life, property and pasture biomass, manipulating pasture composition, and managing woody vegetation structure. Current fire regimes in fire-prone pastoral environments range from frequent, uncontrolled, extensive damaging wildfire in sparsely settled tropical and arid GLMZs (particularly in parts of 1, 2, 5 and 7), through frequent, controlled, lower-intensity fires in more productive and closely settled tropical GLMZs (parts of 2, 3, 4 and 6), to total fire suppression (with occasional damaging wildfire) in the remaining GLMZs, which are either more intensively developed or less fire-prone. The consequences of changed fire regimes for biodiversity have mainly been documented in the most fire-prone environments, where they include decline of fire-sensitive plant species, and woody thickening and habitat change with subsequent declines in some fauna (see Myers et al. 2004).

A complete return to pre-pastoral fire regimes is not compatible with pastoral grazing management, because pastures provide both the main fuel for fires and the main feed for grazing animals. A partial return (e.g. an increase in the spatial and temporal patchiness of controlled burns) requires biodiversity knowledge (e.g. fire-related attributes of species of concern), informed regional planning (e.g. to identify and monitor current and desired fire regimes), appropriately trained and resourced people (e.g. to carry out prescribed burns and monitor their impact), adequate infrastructure (fencing) to allow pastures to be rested for long enough for fuels to accumulate, and a supportive regulatory environment.

Issue	Management approach	Relevant GLMZs
Fires do not respect tenure boundaries	Informed regional planning. Cooperation and networks.	all
Need to know the historical and current fire regimes	Fire history and fire mapping.	all
Need to know the fire-regime requirements of biota of concern	Literature and field research to determine fire attributes of species.	all
Need to have knowledge and capacity to implement and monitor controlled burns	Training and resources in operational aspects of fire implementation and monitoring.	all
Highly flammable introduced pasture grasses (e.g. gamba grass, buffel grass) increase the extent and intensity of wildfires	Use weed risk assessment to screen out inappropriate new introductions; use standard weed hygiene procedures to prevent spread; control of weeds in conservation areas to be a priority.	2, 3, 4, 5, 6
There are not enough people or resources in sparsely settled tropical and arid rangeland regions to implement mosaic burning	Train and resource 'fire teams' using knowledgeable Indigenous people where appropriate. Provide funding for infrastructure resources (e.g. fencing) where necessary for resting paddocks in order to implement conservation burns.	1, 2, 4, 5, 6, 7
It may no longer be appropriate or even possible to implement mosaic burning in intensively used rangelands	Investigate alternative methods of providing appropriate resources for biota of concern (e.g. mechanical thinning of woody vegetation).	3, 4, 8, 9, 10

7.2.2.3. Woody vegetation change

Woody vegetation change includes increased density of native woody vegetation and its encroachment into native grasslands; invasion of exotic woody species into grasslands; and thinning of native woody vegetation due to drought, intense wildfire and deliberate intervention. Woody thickening (increased density, encroachment or invasion) is generally most severe in areas where grazing pressures are high and there has been a reduction in the frequency and/or intensity of fires. Though it has been moderately well documented in the southern rangelands, particularly in western New South Wales, there has been little documentation of its regional distribution in the northern rangelands where extensive thinning also occurs. Similarly, while there is some understanding of where, when and at what rate woody thickening occurs in different land systems and under different management regimes in southern rangelands, there is less specific understanding in the north.

There have also been very few studies of the impact of woody vegetation change on biodiversity in any rangelands except those in Cape York Peninsula, where thickening and encroachment of native woody plants threaten the persistence of several grassland ecosystems, and are a major factor in the decline of several threatened bird species.

Fire can be one of the most effective means of managing vegetation structure, but interactions between fire regimes and grazing are complex, and appropriate management varies among GLMZs. All share a fundamental trade-off, however, in that pastures provide both the main fuel for fires and the main feed for grazing animals. They also provide the main competition for woody seedlings. As woody thickening becomes more established, controlled burning loses its efficacy as a management option, due to the increased tolerance of established woody plants to fire and the suppressive effect of dense woody vegetation on herbage growth. Other control options include mechanical treatments (blade ploughing, selective thinning, chaining), chemical aboricides and browsing by goats. Ongoing management is critical. One-off treatments generally fail and may even exacerbate the problem by promoting dense regeneration. Integrated mechanical, fire and low-dose chemical treatments have had variable success. Their impact on biodiversity is, however, unknown.

Issue	Management approach	Relevant GLMZs
Uncertainty about the extent of woody thickening in northern rangelands	Undertake a systematic regional compilation and comparison of recent and historical records (air photos, landscape photos, written accounts).	2, 3, 4
Uncertainty about priorities for controlling woody thickening at an enterprise scale	Compile spatial information about local variation in woody thickening in relation to management, country type and seasonal variation in order to identify areas where control is likely to be most cost effective.	2, 3, 4, 8, 9
Lack of information about impact of woody change on biodiversity	Undertake comparative studies of biodiversity composition in areas that have experienced different degrees of change in woody vegetation density.	2, 3, 4, 8, 9
Uncertainty about the cost and efficacy of different control strategies, and their impact on biodiversity	Use adaptive management in a cycle of testing, monitoring and improvement to investigate best-bet options including:	
	- grazing management integrated with strategic burning	2, 3, 4
	- grazing management integrated with strategic mechanical treatment and follow-	3, 4, 8, 9

	up burning	
	- grazing management integrated with multiple-treatment strategies.	3, 4, 8, 9

7.2.3. Integrative issues

7.2.3.1. Biodiversity inventories

Coherent management of TGP for biodiversity is often hindered, for large regions within the rangelands, by a basic lack of biodiversity knowledge. Biodiversity information deficiencies include:

- Lack of basic data about the occurrence and distribution of species within the region.
- Lack of appropriate habitat mapping (such as a vegetation map), or mapping only available at a very coarse scale.
- Insufficient data to delineate areas of high conservation significance (which may be due to high diversity: habitat for threatened, endemic, range-restricted and/or sensitive species and communities) in the region.
- Poor understanding of the impact of TGP and various land management regimes on the species and ecosystems occurring in the region.

In combination, the above two points mean that management ‘hotspots’ (see 7.2.1.4) cannot be delineated for the region, and the most appropriate management for these areas is also uncertain.

- Formal listings of threatened (or otherwise significant) species and ecosystems may be inadequate or inaccurate (both failing to list things which require protection, and ascribing threatened status to things that are regionally secure).

Additionally, adequate biodiversity data for some regions may exist, but only in formats that are not readily accessible to regional NRM planners and the agencies and landholders responsible for the management of TGP.

Adequate environmental mapping forms the basis for regional conservation planning, and is usually important in understanding the distribution of TGP as well as determining priority areas for managing TGP for biodiversity. Environmental mapping may be based on one, or a combination, of geomorphology, lithology, soils, ‘land units’, ‘land systems’ and vegetation associations or communities, with the latter generally desirable for describing biodiversity. The ‘regional ecosystem’ approach adopted in Queensland (Sattler & Williams 1999) is one useful example. Mapping at a scale no coarser than 1:250 000 is necessary for good regional planning, although mapping at a finer scale (1:100 000 or better) may be necessary to adequately delineate important ecosystems that are generally linear (e.g. riparian zones) or occur as small patches (e.g. monsoon rainforests, mound springs). A variety of methods are now employed to derive environmental mapping from remote imagery (e.g. Landsat TM), but these still rely on experienced practitioners and adequate ground-truthing to produce robust results.

Biodiversity inventory is most effectively carried out at a bioregional (or similar) scale, and there are numerous examples of good practice in regional biodiversity inventory (Margules & Austin 1991, McKenzie et al. 1991, Burbidge et al. 2000, Dick 2000, Price et al. 2000). While the approach will vary between regions (depending on the nature of environmental variation, logistic considerations and management priorities), key components of regional inventory include:

- Collation of all existing biodiversity information. Some jurisdictions already maintain, or are in the process of developing, comprehensive spatial databases of flora and/or records (e.g. http://wildlifeatlas.nationalparks.nsw.gov.au/wildlifeatlas/watlas.jsp; http://www.calm.wa.gov.au/florabase/index.html). Other data sources include museum and herbarium records, national atlas projects (e.g. Barrett et al. 2003), jurisdictional atlas projects, published and unpublished (e.g. Environmental Impact Assessments) literature.

- Establishment of a spatially explicit database (geographic information systems [GIS]) to contain regional biodiversity records, ideally combined with biophysical and other (e.g. infrastructure) spatial data layers. Initial analysis of the data may indicate where critical knowledge gaps occur.

- Development of an environmental stratification of the area. This may be based on existing or new environmental mapping, but a regionalisation may also be derived from numerical analysis of climate, elevation, lithology, soil or other biophysical surfaces.

- Selection of representative biodiversity sample sites based on the environmental stratification and assessment of knowledge gaps. The sites should encompass the broad environmental gradients within the region, but stratification at a local scale will also be necessary to encompass local variation in topography, soils and vegetation. Site selection may also target restricted habitats that would otherwise be missed or undersampled. A good dispersion of sample points will assist subsequent modelling of, for example, species distributions, but may be logistically difficult. A ‘gradsect’ approach (Austin & Heyliger 1989) may help limit the geographic scope of sampling.

- Biodiversity sampling at selected sampling sites. The taxa sampled will depend on the expertise and resources available and the objectives of the inventory, but it is generally efficient to simultaneously sample a broad range of biota at each site:

    - plants are relatively easy to sample reliably, although botanical expertise is required for good floristic data; vegetation structure and composition can be good indicators of the effects of land use and are relatively good surrogates for many other taxa

    - birds are relatively easy to sample, include species that are sensitive to the effects of land use and may be useful indicators

    - reptiles and frogs require significant trapping effort to sample effectively

- mammals may include taxa of conservation significance and may be sensitive to the effects of land use, but may require high sample intensity for adequate inventory

- invertebrates may reveal biogeographic patterns and be sensitive to the effects of land use; some invertebrates (e.g. ants) are relatively easy to sample but may be taxonomically difficult, as well as being difficult to place into a broader context

- sampling may target particular taxa or species (e.g. significant groups defined under NRM plans, species believed to be good indicators, threatened species), although it may also not be possible to sensibly select these species before a more general inventory has been undertaken.

▪ There are many examples of appropriate sampling methodologies for various taxa (e.g. Andersen 1993, Neldner et al. 1995, Landsberg et al. 1997, Mac Nally 1997, Woinarski et al. 1999, Moseby & Read 2001, Tasker & Dickman 2002, Thompson et al. 2003, Watson 2003, Milne et al. 2004):

  - ideally methodologies should be comparable with those previously applied in the region, or used more broadly within the jurisdiction, and should be rigorously documented to ensure repeatability

  - all species records should be accompanied by precise location, standardised habitat descriptions and (ideally) with estimates of relative abundance

  - notable records should be supported by herbarium vouchers or museum specimens

  - specialised techniques may be required for some taxa (e.g. recording of echolocation calls for censusing bats)

  - plot-based sampling will not be appropriate for some taxa, notably large and mobile vertebrates. Transect-based ground sampling or aerial survey may be used, e.g. for macropods (Clancy 1999), waterbirds (Kingsford & Porter 1993).

▪ Biodiversity inventories may also be efficiently combined with an investigation of the impact of land use regimes, by stratifying (at least a subset of) sites to additionally encompass a range of, for example, grazing pressures or management histories (e.g. Landsberg et al. 1997).

▪ Regional biodiversity inventories may be a useful method for engaging landholders and the broader community with biodiversity conservation issues and improved land management. Landholders and other members of the community can also provide valuable biodiversity data and insights into ecological processes.

▪ Biodiversity surveys may also be targeted towards improving knowledge of formally listed species and communities. In this case, sampling may concentrate on locations and habitats where species are known or believed to occur.

- While the outcomes of biodiversity inventories are often published as comprehensive but fairly dense scientific tomes (e.g. Burbidge et al. 2000), simplified summary versions that are accessible to a range of NRM groups and managers may be more useful (e.g. http://www.nationalparks.nsw.gov.au/PDFs/sbs_cp_stage2_faunawestern.pdf).

7.2.3.2. Integration of regional and property management/ conservation plans

The approaches to management 'hotspots' outlined above cover some of the aspects of integrated regional- and property-scale planning. The planning that INRM groups may undertake at a regional scale includes an understanding of the threats and context associated with species and ecosystems, threatened species and endemic species. This leads to an appreciation of irreplacability values for different parts of the region and this knowledge must filter down to local (property) scales, where management actions are implemented.

Analyses and planning must be done in a spatially explicit way because biodiversity is spatially explicit. Part of the problem with affecting change in the mindset and actions of land managers is the incorrect assumption that the landscape is vast and that the unusual parts on a property probably also occur in other places, so they aren't that 'special'. Different areas are almost certainly different in their biodiversity because they are different locations, even if they are mapped as the same vegetation type or country type. The planning of biodiversity management in rangelands is best done at the regional scale (albeit with local-scale actions) because of the scale of areas and the way species are distributed. It isn't until a regional scale map is presented and the uniqueness of areas relative to each other is explained that people get a sense of what is special, and why, on their particular patch. Relatively common country types may be shown to be special at the property scale, if after a regional-scale analysis, they are shown to be strategically important in achieving targets of representation of biodiversity or targets for habitats in good condition. For example, several types of special areas whose 'specialness' may not be immediately obvious may be identified through a regional-scale analysis of threats and context:

- Country types that are rare within the region (but not rare in an adjacent region).
- Country types that only occur in a few isolated patches across a region (and may well harbour distinctive species that *may* benefit from lighter grazing pressure).
- Small fragments of otherwise widespread country types that remain ungrazed.
- Country types that have become fragmented due to clearing.
- Country types that have become fragmented or adversely affected by inappropriate fire regimes.
- Habitats that form stepping stones that link larger patches of habitat (e.g. ephemeral wetlands).

Property-scale and regional-scale plans need to be linked to reflect the geographic areas over which planning is best undertaken and the appropriate scale at which management actions occur.

At property scales the following aspects of planning should be covered:

- The plan is spatially explicit and is based on appropriate information (e.g. biodiversity databases, vegetation maps, threat analysis).
- The plan takes account of regional priorities.
- The plan needs to include infrastructure planning (i.e. future plans for water points and fences).
- The plan needs to incorporate temporal management through a recognition of grazing management strategies that attenuate risk. For example, spelling country at appropriate times to allow seed banks to recharge.
- Such planning requires that a land manager have access to appropriate data and technical expertise but this need not be too overwhelming. The EMU project in the Gascoyne–Murchison (Pringle 2002) has developed a process of stepping pastoralists through a learning session with such data that eventually empowers them to make their own plans. Data that are needed to inform the process are regional GIS capability (e.g. biodiversity surrogate [vegetation] and threat layers), and other biodiversity databases (e.g. threatened species).

At regional scales, biodiversity assessment and planning can follow examples given in a variety of studies (e.g. Dorricot & Roberts 1993, Dick 2000, James & Saunders 2001, Parkes et al. 2003). Regional plans provide a spatial context for property-scale planning and hence will require different resources and emphases to property plans. Regional plans need to include:

- Short- and long-term analysis of trends.
- Cost-effective biodiversity management actions, possibly derived from SWOT-style analysis (i.e. strengths/weaknesses/opportunities/threats).
- Research to fill data gaps and thereby enable better outcomes.
- Explicit targets for biodiversity conservation that attempt to distribute the 'burden' of management actions as equably as possible among land managers.
- Investment in regionally coordinated management of feral animals and weeds where this is beyond the resources available to individual land managers, or where coordinated action is likely to be more effective than uncoordinated actions.

7.2.3.3. Biodiversity monitoring tools

Biodiversity monitoring is an integral component of adaptive management, and is therefore essential to assess the success of management strategies for TGP. Despite this, there are no comprehensive broad-scale biodiversity monitoring programs in the Australian rangelands, and there is little clarity as to how these should be established. The lack of appropriate biodiversity monitoring schemes has been noted as a factor inhabiting sustainable land management in all of the GLMZs.

Monitoring, evaluating and reporting on natural resource management has been established as an important component of the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality (see http://www.deh.gov.au/nrm/monitoring/indicators/index.html). Regional NRM management groups will be required to define and report on indicators of resource condition relating to specified 'matters for target'. While the recommended indicators are yet to be finalised, those directly relating to biodiversity will include:

- Extent and distribution of native vegetation.
- Condition of native vegetation.
- Condition of river.
- Extent and distribution of wetland ecosystem.
- Condition of wetland ecosystem.
- Extent and conservation status of selected significant native species and ecological communities.
- Extent and impact of selected ecologically significant vertebrate invasive species (i.e. including feral grazers).
- Extent and impact of selected ecologically significant invasive vegetation species.

Considerable effort is already being devoted to monitoring 'land condition' in Australian rangelands, with each rangeland jurisdiction having long-term monitoring programs (see reviews in Whitehead et al. 2001 and National Land and Water Resources Audit 2001b. These programs are now coordinated in the Australian Collaborative Rangeland Information System (ACRIS [National Land & Water Resources Audit 2001b]). While some of the data collected in these programs is relevant to TGP and biodiversity (e.g. monitoring ground cover and pasture composition, and assessment of feral herbivore and kangaroo populations), they do not include specific indicators for biodiversity.

Considerable attention has recently been paid to the problem of rangeland biodiversity monitoring (notably Whitehead et al. 2001 and Smyth et al. 2003). There are four major considerations in developing a biodiversity monitoring program:

- The purpose of monitoring.
- The spatial scale of monitoring (e.g. enterprise, regional, state/national), as well as the temporal scale.
- The selection of appropriate indicators.
- The institutional framework to support an ongoing monitoring program.

A useful set of guiding principles for developing a regional biodiversity monitoring system is given in Smyth et al. (2003, p. 43):

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

Indicators are the key tools for biodiversity monitoring. Biodiversity indicators fall into four groups:

- Pressure – measures of processes that are believed to adversely affect biodiversity (e.g. density of grazing animals).
- Biotic response – actual measurement of components of biodiversity that, ideally, indicate the response of a broader range of taxa (e.g. the distribution and abundance of targeted species).
- Environmental attributes – biophysical measures that provide information about biodiversity (e.g. vegetation characteristics).

- Landscape attributes – derived measures of environmental and pressure attributes across broad scales (e.g. density of artificial water points).

The choice of indicators depends on the purpose of monitoring and the operational constraints, but it is likely that a range of indicators from all of the four groups will give the most robust outcomes.

Whitehead et al. (2001) nominated a set of 11 types of indicators that may be useful in broad-scale biodiversity monitoring in the rangelands:

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

Smyth et al. (2003) list good techniques for monitoring a large number of pressure and biotic response attributes (see 2003, Tables 3.5 to 3.12, pp. 13–17). Smyth et al. (2003, Table 4.2, pp. 20–1) also list a large number of potential indicators for regional- and local-scale biodiversity monitoring, including a number that are directly relevant to TGP and the impact of TGP on biodiversity (Table 7.1).

Case studies at the regional and enterprise scale that have been suggested by Smyth et al. (2003) to test and modify the set of indicators will be undertaken under a consultancy that the Desert Knowledge and Tropical Savanna CRCs are currently providing for DEH.

Table 7.1. Potential indicators for regional- and local-scale biodiversity monitoring from Smyth et al. 2003

Reporting scale and function	Indicator description	Indicator type	Indicator explanation
Local reporting – matrix management	Abundance of feral herbivores	Pressure	Manage populations of feral mammalian herbivores to maintain acceptable low levels.
	Composition of ant fauna	Response	Ants are a ubiquitous, grazing-sensitive group that can be taken as a surrogate for invertebrates as a whole.
	Composition of bird fauna	Response	Different suites of birds are good indicators of different pressures, based on mobility/dispersal characteristics.
	Cover and structure of perennial terrestrial vegetation	Response	Broad indicator of a number of pressures, e.g. grazing, fire, flood, drought, weed invasion, land clearing.
	Composition of perennial terrestrial vegetation	Response	Aimed at maintenance of pastorally productive plant species and habitat for other elements of biodiversity.
	Increase in area of disturbed and eroded land	Response	Indicates overall change in function of areas within a property. Can expand if not checked.
Local reporting – special biodiversity values	Effective recruitment in populations of special biota	Response	Recruitment is key to persistence in species or ecosystems of high value.
	Localised grazing pressure	Pressure	Specific to plant communities that need some areas protected from grazing pressure (e.g. from rabbits).
	Infrastructure to protect special areas	Response	Fences to remove stock, fire breaks etc are indicators of care for special areas and taxa.
Regional reporting – compliance	Composition and abundance of waterbird fauna	Response	Sensitive to changes in water quality and pollution. An integrating indicator because they are at the top of the food chain.
	Composition of perennial terrestrial vegetation	Response	A long-term attribute of landscape function and habitat for other elements of biodiversity.
	Composition of terrestrial fauna	Response	Direct measure of biodiversity. Differential responses among sub-groups may indicate nature of pressures.
	Cover and structure of perennial terrestrial vegetation	Response	A long-term attribute of landscape function and habitat for other elements of biodiversity. Provides qualitative insights into integrity and function of meso-scale landscapes (hectares). Easy to measure and readily interpretable by pastoralists. Has likely links to ground-dwelling/nesting fauna.

Reporting scale and function	Indicator description	Indicator type	Indicator explanation
	Status of threatened species and ecological communities	Response	Improving condition of environment if threatened species and ecological communities are being delisted.
		Response	Confidence in sustainability of harvest and to set quota.
Regional reporting – investment	Abundance and distribution of feral pest animals	Pressure	Considered to be main determinant of decline in small mammal species.
	Composition and abundance of waterbird fauna	Response	Indicates wetland health and there is functional linkage to hydrological change. Easily understood and has social appeal.
	Abundance and distribution of aquatic and semi-aquatic vegetation	Response	Directly measures the effect of changed flow regimes and riparian vegetation and wetland health.
	Landscape pattern change	Response	Indicates potential loss of function and habitat degradation. Simplification of processes but cost effective at large scales.
	Status of threatened species and ecological communities	Response	High public profile and easily collected information, therefore useful for raising profile with decision makers and targeting investment.
	Structure of perennial terrestrial vegetation	Response	Well-established link between grazing pressure and vegetation structure and landscape change. Methods well known and have strong links with other ACRIS indicators. Measurement is of percentage cover and patchiness, composition and relative abundance.
	Number of new agricultural species with weed potential	Pressure	Potential for invasive introductions.
Regional reporting – regulatory	Average stocking rates	Pressure	In combination with water point indicators can indicate grazing pressure on ecosystems.
	Composition of bird fauna	Response	Presence of certain bird species indicates the level of disturbance to environment; hence, the presence of some specific species in least-pressured areas of the landscape is desirable for persistence.
	Composition of perennial terrestrial vegetation	Response	Presence of certain species indicates the level of disturbance to environment; hence, the presence of some specific species in least-pressured areas of the landscape is desirable for persistence.

Reporting scale and function	Indicator description	Indicator type	Indicator explanation
	Cover of perennial terrestrial vegetation	Response	Broad indicator of a number of pressures, e.g. grazing, fire, flood, drought, weed invasion, land clearing.
	Density of artificial water points	Pressure	Surrogate for grazing pressure and land use intensity but also directly correlated with changes in water-dependent species.
	Density of feral and native mammalian herbivores	Pressure	In combination with stocking rate indicators, can indicate total grazing pressure on ecosystems.
	Extent of clearing of remnant native vegetation	Pressure	Habitat loss may directly affect biodiversity of resident communities, and connectivity of habitat patches within landscapes.
	Land tenure change	Pressure	Percentage of land class in each tenure may relate to land use and potential pressures.
	Percentage of land area that is remote from water points	Pressure	Indicates the extent to which grazing-sensitive and water-affected species have refuges from these pressures.
		Response	Indicates relative condition of areas, possibly due to drought and/or grazing. Could indicate weed invasion or disturbance around water points.

7.2.3.4. Barriers to positive outcomes

Many barriers to effective management of TGP have already been identified in previous sections. These are collated below for convenience. If some or many of these could be solved, far better management of rangeland landscapes could be achieved with relatively small budget allocations.

- Misunderstanding of the damaging effect on biodiversity of uncontrolled grazing pressure.
- Misunderstanding of the potentially negative impact of wild stock components of TGP on economic bottom line of an enterprise.
- Lack of appreciation of the potential significance of seemingly common habitat types to regional biodiversity maintenance.
- Lack of resources and knowledge by land managers to know what to do about managing areas that are obviously biologically special (and the areas that they don't yet recognise the value of).
- Lack of formal recognition of landholders who do maintain biologically important areas on behalf of society.
- Government use of incorrect processes and rhetoric in dealings with landholders, which signals an attitude of 'control' that engenders a fear of having things 'taken away' rather than co-managed (e.g. creating small reserves actually disassociates a landholder from a patch of land and dissolves their responsibility for it).
- Poor mechanisms to make data on local and regionally-significant areas available to land managers (once again, an attitude of control, rather than a partnership approach, on the part of those who hold data).
- Lack of incentives for land managers to do things that do not add value to the enterprise.
- Lack of knowledge of the biodiversity benefits of alternative grazing systems (e.g. rotational grazing), which allows pastoralists to dismiss research results in set-stocked systems.
- Poor techniques for monitoring the effects of TGP on elements of biodiversity.
- Inadequate and/or extremely costly techniques for managing TGP (i.e. controlling animals).

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9. APPENDICES

9.1. Appendix 1: List of bioregions and sub-bioregions within the rangelands, with the GLMZ into which they fall

Note that sub-bioregions (provinces) within a bioregion (IBRA v5.2) may fall into more than one GLMZ, and that some sub-bioregions within some bioregions are outside the boundary of the rangelands, as defined here.

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Arnhem Coast	Arnhem Coast P1	ARC1	1
Arnhem Coast	Arnhem Coast P2	ARC2	1
Arnhem Coast	Arnhem Coast P3	ARC3	1
Arnhem Coast	Arnhem Coast P4 Groote	ARC4	1
Arnhem Plateau	Arnhem Coast P5 Wessels	ARC5	1
Arnhem Plateau	Arnhem Plateau P1	ARP1	1
Arnhem Plateau	Arnhem Plateau P2	ARP2	1
Brigalow Belt North	Townsville Plains	BBN1	10
Brigalow Belt North	Bogie River Hills	BBN2	10
Brigalow Belt North	Cape River Hills	BBN3	10
Brigalow Belt North	Beucazon Hills	BBN4	10
Brigalow Belt North	Wyarra Hills	BBN5	10
Brigalow Belt North	Northern Bowen Basin	BBN6	10
Brigalow Belt North	Belyando Downs	BBN7	10
Brigalow Belt North	Upper Belyando Floodout	BBN8	10
Brigalow Belt North	Anakie Inlier	BBN9	10
Brigalow Belt North	Basalt Downs	BBN10	10
Brigalow Belt North	Isaac – Comet Downs	BBN11	10
Brigalow Belt North	Nebo – Connors Ranges	BBN12	10
Brigalow Belt North	South Drummond Basin	BBN13	10
Brigalow Belt North	Marlborough Plains	BBN14	10
Brigalow Belt South	Claude River Downs	BBS1	10
Brigalow Belt South	Woorabinda	BBS2	10
Brigalow Belt South	Boomer Range	BBS3	10
Brigalow Belt South	Mount Morgan Ranges	BBS4	10
Brigalow Belt South	Callide Creek Downs	BBS5	10
Brigalow Belt South	Arcadia	BBS6	10
Brigalow Belt South	Dawson River Downs	BBS7	10
Brigalow Belt South	Banana – Auburn Ranges	BBS8	10
Brigalow Belt South	Buckland Basalts	BBS9	10
Brigalow Belt South	Carnarvon Ranges	BBS10	10
Brigalow Belt South	Taroom Downs	BBS11	10

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Brigalow Belt South	Southern Downs	BBS12	10
Brigalow Belt South	Barakula	BBS13	10
Brigalow Belt South	Dulacca Downs	BBS14	10
Brigalow Belt South	Weribone High	BBS15	10
Brigalow Belt South	Tara Downs	BBS16	10
Brigalow Belt South	Eastern Darling Downs	BBS17	10
Brigalow Belt South	Inglewood Sandstones	BBS18	10
Brigalow Belt South	Moonie R. – Commoron Creek Floodout	BBS19	10
Brigalow Belt South	Moonie – Barwon Interfluve	BBS20	10
Brigalow Belt South	Northern Basalts	BBS21	10
Brigalow Belt South	Northern Outwash	BBS22	10
Brigalow Belt South	Pilliga Outwash	BBS23	10
Brigalow Belt South	Pilliga	BBS24	10
Brigalow Belt South	Liverpool Plains	BBS25	10
Brigalow Belt South	Liverpool Range	BBS26	10
Brigalow Belt South	Talbragar Valley	BBS27	10
Broken Hill Complex	Barrier Range	BHC1	9
Broken Hill Complex	Mootwingee Downs	BHC2	8
Broken Hill Complex	Scopes Range	BHC3	8
Broken Hill Complex	Barrier Range Outwash	BHC4	9
Burt Plain	Burt Plain P1	BRT1	6
Burt Plain	Burt Plain P2	BRT2	6
Burt Plain	Burt Plain P3	BRT3	6
Burt Plain	Burt Plain P4	BRT4	6
Cape York Peninsula	Coen – Yamba Inlier	CYP1	2
Cape York Peninsula	Starke Coastal Lowlands	CYP2	2
Cape York Peninsula	Cape York – Torres Strait	CYP3	2
Cape York Peninsula	Jardine – Pascoe Sandstones	CYP4	2
Cape York Peninsula	Battle Camp Sandstones	CYP5	2
Cape York Peninsula	Laura Lowlands	CYP6	2
Cape York Peninsula	Weipa Plateau	CYP7	2
Cape York Peninsula	(Northern) Holroyd Plain	CYP8	2
Cape York Peninsula	Coastal Plains	CYP9	2
Carnarvon	Cape Range	CAR1	8
Carnarvon	Wooramel	CAR2	8
Central Arnhem	Central Arnhem P1	CA1	1
Central Arnhem	Central Arnhem P2	CA2	1
Central Kimberley	Pentecost	CK1	2
Central Kimberley	Hart	CK2	2
Central Kimberley	Mount Eliza	CK3	2

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Central Ranges	Mann–Musgrave Block	CR1	5
Central Ranges	Wataru	CR2	5
Central Ranges	Everard Block	CR3	5
Channel Country	Toko Plains	CHC1	6
Channel Country	Sturt Stony Desert	CHC2	6
Channel Country	Goneaway Tablelands	CHC3	6
Channel Country	Diamantina–Eyre	CHC4	6
Channel Country	Cooper Plains	CHC5	8
Channel Country	Coongie	CHC6	6
Channel Country	Lake Pure	CHC7	6
Channel Country	Noccundra Slopes	CHC8	8
Channel Country	Tibooburra Downs	CHC9	8
Channel Country	Core Ranges	CHC10	8
Channel Country	Bulloo	CHC11	8
Coolgardie	Mardabilla	COO1	8
Coolgardie	Southern Cross	COO2	8
Coolgardie	Eastern Goldfield	COO3	8
Cobar Peneplain	Boorindal Plains	CP1	8
Cobar Peneplain	Barnato Downs	CP2	9
Cobar Peneplain	Canbelego Downs	CP3	9
Cobar Peneplain	Nymagee – Rankins Springs	CP4	9
Cobar Peneplain	Lachlan Plains	CP5	10
Daly Basin	Daly Basin	DAB	2
Dampierland	Fitzroy Trough	DL1	2
Dampierland	Pindanland	DL2	2
Darwin Coastal	Darwin Coastal	DAC	2
Davenport Murchison Range	Davenport Murchison Range P1	DMR1	5
Davenport Murchison Range	Davenport Murchison Range P2	DMR2	5
Davenport Murchison Range	Davenport Murchison Range P3	DMR3	5
Darling Riverine Plains	Culgoa–Bokhara	DRP1	10
Darling Riverine Plains	Narran – Lightning Ridge	DRP2	10
Darling Riverine Plains	Warrambool–Moonie	DRP3	10
Darling Riverine Plains	Castlereagh–Barwon	DRP4	10
Darling Riverine Plains	Bogan–Macquarie	DRP5	10
Darling Riverine Plains	Louth Plains	DRP6	8
Darling Riverine Plains	Wilcannia Plains	DRP7	8
Darling Riverine Plains	Menindee	DRP8	8
Darling Riverine Plains	Great Darling Anabranch	DRP9	8
Darling Riverine Plains	Pooncarie–Darling	DRP10	9
Desert Uplands	Prairie – Torrens Creeks Alluvials	DEU1	4

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Desert Uplands	Alice Tableland	DEU2	4
Desert Uplands	Cape – Campaspe Plains	DEU3	4
Einasleigh Uplands	Georgetown–Croydon	EIU1	4
Einasleigh Uplands	Kidston	EIU2	4
Einasleigh Uplands	Hodgkinson Basin	EIU3	4
Einasleigh Uplands	Broken River	EIU4	4
Einasleigh Uplands	Undara – Toomba Basalts	EIU5	4
Einasleigh Uplands	Herberton–Wairuna	EIU6	4
Finke	Finke P1	FIN1	6
Finke	Finke P2	FIN2	6
Finke	Tieyon	FIN3	6
Finke	Pedirka	FIN4	6
Flinders Lofty Block	Olary Spur	FLB3	9
Furneaux	Southern Flinders	FLB4	9
Furneaux	Northern Flinders	FLB5	9
Gascoyne	Ashburton	GAS1	8
Gascoyne	Carnegie	GAS2	8
Gascoyne	Augustus	GAS3	8
Gawler	Myall Plains	GAW1	9
Gawler	Gawler Volcanics	GAW2	9
Gawler	Gawler Lakes	GAW3	9
Gawler	Arcoona Plateau	GAW4	8
Gawler	Kingoonya	GAW5	8
Gibson Desert	Lateritic Plain	GD1	5
Gibson Desert	Dune Field	GD2	5
Geraldton Sandplains	Edel	GS1	8
Great Sandy Desert	McLarty	GSD1	5
Great Sandy Desert	Mackay	GSD2	5
Great Sandy Desert	Great Sandy Desert P3	GSD3	5
Great Sandy Desert	Great Sandy Desert P4	GSD4	5
Great Sandy Desert	Great Sandy Desert P5	GSD5	5
Great Sandy Desert	Great Sandy Desert P6	GSD6	5
Great Victoria Desert	Shield	GVD1	8
Great Victoria Desert	Central	GVD2	5
Great Victoria Desert	Maralinga	GVD3	5
Great Victoria Desert	Kintore	GVD4	5
Great Victoria Desert	Tallaringa	GVD5	6
Great Victoria Desert	Yellabinna	GVD6	9
Gulf Coastal	Gulf Coastal P1	GUC1	2
Gulf Coastal	Gulf Coastal P2 Pellews	GUC2	2

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Gulf Fall and Uplands	McArthur – South Nicholson Basins	GFU1	2
Gulf Fall and Uplands	Gulf Fall and Uplands P2	GFU2	2
Gulf Plains	Karumba Plains	GUP1	2
Gulf Plains	Armraynald Plains	GUP2	2
Gulf Plains	Woondoola Plains	GUP3	2
Gulf Plains	Mitchell – Gilbert Fans	GUP4	2
Gulf Plains	Claraville Plains	GUP5	2
Gulf Plains	Holroyd Plain – Red Plateau	GUP6	2
Gulf Plains	Doomadgee Plains	GUP7	2
Gulf Plains	Donors Plateau	GUP8	2
Gulf Plains	Gilberton Plateau	GUP9	2
Gulf Plains	Wellesley Islands	GUP10	2
Hampton	Hampton	HAM	8
Little Sandy Desert	Rudall	LSD1	5
Little Sandy Desert	Trainor	LSD2	5
MacDonnell Ranges	MacDonnell Ranges P1	MAC1	5
MacDonnell Ranges	MacDonnell Ranges P2	MAC2	5
MacDonnell Ranges	MacDonnell Ranges P3	MAC3	6
Mitchell Grass Downs	Mitchell Grass Downs P1	MGD1	3
Mitchell Grass Downs	Barkly Tableland	MGD2	3
Mitchell Grass Downs	Georgina Limestone	MGD3	3
Mitchell Grass Downs	Southwestern Downs	MGD4	3
Mitchell Grass Downs	Kynuna Plateau	MGD5	3
Mitchell Grass Downs	Northern Downs	MGD6	3
Mitchell Grass Downs	Central Downs	MGD7	3
Mitchell Grass Downs	Southern Wooded Downs	MGD8	3
Mount Isa Inlier	Southwestern Plateaus & Floodouts	MII1	2
Mount Isa Inlier	Thorntonia	MII2	2
Mount Isa Inlier	Mount Isa Inlier	MII3	2
Mulga Lands	West Balonne Plains	MUL1	10
Mulga Lands	Eastern Mulga Plains	MUL2	9
Mulga Lands	Nebine Plains	MUL3	9
Mulga Lands	North Eastern Plains	MUL4	9
Mulga Lands	Warrego River Plains	MUL5	9
Mulga Lands	Langlo Plains	MUL6	9
Mulga Lands	Cuttaburra–Paroo	MUL7	9
Mulga Lands	West Warrego	MUL8	9
Mulga Lands	Northern Uplands	MUL9	9
Mulga Lands	West Bulloo	MUL10	9
Mulga Lands	Urisino Sandplains	MUL11	9

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Mulga Lands	Warrego Sands	MUL12	8
Mulga Lands	Kerribree Basin	MUL13	8
Mulga Lands	White Cliffs Plateau	MUL14	8
Mulga Lands	Paroo Overflow	MUL15	8
Mulga Lands	Paroo–Darling Sands	MUL16	8
Murchison	Eastern Murchison	MUR1	8
Murchison	Western Murchison	MUR2	8
Murray Darling Depression	South Olary Plain	MDD1	9
Murray Darling Depression	Darling Depression	MDD6	8
Northern Kimberley	Mitchell	NK1	2
Northern Kimberley	Berkeley	NK2	2
Nullarbor	Carlisle	NUL1	5
Nullarbor	Nullarbor Plain	NUL2	8
Nullarbor	Yalata	NUL3	8
Ord Victoria Plain	Ord	OVP1	2
Ord Victoria Plain	South Kimberley Interzone	OVP2	2
Ord Victoria Plain	Ord–Victoria Plains P3	OVP3	2
Ord Victoria Plain	Ord–Victoria Plains P4	OVP4	2
Pilbara	Chichester	PIL1	7
Pilbara	Fortescue	PIL2	7
Pilbara	Hamersley	PIL3	7
Pilbara	Roebourne	PIL4	7
Pine Creek	Pine Creek	PCK	2
Riverina	Lachlan	RIV1	8
Riverina	Murrumbidgee	RIV2	8
Simpson Strzelecki Dunefields	Simpson Strzelecki Dunefields P1	SSD1	6
Simpson Strzelecki Dunefields	Simpson Desert	SSD2	5
Simpson Strzelecki Dunefields	Dieri	SSD3	5
Simpson Strzelecki Dunefields	Warriner	SSD4	6
Simpson Strzelecki Dunefields	Strzelecki Desert	SSD5	8
Simpson Strzelecki Dunefields	Central Depression	SSD6	8
Simpson Strzelecki Dunefields	Bulloo Dunefields	SSD7	8
Stony Plains	Breakaways	STP1	6
Stony Plains	Oodnadatta	STP2	6
Stony Plains	Murnpeowie	STP3	8
Stony Plains	Peake–Dennison Inlier	STP4	6
Stony Plains	Macumba	STP5	6
Sturt Plateau	Sturt Plateau P1	STU1	5
Sturt Plateau	Sturt Plateau P2	STU2	2
Sturt Plateau	Sturt Plateau P3	STU3	2

IBRA Bioregion	Sub-bioregion (subregion)	Subregion code	GLMZ
Tanami	Tanami P1	TAN1	5
Tanami	Tanami P2	TAN2	5
Tanami	Tanami P3	TAN3	5
Tiwi Cobourg	Tiwi–Cobourg P1	TIW1	1
Tiwi Cobourg	Tiwi–Cobourg P2	TIW2	1
Victoria Bonaparte	Victoria Bonaparte P1	VB1	2
Victoria Bonaparte	Victoria Bonaparte P2	VB2	2
Victoria Bonaparte	Victoria Bonaparte P3	VB3	2
Yalgoo	Yalgoo	YAL	8

9.2. Appendix 2: Summary of the characteristics of each GLMZ.

The summary is derived from values for each attribute for each sub-bioregion (attributes are described in more detail in Table 4.1). The data in the table are generally the mean (weighted by sub-bioregional area) calculated across all sub-bioregions in a GLMZ, with minimum and maximum sub-bioregional values in brackets. Note that the data are from a variety of sources and comes with both caveats and restrictions on use (see Table 4.1)

GLMZ	1	2	3	4	5	6	7	8	9	10
Area (km^2)	101,025	1,155,531	336,019	189,392	1,661,505	542,707	178,999	1,317,589	538,241	529,442
BIOPHYSICAL ATTRIBUTES										
No. of subregions in GLMZ with climate type:										
D5										
E1										
E2								3		1
E3									1	5
E4									2	32
E6					3			24	17	4
E7										1
F3										
G		2	6		25	22	4	16	5	
H		16	3	2	1					
I1	11	17								
I2		16		1						
I3				6						8
J1		2								

BIOPHYSICAL ATTRIBUTES (cont'd)										
% of GLMZ area with vegetation type:										
1. Rainforests and vine thickets	0.8	0.3		0.2						1.1
2. Eucalypt tall open forests	39.8	1.8		2.6				1.0	1.1	3.3
3. Eucalypt woodlands	39.3	41.5	1.8	56.3		1.7	0.7	6.6	9.4	44.2
4. Acacia forests and woodlands		3.3	5.9	6.7	5.4	3.3	11.2	23.1	10.5	18.6
5. Callitris forests and woodlands								0.4	2.8	1.7
6. Casuarina forests and woodlands					0.5			2.0	4.7	2.2
7. Melaleuca forests and woodlands	3.4	7.0	0.1	0.7						0.4
8. Other forests and woodlands	1.9	5.1	0.7	0.6	0.3	5.0		0.9	0.3	0.1
9. Eucalypt open woodlands	9.8	9.6	7.4	29.0	3.9	1.6		1.9	3.7	10.8
10. Acacia open woodlands	0.2	5.3	1	0.4	5.1	29.7	2.3	19.9	30.3	0.7
11. Mallee woodlands and shrublands					2.9	1.8		3.1	14.7	0.8
12. Mixed shrublands		0.7	3.0	0.1	0.5	1.6		3.8	1.7	0.4
13. Tussock grasslands		10.9	64.6	2.6	0.9	14.5	7.1	3.1	4.1	6.6
14. Hummock grasslands		11.2	2.6	0.4	74.5	17.3	75.3	11.5	0.7	
15. Other grasslands, herblands and sedgelands	1.1	0.8	0.3	0.1	0.2	0.1	1.6	0.9	0.8	6.6
16. Chenopod and samphire shrublands and forblands	1.4	0.5	3.3	0.1	4.2	23.3	0.5	19.7	12.7	1.7
17. Mangroves, tidal mudflats, claypan, salt lakes, lagoons, bare	1.0	1.6	0.1	0.2	1.5	0.1	1.1	2.1	2.4	0.7

LAND USE ATTRIBUTES										
% of GLMZ with tenure:										
Aboriginal [c]	90.79	14.02	0.07	0.00	39.00	5.98	9.63	2.98	2.60	0.10
Leasehold [c]	0.86	68.61	58.90	80.53	10.78	83.71	57.84	69.36	61.59	19.46
Freehold [c]	0.01	3.96	38.15	15.94	2.29	2.15	0.13	4.99	24.25	71.64
Vacant Crown land [c]	0.08	4.71	0.20	0.52	37.64	0.54	20.15	14.06	0.46	0.38
Other Crown land [c]	0.00	2.08	1.82	1.10	0.78	0.69	5.78	1.26	1.38	1.15
Conservation reserve	6.84 (0–77.8)	6.57 (0–47.6)	1.13 (0–7.8)	2.41 (0–5.9)	6.48 (0–35.8)	4.62 (0–34.8)	6.45 (?–?)	4.56 (0–16.1)	5.24 (0–32.2)	1.86 (0–36.5)
Total area of GLMZ in conservation reserve [c]	6882	76,340	3795	4549	108,611	25,049	11,515	60,026	28,190	9825
% of GLMZ with land use:										
Irrigated agriculture	0.0 (0–0)	0.0 (0–0.1)	0.0 (0–0)	0.0 (0–0.3)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.2 (0–6.8)	0.0 (0–0.4)	0.9 (0–6)
Dryland agriculture	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.1 (0–0.2)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.4 (0–6)	0.8 (0–7.1)	8.1 (0–45.7)
Grazing on improved pasture	0.0 (0–0)	0.3 (0–4.9)	0.1 (0–0.5)	1.3 (0–3.5)	0.0 (0–0)	0.0 (0–0.3)	0.0 (0–0)	0.0 (0–0.3)	0.7 (0–7.5)	4.8 (0–25)
Grazing on native pasture	0.9 (0–4.2)	74.0 (17.6–99.4)	95.7 (87.1–99.9)	91.6 (86–99.6)	13.6 (0–79.7)	86.4 (34.6–100)	64.5 (48.2–86.6)	73.4 (16.6–99.6)	81.6 (12.9–98.9)	68.7 (32.7–99)
Cleared land	0.0 (0–0)	0.2 (0–9.1)	3.4 (0–24.2)	5.4 (0–13.7)	0.0 (0–0.1)	0.0 (0–0.2)	0.0 (0–0)	0.9 (0–22.3)	7.1 (0–47.7)	54.1 (8–92.9)
Mean property size	0 (0–0)	211,000 (0–628,500)	187,100 (16,000–437,500)	34,200 (12,400–81,100)	170,000 (0–1,021,300)	441,900 (121,200–979,600)	249,500 (111,400–357,300)	134,500 (700–559,700)	27,700 (600–107,900)	23,500 (300–313,200)
Human population density per 1000 km^2	11.5 (3.9–66.4)	8.1 (0.6–384.8)	2.6 (0.3–3.9)	6.8 (1.1–23.5)	1.4 (0.1–57.2)	1.5 (0.1–26.5)	9.6 (2–51.3)	4.8 (0.1–63)	6.4 (0.2–86.4)	50.5 (1.7–805.7)

[c] Derived directly for GLMZ, so no maximum and minimum values for sub-bioregions.

GRAZING PRESSURE ATTRIBUTES										
% of GLMZ estimated to be distant from water points:										
> 6 km	89.12	28.34	9.93	19.15	89.18	34.23	24.07	32.46	14.62	7.67
	(14.7–96.5)	(0–100)	(0.1–31.9)	(2.1–39.5)	(18.4–100)	(8.7–80.3)	(8.1–44.3)	(0–85.3)	(0–91)	(0–43.3)
> 9 km	81.0	16.9	2.3	9.5	82.3	16.0	10.7	22.6	10.0	3.7
	(14.7–94)	(0–100)	(0–10)	(0–31.3)	(1.4–99.9)	(2.5–65.5)	(2.1–26.2)	(0–76.7)	(0–83.7)	(0–23)
Mean catlle density (400 kg km^{-2})	0.20	2.67	3.94	6.04	0.81	1.17	0.87	0.67	1.29	10.41
	(0–1.3)	(0–6.9)	(2.8–6.9)	(1.8–9.1)	(0–2.8)	(0.1–2.3)	(0.5–1.1)	(0–6.6)	(0.2–4.2)	(2.4–25.2)
Mean sheep density (40 kg km^{-2})	0.00	0.33	8.59	3.48	0.24	1.62	0.36	6.02	13.20	13.94
	(0–0)	(0–4.4)	(0–22.6)	(0–9.2)	(0–1.3)	(0–6.4)	(0.3–0.5)	(0.2–55.5)	(4.3–30.8)	(0–103.3)
Mean macropod density (25 kg km^{-2})	0.00	1.20	9.61	4.58	0.93	3.21	1.38	5.84	14.33	10.56
	(0–0)	(0–8.8)	(0.1–20)	(0.9–12.6)	(0.1–4.4)	(0.4–14.4)	(0.1–3.7)	(0.4–33.1)	(2.5–29.4)	(1.6–42.1)
Total stocking density (cattle + sheep + macropods), expressed as:										
Animal equivalents (450 kg per animal)	0.17	2.47	4.80	5.93	0.79	1.37	0.88	1.46	3.11	11.08
	(0–1.1)	(0–7)	(2.8–7.3)	(1.6–8.5)	(0–2.5)	(0.3–3.4)	(0.7–1)	(0.3–11.4)	(1–5.9)	(5.6–27.7)
Dry sheep equivalents (45 kg per animal)	1.73	24.69	48.03	59.34	7.93	13.66	8.79	14.58	31.14	110.80
	(0–10.3)	(0–63)	(25.6–66)	(14.6–76.3)	(0.1–22.7)	(2.5–30.9)	(5.9–9.4)	(2.9–102.4)	(9.3–53)	(50.1–249.3)
Mean goat density from categorical class (0–3)	0.18	0.04	1.00	0.33	0.00	0.14	0.00	1.45	1.96	0.73
	(0–1)	(0–2)	(0–2)	(0–1)	(0–0)	(0–1)	(0–0)	(0–3)	(0–3)	(0–2)
Mean rabbit density from categorical class (0–3)	0.00	0.24	1.00	2.00	1.82	1.95	2.00	2.00	2.04	1.71
	(0–0)	(0–1)	(1–1)	(2–2)	(1–2)	(1–2)	(2–2)	(1–3)	(2–3)	(1–2)
Mean buffalo density from categorical class (0–3)	1.09	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(0–2)	(0–2)	(0–0)	(0–0)	(0–0)	(0–0)	(0–0)	(0–0)	(0–0)	(0–0)
Total mean feral (goat, rabbit, and buffalo) density class (0–9)	1.27	0.64	2.00	2.33	1.82	2.09	2.00	3.45	4.00	2.44
	(0–2)	(0–2)	(1–3)	(2–3)	(1–2)	(1–3)	(2–2)	(2–5)	(2–6)	(1–4)

BIODIVERSITY ATTRIBUTES:										
Irreplacability index (flora)	0.23 (0.04–0.97)	0.27 (0–1.27)	0.08 (0–0.21)	0.40 (0.12–0.69)	0.20 (0–0.76)	0.07 (0–0.36)	0.58 (0.17–0.97)	0.26 (0–1.26)	0.13 (0–0.48)	0.20 (0–0.71)
Irreplacability index (flora and birds)	0.38 (0–1.3)	0.38 (0–1.27)	0.13 (0.02–0.49)	0.43 (0.06–0.77)	0.20 (0–0.81)	0.19 (0–0.64)	0.59 (0.38–0.94)	0.35 (0–1.48)	0.33 (0–1.13)	0.27 (0–1.05)
% of regional ecosystems in reserves	15.5 (0–70)	24.3 (0–100)	13.8 (0–38.2)	33.2 (0–80)	15.0 (0–66.7)	6.5 (0–62.5)	21.4 (10.7–33.3)	27.3 (0–100)	31.3 (0–100)	39.6 (0–100)
Index of land cover change	0.00 (0–0.01)	0.02 (-0.52–0.3)	0.19 (0–1)	0.53 (0–1.73)	0.00 (0–0)	0.00 (0–0.07)	0.00 (0–0)	0.03 (-0.12–1.44)	0.50 (-1.77–5.03)	0.78 (-0.54–7.92)
No. of threatened species:[d]										
Frogs	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.7 (0–4)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.1 (0–1)	0.2 (0–2)	0.1 (0–2)
Birds	1.8 (0–5)	4.3 (0–12)	1.8 (0–3)	3.2 (1–7)	2.0 (0–7)	2.6 (0–8)	1.3 (1–2)	5.9 (0–28)	7.3 (1–29)	6.7 (0–29)
Fish	0.0 (0–0)	0.1 (0–2)	0.3 (0–1)	0.2 (0–2)	0.0 (0–0)	0.0 (0–0)	0.3 (0–1)	0.2 (0–2)	0.3 (0–2)	0.0 (0–1)
Invertebrates	0.1 (0–1)	0.4 (0–5)	0.0 (0–0)	0.3 (0–2)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.7 (0–21)	0.0 (0–0)	0.5 (0–3)
Mammals	2.2 (0–4)	1.5 (0–5)	1.0 (0–3)	0.9 (0–3)	3.4 (0–13)	2.1 (0–6)	2.8 (2–5)	3.2 (0–13)	3.2 (0–20)	2.7 (0–18)
Non-vascular plants	0.0 (0–0)	0.1 (0–3)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.0 (0–0)	0.0 (0–1)	0.0 (0–0)	0.0 (0–0)
Vascular plants	4.3 (0–18)	4.0 (0–38)	2.8 (0–6)	8.1 (2–15)	1.3 (0–8)	1.8 (0–7)	0.8 (0–2)	4.2 (0–20)	9.5 (1–35)	9.4 (0–42)
Reptiles	4.3 (0–6)	1.7 (0–7)	0.0 (0–0)	0.6 (0–4)	0.4 (0–1)	0.3 (0–1)	3.0 (1–9)	1.0 (0–9)	0.7 (0–3)	2.1 (0–8)
No. of threatened ecosystems	1.4 (1–2)	7.2 (1–48)	11.1 (0–19)	16.0 (5–42)	1.0 (0–5)	2.5 (0–10)	7.3 (1–12)	4.9 (0–24)	6.6 (0–24)	21.5 (3–47)

[d] Value is mean number per sub-bioregion, not total number in the GLMZ.