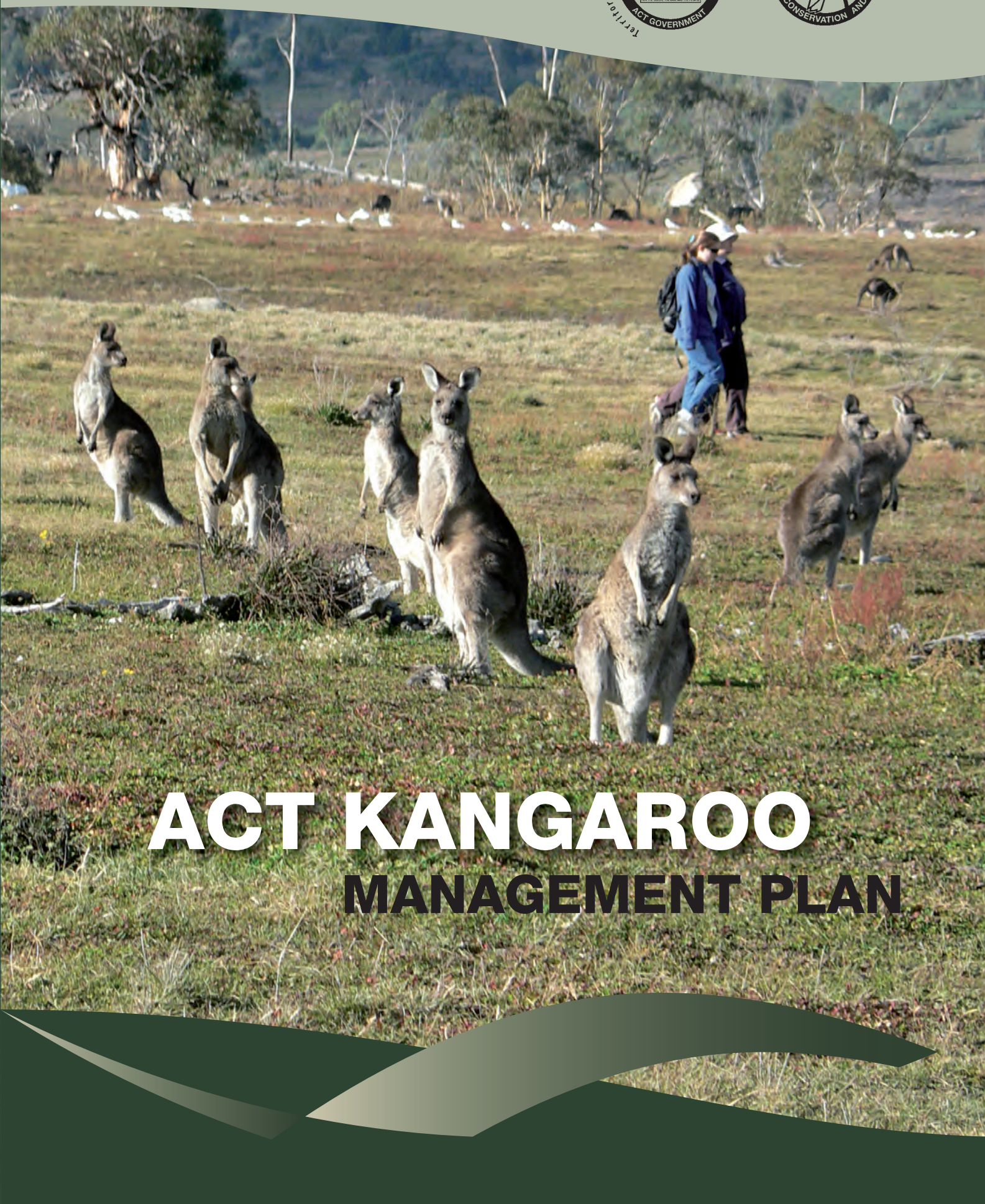

ACT KANGAROO MANAGEMENT PLAN

ACT KANGAROO
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ISBN 978-0-642-60523-8
Conservation Series: ISSN 1036-0441: 25

Published by Territory and Municipal Services (10/0022)
Website: www.tams.gov.au
Phone: Canberra Connect 13 22 81

Design: Big Island Graphics

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Acknowledgements

The ACT kangaroo management plan draws upon a wide range of published material and other information on kangaroos and this is referenced in the text. The three reports of the ACT Kangaroo Advisory Committee (1996–7) are also an important foundation for the plan. Staff of the Department of Territory and Municipal Services (especially Parks, Conservation and Lands (PCL)) and the Department of the Environment, Climate Change, Energy and Water, and members of the ACT Natural Resource Management Advisory Committee provided comment on a draft of the final plan. The plan draws, in particular, on the research by Dr Don Fletcher (Research and Planning, PCL) on developing an ecological model of the interactions between weather, kangaroos and vegetation in a temperate environment. This research is based on the pioneering work of Dr Graeme Caughley (deceased) and his co-workers at CSIRO in the 1970s and '80s, which was focussed on kangaroos in the rangelands. This provided the most detailed and integrated analysis to that time of any grazing system in the world and resulted in a large number of publications and theses. One of these co-workers, WE (Bill) Poole, made valuable comments on the draft plan.

A public consultation draft of the plan was released in March 2009, in response to which, 70 written submissions were received. Parks, Conservation and Lands acknowledges the interest and involvement of those organisations and individuals who prepared submissions. These have been analysed in detail and a range of matters followed up prior to completing the plan.

The plan was prepared by Dr Kevin Frawley in association with Parks, Conservation and Lands, in the Land Management and Planning Division, Department of Territory and Municipal Services. The final plan was reviewed by Dr Graeme Coulson, Department of Zoology, The University of Melbourne.

Ministerial Foreword

Canberra is unique among Australian cities in having large populations of free-ranging kangaroos within and on the margins of the urban area. There are also large populations in grassy valleys within the western ranges. These are mainly eastern grey kangaroos, with common wallaroos, red-necked wallabies and swamp wallabies occurring in suitable habitats.

More than 70 per cent of the ACT is open space and 55 per cent is in formal reserves. At lower elevations, these reserves include substantial areas of grassy ecosystems which provide ideal habitat for eastern grey kangaroos. Some large areas of suitable habitat are National Land managed by Commonwealth Government agencies. The urban area is interlaced with kangaroo habitat including the large number of reserves that make up Canberra Nature Park. The river corridor reserves and rural lands also provide habitat. The kangaroos that can be viewed in a short walk from most suburbs, in the Murrumbidgee River Corridor, at Tidbinbilla, or the southern Namadgi valleys provide a wildlife spectacle that befits the 'Bush Capital'. The presence of these kangaroos is valued by ACT residents and visitors alike.

One of the goals of the kangaroo management plan is to maintain populations of kangaroos as a significant part of the fauna of the 'bush capital' and a component of the grassy ecosystems of the Territory. The scientific knowledge upon which the plan is based, the extensive areas of suitable habitat in reserves, and the concern for animal welfare that underpins the policies in the plan provide a sound basis to realise that goal.

Kangaroos are among the most intensively studied wildlife in the world and there is a vast amount of information about their biology and ecology. It is now well-recognised that in circumstances of good pasture supply and limited predation, like other herbivores, their populations can increase exponentially to reach high densities. This has occurred already in the ACT and the effect on native grassy ecosystems and their component species, some of which are threatened with extinction, can be detrimental. There are also economic and social considerations that derive from having high densities of kangaroos adjacent to urban areas, of which, kangaroo–vehicle collisions are the most obvious. The other goal of the kangaroo management plan, therefore, is to manage and minimise the environmental, economic and social impacts of kangaroo populations on other biota, grassy ecosystems, ACT residents and visitors. This will require ongoing management of the grassy ecosystems and the kangaroos that live in them.

It is for these purposes that this comprehensive kangaroo management plan has been prepared. Kangaroos have a central place in the ACT Government's vision for the grassy ecosystems of the Territory and it is intended that kangaroos continue to be part of the enjoyable, open space experience for ACT residents and visitors.

Jon Stanhope, MLA
Minister for Territory and Municipal Services

Executive Summary

This kangaroo management plan is focussed on eastern grey kangaroos (*Macropus giganteus*); however, the principles it contains are generally applicable to all macropod species occurring in the ACT.

The purpose of the kangaroo management plan is to set out the approach to be adopted in maintaining wild populations of eastern grey kangaroos in the ACT while managing their environmental, economic and social impacts and ensuring their welfare. Particular consideration is given to managing kangaroo grazing pressure on native grassy ecosystems in the context of grazing pressure from all herbivores.

The goals of kangaroo management in the ACT are to:

- **maintain populations of kangaroos as a significant part of the fauna of the 'bush capital' and a component of the grassy ecosystems of the Territory**
- **manage and minimise the environmental, economic and social impacts of those kangaroo populations on other biota, grassy ecosystems, ACT residents and visitors.**

Kangaroos, like many other animals, are an integral part of native grassy ecosystems. However, parts of the ACT have high densities, resulting in a range of impacts, and related animal and human welfare considerations. These issues are not new. They were comprehensively investigated by the (then) ACT Kangaroo Advisory Committee (KAC) in 1996/97. The Committee recommended that an overall kangaroo management plan be prepared for the ACT and its reports and recommendations have assisted the preparation of this plan.

A distinctive feature of Canberra is the extensive areas of grassland, grassy woodland, and dry forest, along with more developed open space that occur throughout the city. These areas include the 'hills, ridges and buffer spaces' separating the different urban areas, as well as the reserves created from the late 1990s to protect highly significant remnants of natural temperate grassland and yellow box – red gum grassy woodland. Many of these areas are ideal kangaroo habitat and important wildlife corridors.

The plan includes the legislative and policy framework for kangaroo management in the ACT. It briefly outlines current knowledge of the biology and ecology of eastern grey kangaroos and discusses kangaroo populations and impacts. It sets out the *principles* that underlie kangaroo management in the ACT and the *general policies* that apply to management issues wherever they might arise. The plan includes policies for managing the environmental impacts of kangaroos in grassy ecosystems, as well as policies for managing economic and social impacts of free-ranging kangaroos. The plan explains the difference between an 'animal welfare' and an 'animal rights' perspective when managing kangaroo populations.

Animal welfare is given a high priority in kangaroo management in the ACT and this is reflected in policies in the plan covering codes of practice (e.g. the *Code of Practice for the Humane Destruction of Kangaroos in the ACT*), care and management of captive populations, kangaroos in the urban area, wildlife carers, and translocation of kangaroos. The ACT has the strictest requirements for licensing of non-commercial kangaroo shooting in Australia. The plan continues the long-standing policy of not permitting the translocation of eastern grey kangaroos as a technique for reducing kangaroo numbers. Human welfare is also given attention especially in relation to human contact with the relatively large urban kangaroo population. The plan contains specific policies for managing kangaroo densities, including the continuation of cooperation between the ACT Government and research institutions in the development of fertility control methods.

Central to the purpose of the plan is the management of kangaroo impacts on native grassy ecosystems. In the published literature on kangaroo or grassland ecology, there is little specific guidance on kangaroo densities that maintain grassy ecosystem condition. However, research in the ACT found that a significant increase in herbage mass was associated with kangaroo densities that are in the range of approximately 0.6 to 1.5 per hectare in grassland areas. These are termed *grassland conservation densities* in the plan. An important basis for kangaroo management in these grassy ecosystem areas is an ecological model of the interaction between weather, kangaroos and vegetation.

The plan contains specific policies for kangaroo management in lowland native grasslands and woodlands. These areas are very important because they contain threatened species and ecological communities and therefore require greater management attention. There are also policies for other ACT Government managed areas of lower conservation value.

The main economic considerations for the plan are in relation to kangaroos on rural lands and the costs of kangaroo–vehicle collisions. Culling of kangaroos on rural leases has been undertaken under a licence system since 1998. The plan provides for the continuation of this along with the strict requirements for a shooter's licence. Kangaroo–vehicle collisions remain an intractable problem as no technique has proved effective in significantly reducing their frequency. The plan outlines the three main categories of mitigation techniques: modifying road attributes; modifying animal behaviour; and modifying driver behaviour. The plan proposes more consideration of fencing and underpasses along high-risk roads. The plan gives close consideration to the question of commercial kangaroo harvesting in the ACT, but concludes that due to a range of significant constraints this will not be pursued in the foreseeable future.

The plan notes that there are entrenched conflicts over kangaroo management in Australia, especially with regard to commercial harvesting. Also, some have expressed concern that harvesting could lead to the extinction of the harvested species. However, the latest edition of *The Mammals of Australia* (2008) shows that all of the harvested species are assessed as being common or abundant.

This kangaroo management plan shows that ACT populations of eastern grey kangaroos are probably greater than at any time during the twentieth century. For example, parts of Namadgi National Park and Tidbinbilla Nature Reserve have exceptionally high densities. In the lowland grassy areas, densities are high and in many areas still increasing. The plan also shows that management approaches need to be tailored to the management objectives of the land in question, and the range of values of that land that need to be protected and managed.

The plan aims to be comprehensive, covering the different categories of land in the ACT, the issues that surround kangaroo management, and the scientific underpinnings for both kangaroo and grassy ecosystem management. In this way it should provide a sound basis for the concerned individual to assess the various claims made about kangaroos and their management in the ACT and surrounding area.

1 Introduction

The eastern grey kangaroo (*Macropus giganteus*) is the most widespread and abundant kangaroo species in the ACT; inhabiting grassland, woodland and open forest habitat.

1 Introduction

Within the Superfamily Macropodoidea (kangaroos and their kin), two main families are recognised: Macropodidae (kangaroos, wallabies, pademelons, tree-kangaroos and others); and Potoroidae (potoroos and bettongs). A third family, Hypsiprymnodontidae, contains only one species (musky rat-kangaroo). All of these are collectively known as macropods and are endemic to Australia and/or New Guinea. Macropods form the largest group of marsupials and range in size from 500 grams to over 90 kilograms. The family Macropodidae is currently recognised as containing at least 62 species and Potoroidae ten species, including extinct species in both families (Van Dyck and Strahan 2008).

1.1 Kangaroos and wallabies in the ACT

Though a larger number of macropod species are known or are thought to have occurred in the ACT in the past, only four species are now naturally present: the eastern grey kangaroo (*Macropus giganteus*), common wallaroo (*Macropus robustus*), red-necked wallaby (*Macropus rufogriseus*), and swamp wallaby (*Wallabia bicolor*). ACT populations (see **Glossary**: Population) of these species are part of much larger distributions in eastern Australia, and across the continent in the case of the common wallaroo. The brush-tailed rock-wallaby (*Petrogale penicillata*), recorded as recently as the late 1950s, is now presumed to be extinct in the ACT and has a sparse distribution across its former range in south-eastern Australia (Van Dyck and Strahan 2008). Some of the potoroids, such as the Tasmanian bettong (*Bettongia gaimardi*) and the rufous bettong (*Aepyprymnus rufescens*) probably occurred in the ACT in the past, but like the rest of the family, these species have decreased dramatically in range and are not found in the ACT today (KAC 1997; Van Dyck and Strahan 2008). Bone deposits from the last 200 years indicate a much more diverse small/medium mammal fauna in the ACT than is currently present (F. Ford, pers. comm.).

In this plan, the use of the word 'kangaroo' refers to populations of eastern grey kangaroos unless specified otherwise. However, the principles (s. 4.2) and the majority of the policies in the plan are generally applicable to all macropod species occurring in the Territory. Most of these kangaroo populations are free-ranging. However, the increased urban development of Canberra has meant that many populations, while described as free-ranging, have their movements constrained in some way. There are also large-area enclosed populations e.g. at Government House (Yarralumla), Belconnen Naval Transmitting Station, and Mulligans Flat Sanctuary.

Distribution and habitat of the macropod species found in the ACT is as follows:

- **Eastern grey kangaroo**: This is the most widespread and abundant kangaroo species in the ACT, inhabiting grassland, woodland and open forest habitat. This habitat is widespread in the ACT, extending from the grassy plains and river valleys to the foothills and broad lower elevation valleys of the western and southern ranges.
- **Common wallaroo**: Habitat is more restricted for the other kangaroo species in the ACT, the common wallaroo. The species is usually found on rocky slopes and adjacent areas, and occurs mainly along the Murrumbidgee River Corridor, Paddys River, and in parts of Namadgi National Park.
- **Red-necked wallaby**: This species is common in a few areas, especially where large areas of forest adjoin grassland that is subject to fox control, but are uncommon overall. Small areas of apparently suitable vegetation, such as parts of Canberra Nature Park, are not occupied by red-necked wallabies.

- **Swamp wallaby**: This species is more solitary than the red-necked wallaby but is more widespread and common in suitable habitat. Swamp wallabies use open grassy areas less, and appear to be better able to persist in small habitat 'islands' such as Black Mountain, where there is a well developed shrub layer in the forest.
- **Brush-tailed rock-wallaby**: This species is presumed to be locally extinct with the last confirmed sighting near Gibraltar Gap in Tidbinbilla Nature Reserve in 1959 (Ormay 1996). A captive-breeding colony is maintained at Tidbinbilla Nature Reserve and has been used to restock depleted colonies in Victoria and New South Wales.

1.2 Status of kangaroos and need for management

1.2.1 Overview

Most of the Australian macropods have suffered significant declines in numbers and/or distribution since European settlement, some to extinction. There has been little adverse effect on the larger kangaroos (red kangaroo (*Macropus rufus*), western grey kangaroo (*M. fuliginosus*), eastern grey kangaroo (*Macropus giganteus*)) (Eldridge 2008). This conclusion is drawn from fifty years of scientific research into the biology and ecology of kangaroo populations and management of the commercial harvesting of some species. There is now a vast amount of scientific information on these species, including distribution and abundance. An overview of this accumulated knowledge can be obtained from Caughley et al. (1987), Coulson and Eldridge (2010), Dawson (1995), Frith and Calaby 1969; Pople and Grigg (1999) and Van Dyck and Strahan (2008). To varying degrees, this scientific information is contested, especially by those with differing values and opposing ethical positions (see, for example, Wilson and Croft 2005).

Eastern grey kangaroos occur across their potential range in eastern Australia at varying densities. In more arid areas away from water and in more intensively developed agricultural and pastoral areas, densities may be particularly low (Poole 1975; Short and Grigg 1982). However, pastoral development has extended the area of suitable habitat (through clearing) and created permanent and more reliable water sources. These factors as well as loss of natural predators and establishment of protected land areas (e.g. national parks) can result in very high local densities.

These densities can have negative effects on the welfare of the kangaroos and other native animals, the maintenance of the ecosystems that form their habitats, the economic viability of rural properties, as well as other economic and social impacts (such as those deriving from collisions between kangaroos and motor vehicles). For this reason, culling programs are conducted or managed by state and territory wildlife agencies for 'overabundant' populations in addition to the commercial harvesting that is undertaken (Coulson 2001, 2008; Pople and Grigg 1999). This concept of 'overabundance' is not universally accepted (see, for example, Croft 2005a). Culling of kangaroos on public lands is often controversial and there is also long-standing organised opposition to commercial harvesting (Australian Wildlife Protection Council 2008; Linden 2005; National Kangaroo Protection Coalition 2008a; O'Brien 2005; Voiceless 2008; Wildlife Protection Association of Australia 2008; Wilson 1999; Wilson 2005).

Ironically, it has been the building of Canberra in the post-war period that has resulted in the growth of large kangaroo populations in the ACT. Up until the 1960s most of the Territory was in rural use and kangaroo populations and densities were low (s. 3.2). Withdrawal of rural leases, establishment of reserves from the 1960s (beginning with Tidbinbilla), and planning that provided for extensive areas of open space in the urban area, all contributed to conditions conducive for eastern grey kangaroos to increase in numbers. From the 1990s recognition that the ACT

retained high quality and relatively extensive remnants of natural temperate grassland and yellow box – red gum grassy woodland resulted in the reservation of large grassland and woodland reserves, particularly in the Gungahlin area (Mulligans Flat, Goorooyarroo, Mulanggari Grasslands, Gungaderra Grasslands, Gungahlin Hill and Crace Grasslands nature reserves), the Jerrabomberra Valley (Callum Brae Woodland Reserve, Jerrabomberra Grassland reserves) and at Dunlop (Dunlop Nature Reserve). Underpinning these land reservations are the ACT Lowland Native Grassland and ACT Lowland Woodland conservation strategies, which incorporate the ACT Action Plans for grassy ecosystem threatened ecological communities and plant and animal species (ACT Government 2004, 2005).

1.2.2 A comprehensive management plan

Kangaroos, like many other animals, are an integral component of native grassy ecosystems. However, parts of the ACT have high densities of eastern grey kangaroos, resulting in a range of environmental, economic, and social impacts, and related animal and human welfare considerations. These issues are not new. A comprehensive investigation was undertaken by the (then) ACT Kangaroo Advisory Committee (KAC) in 1996/97, which made a large number of recommendations, including that an overall kangaroo management plan be prepared for the entire ACT (KAC 1996a: Rec. 1). The Kangaroo Advisory Committee reports and recommendations have been used to guide subsequent kangaroo management in the ACT, and have provided a valuable background for the consideration of current issues. This kangaroo management plan applies to all land in the ACT regardless of tenure.

1.2.3 Scientific knowledge: eastern grey kangaroos

It is important to base kangaroo management in the ACT on a firm scientific base. There are two foundations for this: the first is the extensive research, generally, into the biology and ecology of kangaroos undertaken since the 1960s; the second, more specifically, is the research on eastern grey kangaroos in moister temperate environments (compared with inland and rangeland environments). Much kangaroo research and most population dynamics research has been carried out in the semi-arid rangelands, mainly with western grey and red kangaroos. The ACT Government has supported the first kangaroo population dynamics research in temperate south-eastern Australia, also the first on eastern grey kangaroos (Fletcher 2006a).

Research on eastern grey kangaroos has provided evidence to correct the generalisations often stated about kangaroos, usually based on the biology of the rangelands species. In particular, the breeding patterns in red kangaroos tended to be accepted as the norm for all kangaroos, following their popularisation in the CSIRO film *Birth of the Red Kangaroo* and other media from the mid 1960s.

Other ACT research that has informed this plan includes that on native grassy ecosystems, grassland species, kangaroo fertility control, kangaroo population estimation methods, and macropod grazing impacts on tree and shrub regrowth. This research is referred to throughout the plan. The source documents are mostly publicly available through public and institutional libraries, commercial sources, and websites. The plan contains over 400 references comprising approximately 125 articles in peer-reviewed journals and 115 books or book chapters (mostly from major publishers for which the contents have been through a review process). The remaining references comprise government publications, monographs (including technical reports), consultants' reports, conference proceedings, theses and websites.

While a sound scientific basis is essential for the kangaroo management plan, it is a policy document that covers a range of matters for some of which there is not an established body of scientifically based knowledge at present (e.g. the effectiveness of road warning signs and publicity about the risk of motor vehicle – kangaroo collisions) or which involve ethical considerations (e.g. kangaroo and human welfare) that lie wholly or partly outside of the framework of scientific analysis.

1.3 Purpose and outline of the Kangaroo Management Plan

PURPOSE

The purpose of the kangaroo management plan is to set out the approach to be adopted in maintaining wild populations of eastern grey kangaroos in the ACT while managing their environmental, economic and social impacts and ensuring their welfare. Particular consideration is given to managing kangaroo grazing pressure on native grassy ecosystems in the context of grazing pressure from all herbivores.

GOALS

The goals of kangaroo management in the ACT are to:

- **maintain populations of kangaroos as a significant part of the fauna of the 'bush capital' and a component of the grassy ecosystems of the Territory**
- **manage and minimise the environmental, economic and social impacts of those kangaroo populations on other biota, grassy ecosystems, ACT residents and visitors.**

To achieve the purpose of the plan:

Chapter 1: Sets out why a management plan for eastern grey kangaroos is required in the ACT and outlines key considerations and issues.

Chapter 2: Outlines ACT legislation, land management responsibilities and the relationship of the kangaroo management plan to other plans, agreements and strategies.

Chapter 3: Considers ACT kangaroo management in the broader context of the distribution of eastern grey kangaroos. The chapter outlines the biology and ecology of eastern grey kangaroos and the grassy ecosystems that are their main habitat, as well as kangaroo impacts on those ecosystems. This chapter also includes economic and social impacts.

Chapter 4: Sets out principles and policies to guide kangaroo management in the ACT regardless of land tenure or location.

Chapter 5: Focuses on managing environmental impacts on different land areas in the ACT. The chapter commences with a brief outline of an interactive grazing model for kangaroos in the ACT.

Chapter 6: Focuses on managing economic and social impacts of free-ranging kangaroos with particular consideration of rural lands, horse paddocks, commercial kangaroo harvesting, and vehicle–kangaroo collisions.

1.4 Considerations and issues for the Kangaroo Management Plan

Australia-wide, kangaroos are seen as a national icon and significant part of the fauna, a resource, and a pest (Pople and Grigg 1999). These perceptions are not mutually exclusive and kangaroos (especially the common species) may be seen as all three at any one time. Spanning these three categories, a range of uses, attitudes towards, and perceptions of kangaroos can be identified over time, which are generally applicable today to varying degrees:

- totems and food for Aboriginal people
- scientific curiosity to Europeans (from first settlement until the present)
- a target of hunting for meat and/or 'sport'
- included in a more general disdain for, or lack of interest in Australian wildlife
- agricultural and pastoral pests (along with other macropods)
- a commercial harvestable resource providing meat (for pet food and human consumption) and skins for leather
- part of the experience of wildlife and nature
- an animal central to tourist experiences of Australia
- a traffic hazard
- a national symbol widely used to represent Australia and a symbol for Australian nationalism
- valued intrinsically (i.e. for their own sake), with relationships in kangaroo social structure (e.g. bonding between mothers and young-at-foot) seen in an ethical framework similar to such relationships in humans
- a successful herbivore in the European modified landscape, in which the species is capable of destroying its own grassland resource base and that of other grassland species, some of which are threatened with extinction.

(Australian Wildlife Protection Council 2008; Birrell 1987; Croft 2005b; Dawson 1995; KAC 1996a, 1996b, 1997; Flood 1983; Lindenmayer and Burgman 2002; Mulvaney and Kamminga 1999; National Kangaroo Protection Coalition 2008a; O'Brien 2005; Pople and Grigg 1999; Ratcliffe 1970; RSPCA 2009; Voiceless 2008; Wildlife Protection Association of Australia 2008).

In the ACT, kangaroo populations are an important component of the 'bush capital' imagery of the National Capital and are widely distributed across those areas where people live, work, travel and visit for recreation. Unlike most other urban areas in Australia, there is considerable exposure of the Canberra population and visitors to the eastern grey kangaroo population in the territory. In no other Australian city do so many residents live close to large numbers of free-ranging kangaroos. As well as reserves, there are also other lands that provide suitable and often ideal kangaroo habitat, in particular, rural land, other ACT Government managed land, and extensive areas of Commonwealth controlled land (National Land). To establish baseline information and better understand the attitudes of ACT residents towards kangaroos and kangaroo management, a survey of 600 randomly selected ACT residents was conducted in December 2008 by a market research company contracted by ACT Parks, Conservation and Lands (Micromex 2008). The results of this survey show that a high proportion (82%) of ACT residents values the presence of these kangaroos. Other results of the survey are referred to in relevant sections of the plan (see s. 1.4.3(c) for a summary of some of the main findings).

The ACT is located within the extensive geographic range of the eastern grey kangaroo and has a number of characteristics conducive to the establishment, maintenance and growth of kangaroo populations. In particular, the types of land uses in the ACT and management regimes applying to those areas have resulted in the establishment of large kangaroo populations, which in some instances have high densities in comparison to densities elsewhere (see s. 3.1). Important questions arising from this include:

a) Are the populations and their densities resulting in unacceptable environmental, economic or social impacts or raising animal and human welfare concerns?

b) What is the appropriate or ideal density in a particular location?

The latter has to relate to the management objectives for the land in question and is likely, in any particular instance, to be influenced by a range of factors. The key considerations and issues for the kangaroo management plan are summarised in Table 1.1.

Table 1.1 Considerations and issues for this Kangaroo Management Plan

Environmental	Economic	Social
1 Impact of large kangaroo populations and high densities on grassy ecosystems (in context of total grazing pressure). Impact on: a) threatened grassland communities b) threatened species of grassy ecosystems c) all pastures (overgrazing and soil erosion). ..... **2** Management of free-ranging kangaroos in parks and reserves.	**1** Positive ecotourism benefit and part of National Capital image. ..... **2** Negative impacts: a) rural lands b) other lands c) motor vehicle collisions (injured/dead animals, injury cost). ..... **3** Commercial kangaroo harvesting.	**1** Positive spectacle of free-ranging kangaroos and contact with national icon. ..... **2** Kangaroo welfare (e.g. road injury, inhumane treatment, attacks by dogs, captive populations). ..... **3** Welfare of people (road trauma, kangaroo attacks, controversy over kangaroo management).

1.4.1 Environmental considerations

Though the potential for eastern grey kangaroo populations to reach high densities in suitable environments has been recognised for some time, historically, concerns about this were usually related to assumed impacts on agricultural or pastoral production (Pople and Grigg 1999; Ratcliffe 1970). The Kangaroo Advisory Committee recognised that management of kangaroos (particularly enclosed populations) and other grazers might be necessary in areas containing threatened native species (KAC 1996b).

1.4.1 (a) Excessive grazing pressure

Eastern grey kangaroos are either the dominant or co-dominant herbivores of the grassy ecosystems habitats that they occupy. The other main mammalian herbivores are sheep, cattle and horses (rural lands, horse paddocks, and some agistment on unleased land) and rabbits (across all land uses). Some of these ecosystems are native ecological communities with varying levels of natural integrity (see **Glossary**). With the recognition in the ACT of the threatened status of native grassy ecosystems and their component species and reservation of land to protect grassy ecosystems, concern has grown in recent years about the impact of excessive kangaroo grazing pressure on those ecosystems. The communities and the species within them (some of

which are endangered or critically endangered) may be placed at risk when grazing pressure is too intense. Grazing pressure may also come from rabbits and this has grown as a management issue with the decline in the effectiveness of the Rabbit Haemorrhagic Disease ('calicivirus'). Low rainfall conditions are an important consideration in ecosystem effects, but characteristically the decline in the condition of the pasture precedes the decline in the condition of the herbivore i.e. the herbivore population may appear 'healthy' even though its food source is in severe decline (s. 3.3.8).

Current management needs to take into account the conditions under which various plants and animals in the grasslands evolved but are no longer present today; in particular, dingo and Aboriginal predation of native herbivores, the fire regime, and small-scale soil disturbance by animals such as bandicoots and bettongs (s. 3.5.1). On-going management will always be required to substitute for the elements and processes that are now missing from the system (Braid et al. 2008). Some of the threatened grassland plant and animal species are now restricted to only one or a few scattered populations and are highly vulnerable to adverse changes in their habitat. These changes such as habitat loss through over-grazing have the potential to tip small, isolated populations into local or absolute extinction. Maintaining and restoring the ecological integrity of these grassy ecosystems and therefore habitat for threatened species, as well as other grassland dependent species, is the primary reason for reducing grazing pressure.

Many of the threatened plants and animals in native grassy ecosystems are rare (though they may be locally common), often cryptic and inconspicuous, possess unusual life cycles that result in them being rarely observed, and are little known out of scientific and conservation circles. While there are animal rights campaigns regarding kangaroos (s. 1.4.3(b)), there are no equivalent campaigns for the protection of these small grassland animals, some of which are critically endangered and are the subject of specific conservation management programs.

In recent years, the issue of excessive kangaroo grazing pressure has arisen most notably in relation to three areas where culls were undertaken: Majura Training Area, the decommissioned Royal Australian Naval Transmitting Station at Lawson (commonly and herein, referred to as Belconnen Naval Transmitting Station), and Googong Foreshores. It was also a significant management issue for Tidbinbilla Nature Reserve in the 1990s. There are some less well known areas where excessive kangaroo grazing pressure is a growing management problem including Mt Painter (kangaroo and rabbit grazing inhibiting rehabilitation work); Jerrabomberra Grassland reserves (habitat for grassland threatened species); and Mulligans Flat – Goorooyarroo nature reserves (where experimental kangaroo exclosures were established in 2009 to rest native grasses from grazing pressure and allow seeding).

1.4.1 (b) Can a native species negatively impact on another native species?

The question sometimes arises as to whether a native species can impact on another native species to the extent that this contributes to, or causes extinction. There are many examples of species, aided by human activity, which have increased their population to unsustainable levels, such as deer in North America and Scotland (Côté et al. 2004; Diamond 1992; Hercock 2004; Hone 2007; Porter and Underwood 1999; Watson 1989). It is common for such species, as well as species whose range has expanded, to have undesirable effects on other native species (ACT Government 2004; Goodrich and Buskirk 1995) (s. 3.6.4). The potential impact of excessive kangaroo grazing pressure on remnant native grassy ecosystems and their constituent species in the ACT has become apparent due to the substantial increase in knowledge and understanding of those ecosystems since the early 1990s.

1.4.1 (c)Free-ranging kangaroos in parks and reserves

Free-ranging kangaroo populations in ACT parks and reserves provide a wildlife spectacle (s. 1.4.3) with the management issues varying between different areas. The management plan considers the ongoing management of these populations including those at the reserve–rural land interface.

1.4.2 Economic considerations

The presence of kangaroo populations can have both positive and negative economic impacts. In both instances these impacts are often difficult to quantify. However, for some impacts there is data such as the insurance costs for vehicle damage in collisions or avoidance of collisions with kangaroos. With regard to rural lands, while there is no doubt that kangaroos compete with domestic livestock for food and water, the extent of this impact and the strength and nature of the competition are very difficult to quantify, though across Australia kangaroos are clearly perceived as pests by the majority of primary producers whose land they share (Pople and Grigg 1999, referring to Gibson and Young 1988; Shepherd and Caughley 1987).

1.4.2 (a) Positive economic impacts: nature-based tourism

Kangaroo populations in the ACT including free ranging mobs in parks and reserves (e.g. at Tidbinbilla Nature Reserve and in Namadgi National Park) as well as urban and near-urban populations, all of which are readily observed, contribute to tourist experiences of the National Capital, and may be seen as contributing to the economic benefit of the Territory through nature-based tourism.

1.4.2 (b) Negative economic impacts: rural lands

Kangaroo populations are considered by rural lessees to have a negative impact on the economic viability of rural properties as one of the components of total grazing pressure. Consideration of this economic harm has been factored into a number of previous and current ACT Government policies (provision of rental rebates, construction of electric fences at reserve boundaries, and culling licences). The key issues for rural lessees are competition with livestock for pasture (Shepherd and Caughley 1987) and damage to fences. Other impacts include kangaroo grazing on improved pasture and fodder crops; the potential for land degradation related to over-grazing by livestock, kangaroos and feral animals; and competition with stock for drinking water in drought conditions (Pople and Grigg 1999).

1.4.2 (c) Negative economic impacts: other lands

Kangaroo management may be an issue also on other lands, which include ACT Government managed land, leased Territory Land and Commonwealth managed National Land (see s. 2.2). Some of these areas have high densities of kangaroos, including populations that are enclosed by boundary fences. With regard to the latter, management of the kangaroo population at Government House (Yarralumla) since the early 1990s has shown the long-term benefit of taking action to control kangaroo numbers.

1.4.2 (d) Negative economic impacts: vehicle collisions and collision avoidance

The presence of free-ranging kangaroos along roadsides has a significant economic impact in the ACT due to collisions between kangaroos and motor-vehicles and accidents derived from

collision avoidance (both termed 'collisions' herein). These also have animal welfare and social impacts. Community awareness programs have been run since 2000 aimed at influencing driver behaviour. In addition, advisory signs have been installed at road 'hot spots'. Attendance by a qualified wildlife handler at reported collisions to attend to injured kangaroos is also a significant cost.

1.4.2 (e) Commercial kangaroo harvesting

There is no commercial harvesting of kangaroos in the ACT though the question of whether the animals that are culled (e.g. on rural properties) could be used is sometimes raised. Prior to 2004 the whole of the eastern area of New South Wales and the ACT was classified as a non-commercial zone. However, a trial commercial harvest was undertaken in NSW in the south-eastern part of that zone over a four year period (2004–2007). Subsequently, a new South-East Zone has been included in the *New South Wales Commercial Kangaroo Harvest Management Plan 2007–2011* (NSW DEC 2006). In this context, commercial harvesting is considered in this management plan, primarily in relation to rural lands (s. 3.9.5; s. 6.4).

1.4.3 Social considerations

The fate of individual kangaroos, and the populations of which they are a part, are of great interest to many people whether they are viewed as a pest, a resource or a national symbol to be valued intrinsically. Kangaroo management, therefore, has a social dimension related to human values and ethics and these considerations will always need to form part of any plan to manage kangaroo populations.

Social considerations refer broadly to how the presence of kangaroos in the ACT, interactions with them, and a range of policies and actions regarding kangaroo management affect the well-being of ACT residents and visitors. Some of these considerations directly affect and influence kangaroo management, while others involve conflicts of values that cannot be resolved by the management plan.

Communities in other parts of Australia have also worked on ways to co-exist with resident kangaroo populations; however, plans need to be adapted to local circumstances. In highly modified environments, the conflicts needing resolution may be primarily social and economic rather than having the environmental dimension so important in the ACT (e.g. the community based management plan for kangaroos in Anglesea, Victoria (Inwood, 2006)).

1.4.3 (a) Positive wildlife spectacle

The presence of free ranging mobs of kangaroos, especially in parks and reserves such as Tidbinbilla Nature Reserve, Namadgi National Park and the many reserves close to the urban area, provide a wildlife spectacle and contribute to the enjoyment of visiting those areas. There is strong community support for maintaining such populations (Micromex 2008).

1.4.3 (b) Kangaroo welfare

In response to community concern, governments have legislated over time for animal welfare, covering both domestic and wild animals. The foundation of a concern for animal welfare is that humans are considered to have moral obligations towards animals. The basis of this is that it is considered wrong to treat animals with callous disregard towards their suffering, or to inflict cruelty or unnecessary pain (Passmore 1980).

There are differing ethical positions regarding moral obligations towards animals and this is important in understanding attitudes towards kangaroo management. Of particular importance is the extension of the concept of moral obligations beyond animal welfare to the concept of 'rights' (Passmore 1980; Regan 1976; Singer 1975). The animal liberation movement opposes the human chauvinism of the 'old humanitarian movement' with its focus on cruelty, replacing it with a belief in the 'rights of animals' (Nash 1989). 'Animal welfare' and 'animal rights' share some principles, such as assigning intrinsic value to animals, but an animal rights position stands for the sanctity of the life of individual animals. Under this approach, life should not be taken except where it is the only humane option in the face of overwhelming suffering.

In the ACT context, managing kangaroo populations in native grassy ecosystems is likely to involve a conflict in human values between people who give different emphasis to conservation, animal welfare and animal rights. Conservation is concerned with preserving natural processes and biodiversity; animal welfare is about treating animals humanely and minimising unnecessary suffering caused by human actions; and animal 'rights' involves opposition to the killing of animals. There is legislation on conservation and animal welfare, but the concept of animal 'rights' is not as widely accepted by society or governments.

1.4.3 (c) Welfare of people

The main human welfare considerations are road trauma, occasional reported kangaroo 'attacks', and controversies over kangaroo management.

Road trauma involves injury deriving from vehicle collisions with kangaroos and distress at seeing and feeling responsible for injuries to kangaroos. As well as the distress caused to vehicle occupants and the injury to the kangaroo, there are particular issues for wildlife handlers who attend such incidents, relating to traffic danger and the euthanasia of a large injured animal (s. 4.4.3).

Nationally, there are controversies over kangaroo management policies, but it is difficult to know the active or considered level of support for either prevailing policies or the opposing positions to those policies. Fundamentally these conflicts derive from differences in ethics and values, but knowledge of and beliefs about kangaroo biology and ecology in the context of Australian environments are also pertinent. These conflicts are manifest in the ACT and region to varying degrees, but are more likely to be apparent when particular kangaroo management issues arise. In particular, conflicts relate to policies on:

- commercial kangaroo harvesting (not currently applicable to the ACT)
- culling of 'overabundant' populations
- translocation of kangaroos (e.g. populations subject to habitat loss or 'overabundant' enclosed populations)
- hand-raising of orphaned or abandoned young kangaroos.

There is also disagreement on other matters, such as application of the codes of practice for the humane shooting/destruction of kangaroos and wallabies (s. 2.1.3(a)).

Attitudes of ACT residents to a range of issues associated with kangaroo management were sought in a survey in 2008 (Micromex 2008). The results of this survey indicated that:

- 82% of respondents considered it important to have native kangaroos in the ACT
- 76% of respondents supported kangaroo killing under certain circumstances (the most prominent reason being if the population was too great)

- 57% of respondents supported culling on rural lands
- 52% of respondents would support culling to reduce vehicle collisions (this does not currently occur)
- 53% of respondents would support commercial harvesting in the ACT (this does not currently occur)
- 49% of respondents believed the scenario put forward by grassland scientists that kangaroos can have adverse ecological impacts in lowland grasslands (a high proportion (38%) were unsure)
- 59% of respondents supported kangaroo culling to assist in the conservation of native grasslands.

The survey found that 73% of respondents correctly identified the eastern grey kangaroo as occurring in the ACT but 26% did not know any of the macropod species. Asked where they would take visitors to see kangaroos, the most popular stated destination is Tidbinbilla Nature Reserve (23%) where surveys have recorded that approximately one-quarter of the visitors are from overseas. Other important destinations are Red Hill, Government House, Weston Park and the Royal Canberra Golf Club.

1.5 Need for and intended use of the Kangaroo Management Plan

The considerations and issues outlined above support the need to prepare a comprehensive kangaroo management plan for the ACT. The territory and especially the urban area is no longer the extensive grassy environment it was prior to European settlement and it is not possible to turn the landscape back to what may have existed at that time. Nevertheless, the planning of Canberra has resulted in relatively large areas of bushland and grassland being retained throughout the city and its surrounds. Some of these areas contain grassy ecosystems of high conservation value, which need to be actively managed if they are to retain their natural integrity. This will include management of grazing pressure from all sources so as to retain habitat critical to the survival of the range of grassland species. The urgent and ongoing need for active management of kangaroo densities in lowland grassy ecosystems contrasts with some higher altitude reserve areas, where no or only limited management input appears to be necessary at the present time.

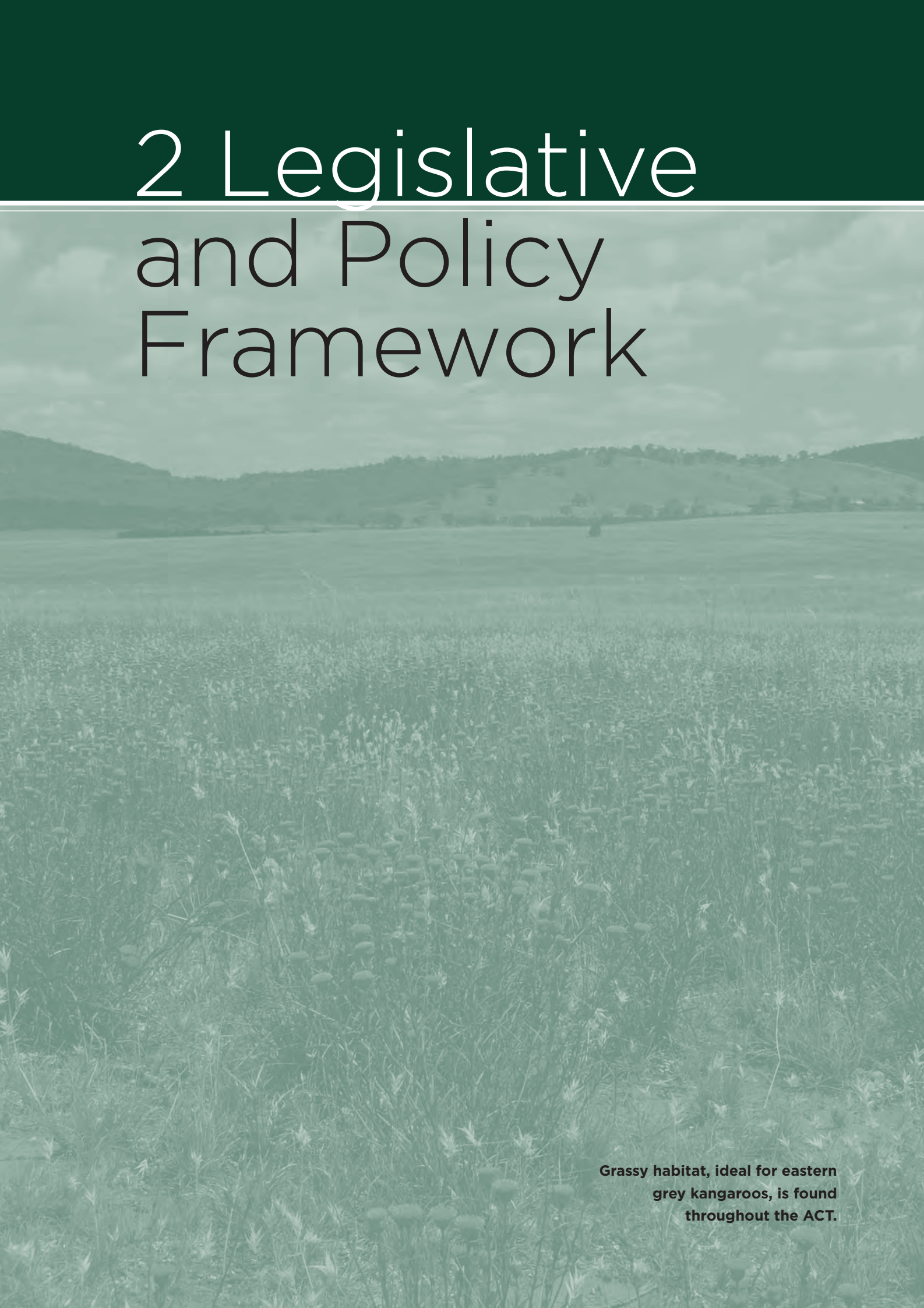
The plan sets out policies for managing kangaroo populations in the ACT regardless of land tenure and recognises that some impacts are widespread and relate to a range of tenures. The plan is also intended for use by land holders and land management agencies in the context of:

- management objectives for various land tenures and land uses
- comprehensive area-based management plans, where these exist, including statutory plans for Public Land prepared under the Planning and Development Act 2007 (see Part 10.4 of the Act)
- other relevant plans or strategies such as the ACT Lowland Native Grassland and Lowland Woodland conservation strategies (ACT Government 2004, 2005).

The kangaroo management plan will serve as a more detailed sub-plan of area-based management plan documents, where these exist.

The kangaroo management plan is a document setting out principles and general policies that apply to kangaroo management issues wherever they arise (Chapter 4), policies related to native grassy ecosystems (Chapter 5), and policies related to economic and social considerations (Chapter 6). It is not practicable or necessary to prescribe the detailed arrangements for kangaroo management on every piece of land in the ACT. For some locations, more information can be obtained from area management plans, such as the plans prepared for Public Land under the *Planning and Development Act 2007*. The plan does not contain the detailed operational procedures necessary to undertake wildlife management generally, and in reserved areas, in particular. Techniques, methods, procedures, protocols, standard operating procedures and codes of practice for field operations are generally well-established and are reviewed, when required, by management agencies.

2 Legislative and Policy Framework



Grassy habitat, ideal for eastern grey kangaroos, is found throughout the ACT.

This chapter briefly outlines the existing framework of legislation, government policy, land tenure, land management, and conservation planning in the ACT that is relevant to this kangaroo management plan. The applicability of the considerations and issues discussed in s. 1.4 to different land categories and particular locations is also outlined.

2.1 ACT Legislation

The kangaroo management plan does not have a direct statutory basis i.e. there is no legislation in the ACT that requires the preparation of such a plan. However, there is legislation that is relevant to both the purpose of the plan and how it would be put into action.

2.1.1 Nature Conservation Act 1980

The *Nature Conservation Act 1980* is the primary legislation for nature conservation in the ACT. The Act provides for the protection and conservation of native plants and animals and appointment of a Conservator of Flora and Fauna. The Conservator may enter land for investigation purposes and may give directions to an occupant of land regarding the protection and conservation of native animals. As a native animal, the eastern grey kangaroo is protected by the provisions of the Act.

In relation to native animals, the following activities are controlled and may not be undertaken without a licence from the Conservator: interference with a nest; killing; taking; keeping; selling; importing/exporting; and release from captivity.

An animal declared a 'pest animal' under the *Pest Plants and Animals Act 2005* is excluded from the definition of 'native animal' under the Nature Conservation Act.

Part 2 of the Nature Conservation Act establishes the ACT Flora and Fauna Committee with responsibilities for assessing the conservation status of ACT flora and fauna and the ecological significance of potentially threatening processes. The Nature Conservation Act (Division 3.4) requires the Conservator to prepare a Draft Action Plan for a declared vulnerable or endangered species or ecological community and for a declared threatening process. Following public consultation an Action Plan may be prepared. Action Plans have been prepared for threatened ecological communities and plant and animal species of ACT lowland grassy ecosystems (ACT Government 2004, 2005).

This kangaroo management plan is not a statutory Action Plan as identified in the Nature Conservation Act, as the eastern grey kangaroo is not a declared threatened species.

2.1.2 Planning and Development Act 2007

The *Planning and Development Act 2007* provides for the identification and reservation of areas of Public Land in the ACT. Reserved areas (e.g. national park, nature reserve) are shown as overlays on maps in the *Territory Plan* (Volume 1) (ACT Government 2008). Management objectives for the categories of Public Land are defined in the Act (Schedule 3) and may be specified also by the Conservator in a plan of management (s. 317). Areas of Public Land must be managed in accordance with the objectives in the Act (Schedule 3) and the plan of management (s. 316).

2.1.3 Animal Welfare Act 1992

The *Animal Welfare Act 1992* is significant legislation in relation to kangaroo management covering acts of cruelty on animals, scientific research, and gazetted codes of practice for management and control of animals.

2.1.3 (a) Code of Practice for the Humane Destruction of Kangaroos

A *Code of Practice for the Humane Destruction of Kangaroos in the ACT* was approved under the provisions of the Animal Welfare Act in 1994 (ACT Government 1994). The code is based on a *National Code of Practice for the Humane Shooting of Kangaroos*, prepared in 1985 and revised in 1990 (CONCOM 1990) (s. 4.4). In 2008, following a period of revision (NRMMC Working Group 2004; NRMMC 2007), two codes of practice were released, that replace the former single national code. These codes separate commercial and non-commercial shooting:

- *National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Commercial Purposes* (NRMMC 2008a)
- *National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes* (NRMMC 2008b).

2.1.3 (b) Other codes of practice in the ACT

Other codes of practice relevant to kangaroo management are:

- *Australian code of practice for the care and use of animals for scientific purposes* (NHMRC 2004)

  (Gazetted under the Animal Welfare Act (DI2005–188))
- *Code of Practice for the Welfare of Kangaroos Maintained Intentionally in Captivity*.

  (Not gazetted under the Animal Welfare Act)

See s. 4.4 for more detail.

2.1.4 Pest Plants and Animals Act 2005

The main objects of the Act are to protect the land and aquatic resources in the ACT from threats from pest plants and animals; to promote a strategic and sustainable approach to pest management; to identify pest plants and animals; and to manage pest plants and animals. The Act provides for the declaration of pest plants and animals and the preparation of management plans.

The *Pest Plants and Animals (Pest Animals) Declaration 2005* (No 1) (DI2005–255) contains a schedule of declared pest animals which does not include the eastern grey kangaroo. The wild rabbit (*Oryctolagus cuniculus*) is included in the schedule. As noted in s. 2.1.1 above, an animal declared a 'pest animal' under the *Pest Plants and Animals Act 2005* is excluded from the definition of 'native animal' under the Nature Conservation Act. The only native animal included in the schedule is *Canis lupus* (wild) (wild dingo/wild dog).

2.1.5 Other legislation

Other legislation relevant to kangaroo management is the *Domestic Animals Act 2000*, in relation to a native animal being attacked or harassed by a dog, and the *Firearms Act 1996* which controls the ownership and use of firearms in the ACT and provides for firearm licences and the registration of firearms. Some legislation may be applicable generally or in certain circumstances, such as the *Occupational Health and Safety Act 1989*, the *Prohibited Weapons Act 1996*, and the *Health Professionals Act 2004* (for veterinary surgeons).

2.2 Categories of land in the ACT

The kangaroo management plan aims to present a holistic approach to management of wild kangaroo populations across all land in the ACT, providing guidance to relevant land managers. The three main categories of land in the ACT relevant to this plan are:

- Territory Land managed by the ACT Government
- National Land managed by the Commonwealth Government
- Leased Territory Land managed by individual and institutional land holders.

The plan is also relevant to the Googong Dam Area (Googong Foreshores) which is Commonwealth land in New South Wales, leased to and managed by the ACT Government.

These categories are briefly outlined below.

2.2.1 Territory Land managed by the ACT Government

a) *Public Land*: This is established under the *Planning and Development Act 2007* (Chapter 10 of the Act). The Act (Schedule 3) sets out management objectives for the different categories of Public Land. These categories are: wilderness area, national park, nature reserve, special purpose reserve, urban open space, cemetery or burial ground, protection of water supply, lake, sport and recreation reserve, and heritage area.

Areas of Public Land are defined in the *Territory Plan* (Volume 1) (ACT Government 2008).

b) *Other ACT Government managed land*: This is land not classified as Public Land but still managed by the ACT Government. It includes existing and former commercial pine plantation areas (some of which, e.g. lower Cotter Catchment, is now Public Land (protection of water supply)), unleased rural land and urban open space, some horse paddock areas, and specific purpose sites outside the urban area.

2.2.2 National Land managed by the Commonwealth Government

This is land in the ACT retained by the Commonwealth and managed by, or the responsibility of, Commonwealth Government agencies. Examples are Belconnen Naval Transmitting Station and Majura Training Area (Department of Defence), and areas around Lake Burley Griffin such as Stirling Ridge (National Capital Authority) and Government House, Yarralumla (Office of the Official Secretary to the Governor-General).

Section 27 of the *Australian Capital Territory (Self-Government) Act 1988*, specifies that the Crown in right of the Commonwealth shall not be bound by an enactment of the Legislative Assembly for the Australian Capital Territory unless a regulation made under the Act provides otherwise. The Australian Capital Territory (Self-Government) Regulations (Commonwealth) identify the *Nature Conservation Act 1980* as a law of the territory that does bind the Crown in right of the Commonwealth. The provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) also apply to National Land. The kangaroo management plan aims to provide guidance for management of kangaroo populations on National Land; however, adoption of its provisions is at the discretion of the relevant Commonwealth land managers. Kangaroo management actions may require a licence under the Nature Conservation Act, therefore the ACT Government has some influence over actions that may be taken by the managers of National Land.

2.2.3 Leased Territory Land managed by individual and institutional land holders

a) ***Rural Leases***: Rural leases are Territory Land held for rural production purposes. The *Planning and Development Act 2007* provides for the preparation of Land Management Agreements (LMA) between rural lessees and the ACT Government. The agreements recognise a duty of environmental care by rural lessees and seek to integrate both production and conservation objectives, linked to more secure tenure. LMAs may contain specific provisions for biodiversity conservation.

b) ***Other ACT Leased Land***: This is Territory Land and includes areas such as golf courses.

2.2.4 Googong Dam Area (ACT managed)

The Googong Dam Area (Googong Foreshores) is Commonwealth land within New South Wales leased to and managed by the ACT Government. A wide range of New South Wales and some Commonwealth legislation applies to the Googong Dam Area. The *Googong Foreshores Draft Plan of Management* (ACT Government 2007b) and the final plan of management (when it is completed) should be consulted for specific details.

2.3 Management plans for Public Land and for Googong Foreshores

Statutory plans of management for Public Land areas and the non-statutory plan of management for Googong Foreshores provide the context for the operation of the kangaroo management plan on those lands.

2.3.1 Public Land

The *Planning and Development Act 2007* (s. 320 (1)) requires the custodian of an area of Public Land to prepare a plan of management for that land. Four of the Public Land categories (wilderness area, national park, nature reserve, protection of water supply) have a management objective to conserve the natural environment. Management plans for such areas provide for the conservation of plants, animals and ecological communities (including special provisions for declared threatened species and ecological communities), control of threatening processes, and may also include consideration of maintenance of ground cover in relation to erosion and sedimentation (especially in relation to water catchments). For Public Land, control of kangaroo populations may be included in management plans in this context. The Public Land category of 'heritage area' has a management objective to conserve natural and cultural heritage places and objects, which may involve similar considerations.

Monitoring of environmental impacts and the potential need for management of native animal populations (inferring or mentioning eastern grey kangaroos) is included in existing management plans for areas with suitable kangaroo habitat e.g. Murrumbidgee River Corridor (ACT Government 1998), Tidbinbilla precinct (ACT Government 2010a), Canberra Nature Park (ACT Government 1999b), and Namadgi National Park (ACT Government 2010b).

2.3.2 Googong Foreshores

It is intended that the provisions of the kangaroo management plan apply at Googong Foreshores in the context of a Googong Foreshores plan of management, in which detailed consideration is given to kangaroo management (ACT Government 2007b).

Given the primary water supply purpose of the foreshores, maintenance of catchment condition is a crucial management consideration. Previous experience has shown that excessive kangaroo grazing pressure, combined with drought conditions, can result in a large volume of organic matter and eroded soil being washed into the reservoir if there is a storm event.

2.4 Declared threatened species and ecological communities

In the ACT, plant and animal species as well as ecological communities may be declared threatened under ACT legislation (*Nature Conservation Act 1980*) (see s. 2.1.1) and/or Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act 1999*). Action plans (ACT) and recovery plans (Commonwealth) are required for declared species and ecological communities. Similar provisions, including preparation of recovery plans, apply under the *Threatened Species Conservation Act 1995* (NSW). All these plans are statutory documents within their jurisdictional context and provide a formal basis for actions directed to the conservation of species and ecological communities, including dealing with threatening processes.

2.4.1 ACT declared threatened species/ecological communities

About 30 plant and animal species and two ecological communities have been declared as vulnerable or endangered under the *Nature Conservation Act 1980*. To integrate where possible the conservation of threatened species with the ecological communities of which they are a part, three nature conservation strategies have been prepared for the ACT. Two of the strategies are based around the ecological communities that are declared endangered: yellow box – red gum grassy woodland and natural temperate grassland (Table 2.1). In Table 2.1 only those birds associated with the grassy understorey of woodland are shown. The third strategy, for ACT aquatic species and the riparian zone, includes two terrestrial species declared threatened under ACT legislation (Table 2.1).

2.4.2 Commonwealth declared threatened species/ecological communities

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the primary Commonwealth legislation for environmental protection. The Act provides for the declaration of threatened species and ecological communities and includes these as *matters of national environmental significance*, for which there are special provisions in the Act in relation to assessment of environmental impact. Species and ecological communities occurring in grassy ecosystems in the ACT that are declared threatened under the EPBC Act are shown in Table 2.1.

The EPBC Act provides for the preparation of recovery plans for threatened fauna and flora (other than conservation dependent species) and threatened ecological communities listed under the Act. The aim of a recovery plan is to maximise the long term survival in the wild of a threatened species or ecological community. Recovery plans are binding on the Australian Government. Once a recovery plan is in place, Australian Government agencies must act in accordance

with that plan. Current recovery plans for EPBC listed species and ecological communities are located on the website of the Department of the Environment, Water, Heritage and the Arts: <http://www.environment.gov.au/biodiversity/threatened/recovery-list-common.html>.

2.5 The ACT Vertebrate Pest Management Strategy

This kangaroo management plan is not based on a premise that kangaroos are a pest in the ACT. It recognises that eastern grey kangaroos, especially when their densities are high, may have negative environmental, economic and social impacts. This focus on impacts accords with the *ACT Vertebrate Pest Management Strategy* (ACT Government 2002), which provides a framework for dealing with vertebrate pests in the ACT. The structured, strategic approach outlined in the strategy is relevant to the management of kangaroo populations. The strategy is non-statutory (i.e. it is not based upon a legislative requirement). While the Vertebrate Pest Strategy is mainly focused on introduced species, it recognises that some native animals can also have negative impacts on conservation and/or rural production values, as well as other social and economic impacts. The basis of a strategic approach to pest animal management is a focus on damaging impacts rather than pest species *per se* (Braysher 1993). A revised ACT Vertebrate Pest Strategy is currently being prepared.

Table 2.1 Grassy ecosystems: ecological communities, plant and animal species declared threatened under Commonwealth and ACT legislation

Ecological community/ species	Common name	Cwlth	ACT	ACT Conservation Strategy
Ecological communities				
Natural Temperate Grassland of the Southern Tablelands of NSW and the ACT		E	E	Grassland Strategy (ACT Government 2005)
White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland[1]		CE	E	Woodland Strategy (ACT Government 2004)
Plant species				
Prasophyllum petilum	Tarengo Leek Orchid	E	E	Woodland Strategy
Swainsona recta	Small Purple Pea	E	E	Woodland Strategy
Arachnorchis actensis	Canberra Spider Orchid	CE	E	
Rutidosis leptorrhynchoides	Button Wrinklewort	E	E	Grassland Strategy
Lepidium ginninderrense	Ginninderra Peppercress	V	E	Grassland Strategy
Muehlenbeckia tuggeranong	Tuggeranong Lignum	–	E (SPS)	Riparian Strategy (ACT Government 2007a)
Diuris pedunculata	Golden Moths	E	–	
Leucochrysum albicans var. tricolor	Hoary Sunray	E	–	
Thesium australe	Austral Toadflax	V	–	
Animal species				
Melanodryas cucullata	Hooded Robin	–	V	Woodland Strategy
Climacteris picumnus	Brown Treecreeper	–	V	Woodland Strategy
Lalage sueurii	White-winged Triller	–	V	Woodland Strategy
Polytelis swainsonii	Superb Parrot	V	V	Woodland Strategy
Petrogale penicillata	Brush-tailed Rock Wallaby	V	E[2]	
Delma impar	Striped Legless Lizard	V	V	Grassland Strategy
Tympanocryptis pinguicolla	Grassland Earless Dragon	E	E	Grassland Strategy

Synemon plana	Golden Sun Moth	CE	E	Grassland Strategy
Perunga ochracea	Perunga Grasshopper	–	V	Grassland Strategy
Aprasia parapulchella	Pink-tailed Worm Lizard	V	V	Riparian Strategy

Note: 1 The White Box component of the community does not occur in the ACT.
2 Considered extinct in the ACT.

CE = Critically Endangered; **E** = Endangered; **V** = Vulnerable; **SPS** = Special Protection Status

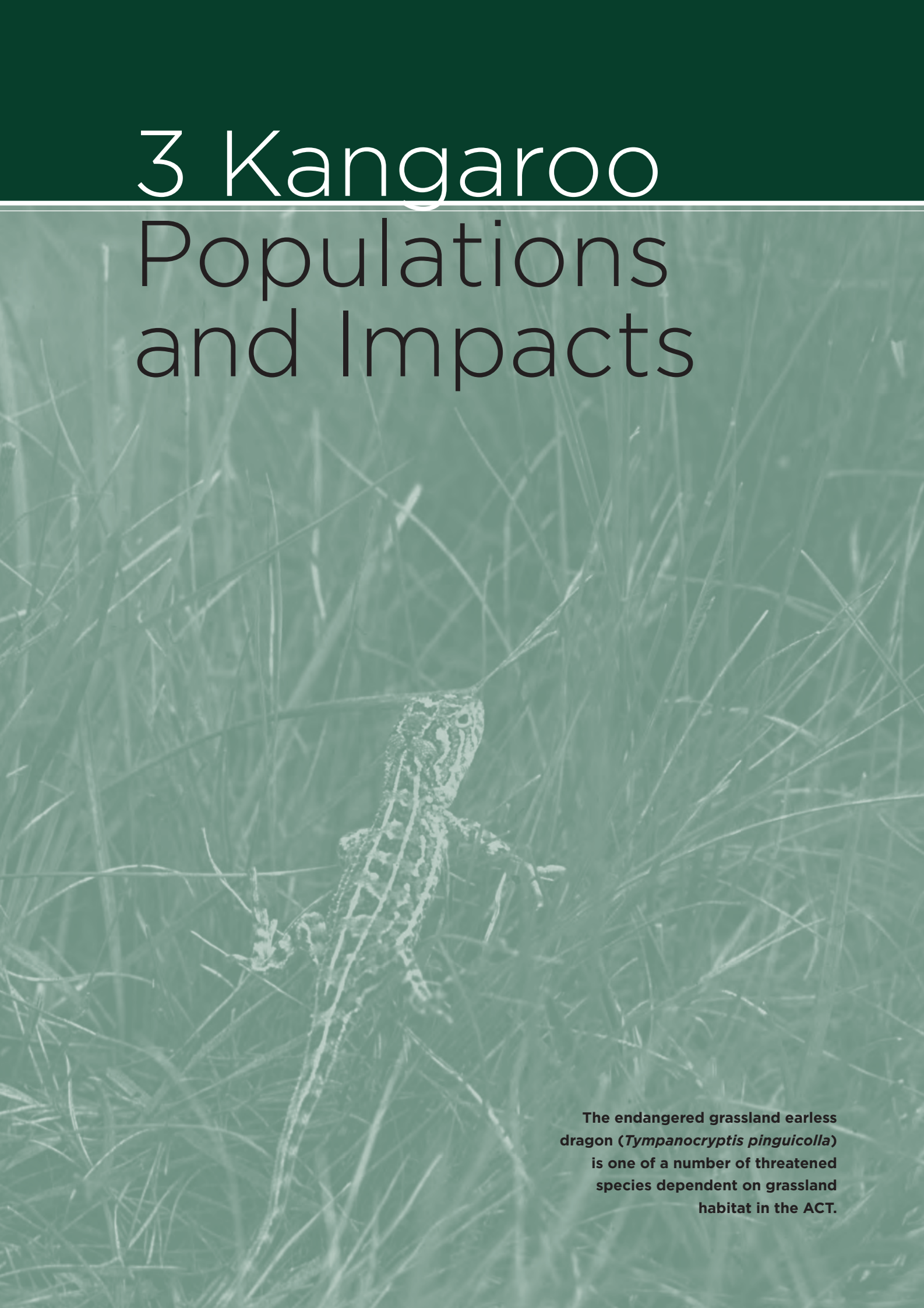
Many of the grassy ecosystem species in the table, as well as others, are declared threatened in NSW and other jurisdictions (see ACT Government 2004, 2005; Environment ACT 2005).

2.6 Management plans for National Land

Preparation of management plans for areas of National Land is the responsibility of the Commonwealth Government agencies managing particular areas. A number of National Land areas contain lowland native grassland or grassy woodland. The largest and most significant grassland areas containing kangaroo populations are at the Majura Training Area (in the Majura Valley north of Canberra Airport) and the Belconnen Naval Transmitting Station (Belconnen). Various management planning documents have been prepared for the different National Land areas (e.g. Environmental Resources Management Australia 2008a, 2008b).

Memoranda of Understanding (MOUs) have been signed between the relevant Commonwealth agencies (Department of Defence, CSIRO and the National Capital Authority) and the ACT Government aimed at achieving co-ordinated conservation strategies for threatened species and ecological communities in areas that they manage. The MOUs do not detail specific management issues and actions (such as kangaroo management) but include provisions for implementing or modifying land management practices. This includes minimising fragmentation and degradation of natural habitat, controlling degrading processes such as weed invasion and pest animal activities, and rehabilitating degraded areas. Grazing pressure is an obvious factor to be considered in this context.

3 Kangaroo Populations and Impacts



The endangered grassland earless dragon (*Tympanocryptis pinguicolla*) is one of a number of threatened species dependent on grassland habitat in the ACT.

3.1 ACT kangaroo management in context

The ACT is a relatively small area within the broader distribution of the macropod species currently present in the territory. The most recent Australia-wide assessment of the distribution and abundance of those species is shown in Table 3.1 using information provided by contributing authors to *The Mammals of Australia*. 3rd Edition (Van Dyck and Strahan 2008). Two of the species, the eastern grey kangaroo and common wallaroo, are included in the Australian commercial kangaroo harvest (which does not include the ACT). Their numbers within the commercial harvesting zones are monitored yearly as a basis for setting annual quotas, in accordance with the management plans established under the EPBC Act (DEWHA 2009a).

Table 3.1 Australia-wide distribution and abundance of kangaroo and wallaby species presently occurring in the ACT

Species	Distribution	Abundance[1]
Eastern grey kangaroo (*Macropus giganteus*)	Cape York to eastern Tasmania, central and south-western Queensland, all of NSW, all of Victoria except the north-west, eastern and south-eastern South Australia[2].	Abundant (Coulson 2008)
Common wallaroo (*Macropus robustus robustus*)	Species has Australia-wide distribution. Four sub-species recognised. *M. r. robustus* occurs on the eastern and western slopes of the Great Dividing Range from north-eastern Victoria/southern NSW to at least as far north as Cooktown Qld.	Common. Can be locally abundant. (Clancy and Croft 2008)
Red-necked wallaby (*Macropus rufogriseus*)	East and west of the Great Dividing Range from north-eastern Victoria/southern NSW to Gladstone Qld, Tasmania, south-eastern South Australia, coastal and south-western Victoria.	Common to abundant. (Jarman and Calaby 2008)
Swamp wallaby (*Wallabia bicolor*)	East and west of the Great Dividing Range from south-western Victoria to Cape York, further inland in the southern Qld brigalow belt.	Common (Merchant 2008)

Notes: 1 See **Glossary** for definition of abundance.
2 The limited distribution and need for conservation of the south-eastern South Australian population was described by Poole (1977). Eastern greys have expanded their distribution into the arid zone but their westward spread into South Australia is limited by the dog fence.

Important factors in the maintenance of populations of these species are:

- The larger and most generalist species of macropods, with the most robust resource base, have the best prospects of survival.
- Monitoring of population numbers of the commercially harvested species over almost thirty years shows an enormous capacity for population recovery after drought and consequent pasture decline e.g. a national population that had declined to about 16 million in 1984 during the drought had risen to about 34 million in 1991 (Pople and Grigg 1999).
- Though the range of two species (eastern grey kangaroo and common wallaroo) extends into more arid areas, they occur in the highest rainfall bioregions, where mammal persistence is generally higher.
- Predation threat, especially by the dingo, has been removed over large areas.
- Some species have the ability to subsist on vegetation of relatively low quality (e.g. common wallaroo).

- There are extensive areas of habitat comprising forest, woodland and heath in reserves, pastoral land and areas unsuitable for agriculture, often with other suitable habitat features such as rocky foothills (common wallaroo, red-necked wallaby, swamp wallaby). Partial clearing of some areas is likely to have extended the area of suitable habitat for the red-necked wallaby.
- Partial clearing of forest, woodland, shrubland and heathland for agricultural and pastoral purposes combined with the provision of more permanent water supplies are considered to be significant for the persistence of an abundant population and an expansion in range (to more arid areas) of the eastern grey kangaroo. Clearing extends the area of grassland and other edible vegetation while retaining the cover used for protection from sun, wind, rain and predators.

(Caughley et al. 1980; Caughley et al. 1984; Hume et al. 1989; Land and Water Australia 2002; Pople and Grigg 1999; Van Dyck and Strahan 2008)

The ACT is located within the extensive geographic range of the eastern grey kangaroo and has a number of characteristics conducive to the establishment, maintenance and growth of kangaroo populations. A large proportion (over 70 per cent) of the territory is reserved Public Land or other government managed open space land (s. 2.2.1). Most of these lands are undeveloped or minimally developed, though many areas had pastoral, some agricultural and other uses in the past and various uses continue. There are also extensive areas of relatively undeveloped National Land (s. 2.2.2). Suitable kangaroo habitat, combining open grassland and adjacent woodland and/or forest cover, extends throughout these areas, from the lower elevation grassy valleys in Namadgi National Park to the lowland grasslands, grassy woodlands and open forests of the plains, hills and ridges, and river corridors. A significant area of the ACT is held under rural lease and, together with other leased land such as golf courses (s. 2.2.3), provides suitable, often ideal, kangaroo habitat.

3.2 Determining kangaroo densities

Measuring the density (number per unit area) (see **Glossary**) of a population of an organism is one of the perennial challenges in ecology and has attracted considerable attention in relation to kangaroos, especially for those species that are commercially harvested. Methods used to count kangaroos are outlined in Appendix 1, because some important decisions in this plan depend on estimates of kangaroo density. Also, the history of contention about kangaroo management in the ACT has included much disagreement and misunderstanding about how many kangaroos there are (e.g. see ACAT 2009). Australian ecologists have used six main methods to estimate kangaroo density: spotlight count (density index); direct observation counts (for small areas); sweep or drive counts; distance sampling or line transect methods (including helicopter line transects); faecal pellet surveys; and aerial strip surveys.

Kangaroo numbers in Australia at the time of European settlement are not known and there are divergent views about the size of, and changes in, kangaroo populations over the following centuries (Auty 2004; Barker and Caughley 1992; Eldridge 2008; Croft 2005a; Pople and Grigg 1999). Historical reports of kangaroo abundance, for example, by first European explorers, early settlers, and later pastoralists, are not reliable indicators of abundance in the modern context. Most scientists accept the proposition that eastern grey kangaroos have expanded their range inland, while tree clearing and pasture establishment in temperate areas such as the ACT have made rural lands ideal kangaroo habitat. Densities at any one time in a particular location relate to environmental conditions, local kangaroo movements and management regimes.

Historical and oral accounts described kangaroo numbers in the ACT as being in 'plague' proportions in the latter part of the 1800s, when kangaroo and wallaby drives were carried out and states introduced bounties. There is no way of determining what these densities were. In the mid-1900s, most of the ACT was still in pastoral use and kangaroos were considered relatively uncommon due to widespread shooting to reduce perceived competition with sheep, provide food for dog packs, to reduce damage to fences and for recreation. From the 1950s, biological, cultural and economic changes reduced the need, incentive and ability of ACT graziers to control kangaroo numbers. The economic importance of rabbit fences declined rapidly after the spread of myxomatosis. There were fewer farm labourers (therefore, fewer guns and dogs), more intensive pasture improvement, rural land withdrawals and conversion of the land to leasehold (KAC 1996a). Sharp increases in local kangaroo populations were noticed from the 1960s to the 1990s, especially in reserve areas, some of which border rural leases and provide a reservoir of animals that can move out to graze on adjacent pastures.

The first credible estimate of kangaroo densities in the ACT was by prominent herbivore ecologist Graeme Caughley in 1983 who visually estimated a density of 200 kangaroos per square kilometre (2 per ha) at Tidbinbilla Nature Reserve, surprisingly close to the more rigorous later estimates. In the 1980s and 1990s, Perry and Braysher (1986) estimated kangaroo densities in reserves and on ACT rural properties for rental rebate purposes, from the density of faecal pellets.

Between 1995 and 1999, line transect methods were used to estimate kangaroo densities in reserve areas and Googong Foreshores. These areas showed densities in the range from 1.9 to 3.7 per hectare (190–370 per km^2) (Freudenberger 1996; KAC 1997; Muranyi 2000; Nelson 1996). In a survey of three reserve areas between 2001 and 2003, Fletcher (2006a) found densities in grasslands between 4.5 and 5.1 per hectare (450–510 per km^2). These are among the highest recorded in Australia and compare with almost 0.56 per hectare (56 per km^2) for a mix of eastern grey and red kangaroos at Kinchega (Bayliss 1987) and 2.2 per hectare (220 per km^2) for eastern grey kangaroos at Yan Yean Reservoir, near Melbourne (Coulson et al. 1999). Relatively high densities have been recorded also in favourable environments such as in and around golf courses e.g. 3.6 to 4.1 per hectare at Anglesea, Victoria (Catanchin 2005; Inwood 2006). Inside the 1.1 km^2 fenced area at Belconnen Naval Transmitting Station, kangaroo density was 5.6 per hectare before a cull undertaken in 2008. At the Majura Training Area, in May 2008, the density reached 3.3 per hectare over the whole site, including 5.3 per hectare in the grassland section (unpublished data, Department of Defence).

The densities in ACT reserves are considerably higher than on ACT rural leases where culling occurs. Between 1995 and 1997, densities of 0.39–0.59 per hectare (39–59 per km^2) (see Appendix 5) were estimated on ACT rural leases (KAC 1997) and provided evidence in support of the arguments being put forward by rural lessees for culling. Densities on rural land in New South Wales surrounding the ACT in 2003 and 2006, based on helicopter line transects methods, were 0.12 and 0.14 kangaroos per ha (12 and 14 per km^2) respectively (Cairns 2004; 2007). However, helicopter line transect surveys underestimate kangaroo density compared to walked line transect surveys (Clancy et al. 1997).

Examples of kangaroo density estimates for the ACT and elsewhere are shown in Appendixes 5 and 6.

3.3 Biology and ecology of eastern grey kangaroos

Despite early introduction of both live and museum specimen of kangaroos into Europe in the early years following European settlement of Australia, little was known of kangaroo biology other than external and cranial morphology. A gestation period (38 days) was determined from one female *Macropus giganteus* in Regent's Park Zoo (London) in 1830. Interest in developing a scientific (as opposed to anecdotal) understanding of the biology and ecology of eastern grey kangaroos was spurred from the late 1950s. This was driven by the conflict between pastoral and conservation interests; concern that the species could be under threat; and with the development of commercial harvesting, the recognition that such knowledge was needed to form the basis for credible species management (Dawson 1995; Ratcliffe 1970). Research over subsequent decades, especially for the harvested species of kangaroos, has resulted in them being among the most intensively studied wildlife species in the world (Southwell 1989). There is a vast amount of information about their biology in general and their ecology in particular (Grigg et al. 1989; Pople and Grigg 1999; van Dyck and Strahan 2008). It is now known that while the various macropod species share marsupial characteristics, there are subtle differences between them including in their reproductive biology. Historically, significant attention has been given to kangaroo population dynamics in the arid and semi-arid zones of the continent. However, much of this is also relevant to the moister temperate areas. There is now also a substantial literature on temperate zone eastern grey kangaroos. The initial modern study of the taxonomy and distribution of the grey kangaroos was undertaken using animals taken from sites throughout their individual ranges (Kirsch and Poole 1972). This investigation supported a primary division of grey kangaroos into an eastern (*Macropus giganteus*) and western (*M. fuliginosus*) species.

3.3.1 Evolutionary history

The fossil record suggests a 50 million year evolutionary history for modern kangaroos, with the tendency to giant size (mega-fauna) being the outstanding feature of the Pleistocene (1.8 million to 10 thousand years ago) (Dawson 1995; Flannery 1994; Hume et al. 1989; Archer et al. 1991). Adaptations for an herbivorous diet are evident in the fossil record, crucial to the later success of the kangaroos (Dawson 1995). As the Australian continent dried out, macropods evolved and occupied a wide range of habitats, but were favoured particularly by the spread of grasslands (Dawson 1995). Humans and many mega-fauna species co-existed in Australia for a period in the Pleistocene. For how long is not clear, though Mulvaney and Kamminga (1999) suggest at least 10 000 years. The roles of natural and/or human induced environmental changes and over-hunting by Aborigines in the demise of the mega-fauna are the subject of debate (e.g. Flannery 1994; Mulvaney and Kamminga 1999).

Mitochondrial DNA shows a clinal distribution (see **Glossary**: Cline) of eastern grey kangaroos along a north-south axis, from north Queensland to Tasmania. The genetic data do not support a sub-specific distinction between the nominate mainland taxon *Macropus g. giganteus* and a Tasmanian form, previously recognised as *Macropus g. tasmaniensis* (forester kangaroo) (Van Dyck and Strahan 2008; Zenger et al. 2003).

3.3.2 Social structure and movement patterns

Eastern grey kangaroos are relatively gregarious. A mother and her young of recent years make up the core unit (Dawson 1995). Individuals that share a feeding patch may form fluid groups of two to twenty or more depending on local population density. These temporary groups may

combine into a larger social unit, known as a 'mob' or 'aggregation', which is composed of up to 50 individuals that meet each other frequently (Caughley 1964a; Coulson 2008; Jarman and Coulson 1989). This is not a stable grouping, as individuals move in and out of aggregations randomly and continually (Dawson 1995; Southwell 1984a, 1984b, 1987). Large mobs are formed by the coalescence of smaller family units (females and recent young) and the transient association between males and females in oestrus. Adult males and juveniles are irregularly distributed among mobs (Kirkpatrick 1966; Poole 1982a).

Most kangaroo species are fairly sedentary, with groups occupying a persistent home-range rather than being migratory or nomadic (Hume et al. 1989; Viggers and Hearn 2005). However, inland red kangaroos can undertake significant movements in search of better food (Dawson 1995; Olsen and Low 2006). Home-ranges refer to the areas covered by kangaroos in their normal activities of feeding, mating and caring for young. These are not 'territories' as they do not appear to be defended (Dawson 1995). Home ranges for eastern grey kangaroos have been identified from a small number of ecological studies (e.g. Kaufmann 1975; Jarman and Taylor 1983; Johnson 1989; Jaremovic and Croft 1991), but comprehensive information is lacking. Home ranges of ACT kangaroos have been measured by radiotelemetry at Googong, Tidbinbilla and a rural property on the Cotter Road (Viggers and Hearn 2005). Most telemetry studies have been for short periods (often one year) compared to the life span of kangaroos. The few longer observations suggest that females usually have strong site fidelity, living out their lives close to female relatives, while males range more widely.

Contrary to the telemetry studies, genic and genotypic studies reveal weak genetic structure of populations on both a local (<50 km) and regional scale (50–230 km), from which high levels of dispersal may be inferred, up to 230 km. The observed range length increases with the size of the animal, but is generally less than 20 km (Zenger et al. 2003). Home ranges of individual eastern grey kangaroos overlap the ranges of other individuals. These ranges vary in size from 30–160 hectares in southern Victoria to areas about ten times larger in semi-arid western New South Wales (Coulson 2008). Home ranges are influenced by food supply and environmental conditions and not all areas in a home-range are used equally (Dawson 1995).

Eastern grey kangaroos have a pattern of movement related to feeding, leaving their cover to feed in open grassy patches. Individuals typically emerge two or three hours before sunset and feed through the night, then return to cover an hour or two after sunrise, although this pattern is modified by extremes of rain and temperature (Coulson 2008). Kangaroos are more likely to seek cover in the middle of the day in hot dry conditions typical of the inland, but in more temperate environments will often remain in the open throughout the day (Dawson 1995; Fletcher 2006a).

When feeding in the open, eastern greys are vulnerable to predators such as dingoes/wild dogs and domestic dogs that hunt by running their prey down and also to foxes which kill young-at-foot (Banks 2001; Banks et al. 2000). To counter this threat, they form groups, thereby reducing the risk to each individual and allowing individuals to devote more time to feeding instead of scanning for danger (Colagross and Cockburn 1993). The presence of predators results in kangaroos limiting their potential grazing opportunities (predation sensitive foraging) and this can be an important limiting factor for affected kangaroo populations (Banks 2001; Fletcher 2006b).

3.3.3 Reproduction

The reproductive cycle of macropods is remarkable in the capacity to rapidly replace young which may be lost and this means that populations can recover quickly from adversity (e.g. drought conditions). Though species vary in this regard, there is the capacity to have three young

simultaneously at different stages of development: an embryo (blastocyst; see **Glossary**) in diapause (development suspended); one pouch young; and one young-at-foot. The latter two will be suckling milk of different composition, from different teats, simultaneously (Pople and Grigg 1999). These reproductive characteristics give macropods the ability to respond to the variable climatic regimes that are typical of the Australian environment. It is important to recognise that there are variations in the patterns of macropod reproduction peculiar to particular groups of species and that the pattern for the much-publicised red kangaroo is not the norm for all species. These variations were reported as early as 1966 (Sharman et al. 1966).

Kangaroos are typical marsupials in that gestation is short, typically 30–35 days. The embryo is born at an early stage of development in comparison to placental mammals and must find its way to the pouch and one of four teats for further development to occur. This means that kangaroos expend far less energy in reproduction than do placentals, for which so much of the reproductive cost is pre-natal. Unfavourable environmental conditions may lead to abandonment of the young at this early embryonic stage, before the maternal energetic investment has become too high (Pople and Grigg 1999).

The basic pattern of reproduction in female kangaroos was described in detail by Sharman et al. (1966). An understanding of the reproductive biology of grey kangaroos was established in the 1970s by the research of WE Poole and co-workers at the CSIRO. Unlike the desert kangaroos which are opportunistic breeders, the grey kangaroos are seasonal breeders (Poole 1973, 1982a; Tyndale-Biscoe 2005). In eastern grey kangaroos, mating is in response to the female oestrous cycle and can occur at any time of the year, but is most common in spring and early summer and there is a peak in births in summer. In the ACT region, in late September and early October typically 80 per cent or more of females have pouch young large enough to be easily observed. Oestrus least often occurs in winter when, depending on the severity of seasonal conditions, up to 65 per cent of females may be without pouch young and in anoestrus (Poole 1973, 1982a). This seasonal pattern is strongest in southern Australia (Coulson 2008; Fletcher 2007a; Poole 1975; Pople and Grigg 1999). There is a corresponding emergence of pouch young in spring, the most favourable time of the year. Eastern grey males reach reproductive maturity at about 4 years old, which is older than for the rangeland species. Females are sexually mature from about 18 months; the oestrous cycle is 46 days (45.6 + 9.8 SD), and the gestation period 36 days (36.4 + 1.6 SD) (Dawson 1995; Poole 1973, 1975; Pople and Grigg 1999).

Unlike the red kangaroo and the common wallaroo, post-partum (birth) mating does not occur for the eastern grey kangaroo (Poole 1973), so the presence of a quiescent blastocyst is uncommon, though occasionally found. This means that there is a longer delay for the eastern grey in replacing any pouch young which may be lost. Female eastern greys return to oestrus within a mean time of 10.9 days (10.9 + 4.8 SD) hence birth may occur about 47 days (36 + 11 days) after the loss (Poole 1982a). Red kangaroos have a shorter delay by carrying a blastocyst, which has developed for about 4 days, so are capable of giving birth about 29–30 days later (normal gestation 33 days less about 4 days). Under exceptionally favourable conditions, a female eastern grey can mate when the pouch young is about six months old (or earlier in some instances), with the resulting embryo remaining quiescent due to lactational inhibition, as commonly occurs with red kangaroos (Tyndale-Biscoe 1989). The embryo recommences development to be born immediately after final pouch exit by the previous young, at about 10–11 months of age, or if the pouch young is prematurely lost (Dawson 1995).

3.3.4 Fecundity

In population ecology, fecundity refers to the rate of production of offspring (see **Glossary**: fecundity). One of the widespread assumptions about the biology of eastern grey kangaroos in temperate Australia is that they rapidly control their fertility and stop breeding at the onset of drought. This may have arisen from the generalisation of information about the biology of red kangaroos undergoing harsh droughts in central Australia and the rangelands to cover all kangaroo species. The evidence suggests that temperate eastern grey populations are able to remain extremely fecund even during droughts (Fletcher 2006a, 2007a). Fecundity can be reduced in temperate eastern Australia when exceptional conditions result in the deaths of many adults due to starvation. This has been observed on Maria Island in Tasmania and at Googong Foreshores in 2004, during the 'crash' phase of a herbivore irruption (s. 3.4.4; Figure 3.2), with the pouch young having died in a proportion of the surviving females. Under drought conditions females may gradually cease lactation and young die. Depending on the individual animal and the severity of the drought, some females will return to oestrus in about 10 days, others may remain in anoestrus, even until the next spring (Poole 2009).

Age-specific fecundity records for eastern grey kangaroos from Queensland (Kirkpatrick 1965a) and the ACT (Fletcher 2007b) are almost identical. Almost 70 per cent of 2-year old females produced young, increasing to almost 100 per cent of five and six-year olds, then declining until only about half of the very old females produced young. Overall, eastern grey fecundity levels in the ACT are very high. For example, Fletcher (2006a) gives estimates of annual production of late pouch young at Gudgenby (0.886 + 0.041 SE per female) and at Tidbinbilla (0.783 + 0.058 SE per female) and similar rates have been reported on a number of sites outside the semi-arid zone. Such high fecundity, even in dry years, shows that the *per capita* food shortage associated with high density kangaroo populations in the ACT does not affect either fertility or the survival of pouch young to a degree that might limit the population. In stable populations, such as at Gudgenby, mortality (equal to the high fecundity) must occur after birth to balance the gains and losses to the population (see s. 3.3.5 and s. 3.3.7 below). The high fecundity at high density and low food availability reported for eastern grey kangaroos in the ACT contrasts with the situation for red kangaroos and western grey kangaroos in arid and semi-arid areas, where up to 85 per cent of females have been found in anoestrus in drought conditions (Shepherd 1987).

3.3.5 Development and survival of young

Development of the young in eastern grey kangaroos progresses through a number of stages with the period from birth to weaning being about 540 days (almost 18 months). This is about 180 days longer than for red kangaroos (Poole 1975, 1982a; Sharman et al. 1964). At birth the 800 milligram (0.8 gm) naked and blind neonate climbs to the pouch and attaches to a teat from where it grows rapidly. The first exit from the pouch occurs around 283 days (283 + 24 SD) or 9.3 months and during the 'in-out' period, the pouch young grows rapidly and from the pouch begins eating grass. By the time of permanent exit at 319 days (319 + 18 SD) or 10.6 months, the young-at-foot is 4–5 kg. After permanent emergence from the pouch, the young-at-foot continues to suckle from its usual teat for another 7–8 months or longer, but the level of suckling decreases as the young takes more herbage. No marked change in the relationship between mother and young occurs at weaning. A close association usually continues until sexual maturity, when males tend to leave their mothers. Young male kangaroos usually disperse from their mother's home range one or two years after weaning. While females wander, many set up home ranges near their mother and may remain part of the same aggregation (Dawson 1995).

There is a high mortality of young kangaroos prior to breeding age, which is influenced by seasonal conditions. Approximately 50 per cent of young failed to live to independence in southern Queensland (Kirkpatrick 1965a). A mortality rate of 1.82 per cent per 28 days was estimated for sets of pouch young through the age range of 113 to 280 days in central New South Wales (Poole 1973, 1982a). Most of these losses occurred within the first few days after birth. Deaths also resulted from accidental injury and coccidiosis (infection of protozoan parasites) in the first month after leaving the pouch (Poole 1975). Over a three year period at Yan Yean (Victoria), 80 per cent of the natural deaths surveyed (324 skulls out of an estimated 640 deaths in total) were of kangaroos aged less than three years (Quin 1989). The initial die-off occurs between permanent pouch exit and weaning and continues until the animals are about three years old. While about half the females die before breeding age, the proportion is much higher for males. The reasons for this are unclear (Dawson 1995). This sub-adult mortality is the main regulator of population size in ACT populations (Fletcher 2006a) and this is suspected to be true more widely (Dawson 1995).

Many young kangaroos are killed by predators (foxes, dingoes, eagles); however, food supply has more often been considered to be the main limiting factor. Sub-adults have high energy needs. In red kangaroos, sub-adults have 1.8 times higher digestible energy intakes than non-lactating females on high quality food (Munn and Dawson 2003). The difficulty of meeting this demand, in competition with other members of the population, results in a disproportionately high death rate of this demographic class when food is in short supply or pasture is of poor quality (Fletcher 2007a). Young kangaroos in crowded populations are also susceptible to heavy loads of gastric nematodes during cold weather when mortality is highest (Coulson 2008; Fletcher 2006a).

3.3.6 Food sources

Eastern grey kangaroos are specialised grazers, with particular physiological features to deal with their abrasive and fibrous grass diet. These features include molar progression to counteract their abrasive diet and complex stomachs for slow fermentation of fibrous material (Coulson 2008). Grasses and sedges have been found to constitute up to 99 per cent of their diet (Jarman and Phillips 1989), and this may comprise both native and/or introduced grass species (Dawson 1995; Fletcher 2006a). Small quantities of other materials such as tree and shrub seedlings, forbs, ferns, bark and agricultural crops may also be consumed (Coulson 2008; Webb 2001), but eastern grey kangaroos are not generally browsers in their normal habitat. In temperate environments such as the ACT, they eat mainly green grass and few forbs, so green grass herbage mass (see **Glossary**) may be an important consideration in kangaroo grazing. Green grass and fresh shoots are preferred to rank dry grass; however, kangaroos in high density populations will eat almost all available herbage, especially in drought conditions. Where there are high density populations, nutritious grass is in short supply by the end of winter with the result that a high proportion of sub-adults do not survive (Fletcher 2006a). Faecal Near Infrared Reflectance Spectroscopy (FNIRS) of kangaroo faeces may become a useful tool to non-invasively determine the nutritional status of kangaroos and relate this to herbage mass (Billing 2007).

3.3.7 Mortality

The relative importance of different mortality factors for kangaroos has changed over time and varies today according to the geographical location of populations. Essentially there are three causes of mortality: a) lack of nutrition; b) predation (including human actions that reduce population numbers); and c) disease. Like many herbivores, once kangaroos reach sexual maturity, they enjoy a relatively high survival rate (Fletcher 2006a). Dawson (1995) notes that males older than 10 years are rare in the wild with the greatest age of kangaroos taken in the field

being estimated at about 20 years (Kirkpatrick 1965b). There may be higher survivorship in older age classes where populations are not heavily culled or predated (e.g. some ACT reserve areas) (Fletcher 2006a).

The importance of nutrition for sub-adult kangaroos has been discussed above. In the ACT the mortality of eastern grey kangaroos is concentrated in late winter and early spring, and the evidence suggests that the ultimate cause of this is starvation. Parasites, hypothermia, pneumonia, other diseases and predation contribute to this mortality as proximal causes (Fletcher 2006a).

Kangaroos evolved with predators some of which existed until relatively recently or are still present: the marsupial lion (*Thylacoleo carnifex*) in the Pleistocene; the thylacine (*Thylacinus cynocephalus*); Tasmanian devil (*Sarcophilus harrisii*) and the dingo (*Canis lupus*) (Robertshaw and Harden 1989). Hunting by Aborigines, European hunting, culling, commercial harvesting and accidental death through vehicle collisions may be considered as forms of, or equivalent to predation. The flight response of kangaroos is positively related to the likelihood of collisions with vehicles, implying that flight by kangaroos may not be an effective defence against vehicles (Lee et al. 2010). The importance of predation sensitive foraging, rather than simply direct predation, in limiting kangaroo population numbers has been noted previously (see s. 3.3.2).

Speare et al. (1989) reviewed the range of diseases that affect Macropodoidea, noting that while individuals in populations die from specific diseases; these are end points of environmental fluctuations and habitat changes that influence population dynamics. Generally, major diseases in wild animals should be treated as multi-layered processes (Dawson 1995). Significant disease outbreaks which cause population 'crashes' often are associated with some form of stress such as extreme environmental conditions e.g. drought, flooding or severe hot or cold weather. In these circumstances the disease may be only the proximal cause of death (Dawson 1995).

Examples of common afflictions of kangaroos are lumpy jaw and the presence of large numbers of nematodes. Lumpy jaw is a chronic infection caused by the bacterium *Fusobacterium necrophorum* and is associated with lowered host resistance due to stress factors (Speare et al. 1989). Kangaroos often have large numbers of benign nematodes in their guts, but the presence of high numbers of harmful internal parasitic nematodes, especially *Globocephaloides trifidospicularis*, has been associated with kangaroo mortality (e.g. Quin 1989). This nematode species can cause heavy mortality in juvenile kangaroos in enclosed populations when winter feed is depleted and when small animals with no fat reserves experience maximum cold stress (Arundel et al. 1990). In these circumstances, starvation is probably both the ultimate cause of death and a necessary precursor for high parasite levels across a population (Fletcher 2006a).

3.3.8 Determination of kangaroo body condition

The definitive measures of condition in wild mammals are kidney fat index and percent marrow fat (Caughley and Sinclair 1994). These can only be derived by taking samples from dead animals and it would be desirable to find measurements which can be taken on living kangaroos that correlate with these standards. Visual assessments of the condition of kangaroos are commonly stated but are rarely checked against independent measurements and can easily be wrong. For example, the *post mortem* results from 306 of the kangaroos shot in a cull at Belconnen Naval Transmitting Station in 2008 contradicted some visual assessments (e.g. National Kangaroo Protection Coalition 2008b). In fact the kangaroos had not been in good condition when visually assessed. Many (42% of females and 56% of males) had no kidney fat remaining and 38% of females and 47% of males had less than 50% marrow fat remaining (unpublished data, ACT Parks,

Conservation and Lands). This indicates a reduced ability to survive periods of food shortage and the coming winter may have threatened death by starvation for many, if the cull had been postponed. Research shows that the condition of a declining pasture–herbivore system is likely to be detected first in the condition of the pasture and ground-surface biodiversity, rather than in the visual appearance of the large herbivore (Fletcher 2006a; McIntyre et al. 2002).

3.3.9 Key features of biology and ecology

The key features of the biology and ecology of eastern grey kangaroos discussed in s. 3.3.2 to s. 3.3.7 are summarised in Table 3.2.

Table 3.2 Summary: key features of biology and ecology of eastern grey kangaroos with particular reference to the ACT

Feature	Description/detail
Distribution	· One species widely distributed from north Queensland to Tasmania and south-eastern South Australia
Home range	· Sex-biased, smaller range for females · Weak genetic structure for populations and dispersal inferred up to 230 km
Sexual maturity	· Males approximately 4 y.o. · Females approximately 1.5 y.o.
Reproductive cycle	· Seasonal breeding in the ACT: most young born in summer with pulse of emergent pouch young in spring · Oestrous cycle 46 days (45.6 ± 9.8 SD) · Gestation 36 days (36.4 ± 1.6 SD) · Birth, neonate climbs to pouch (pouch young) · First pouch exit at 283 days (283 ± 24 SD) or 9.3 months (pouch young) · Permanent pouch exit at 319 days (319 ± 18 SD) or 10.6 months (young-at-foot) · Weaning typically 540 days or 18 months (sub-adult)
Mortality	· High mortality of young prior to breeding age, especially for males · Few males more than 10 y.o. in wild
Fecundity	· ACT data show very high levels of fecundity even at high population density and low *per capita* food availability. This is probably typical of temperate populations.

3.4 Ecosystem function, trophic levels and herbivore population dynamics

A useful way to consider the role of kangaroos in their grassy ecosystem habitat is in terms of the food chain and trophic levels. The food chain refers to the transfer of food energy from its source in plants through herbivores to carnivores. Food chains are linked into more complex food webs within which different trophic levels are recognised. Trophic level refers to the functional classification of organisms in a community according to feeding relationships (Krebs 2001). The simplest expression of this (leaving out higher carnivores, decomposers and parasites) is from the first trophic level of producer species (plants), to the second trophic level of primary consumers (herbivores), to secondary consumers (carnivores) (Krebs 2001). The latter functional group (predators) are at the top of the trophic pyramid. In ecosystems around the world, the loss of the predator trophic level has been found frequently to be of profound importance to an ecosystem.

Herbivory is a major trophic level interaction in which animals prey on plants. This is traditionally considered to be only to the advantage of the animals; but there are many example of mutualism

where plant–animal interactions benefit both species (Krebs 2001: Ch. 14). Detailed studies of herbivory have been carried out around the world, for example, in Africa (Caughley 1983; Owen-Smith 2002; Sinclair 1977; Sinclair and Arcese 1995), Australia (Caughley et al. 1987), Scotland (Clutton-Brock and Albon 1989) and New Zealand (Caughley 1989). Management of herbivore grazing systems requires an understanding of the underlying mechanisms whereby the animals react to the plants and in turn the plants react dynamically to the effects of grazing (Tyndale-Biscoe 1999). One feature of the dynamics of herbivore populations is the *herbivore irruption* (Forsyth and Caley 2006; Leopold 1943), which is a characteristic of kangaroo populations in certain circumstances.

3.4.1 Trophic levels

Awareness of trophic levels is useful for conservation management because the main flows of energy and material which enable an ecosystem to persist in a particular form occur between, not within, trophic levels. If all the species comprising a trophic level were to be removed, the ecosystem would almost certainly be noticeably different, but if one species were removed from a particular trophic level, and many others remained, the ecosystem may function much as it did before.

Some important ecosystem processes are 'top-down', referring to ones originating at the predator trophic levels. An example relevant to kangaroos is a predator such as the dingo that limits the extent to which herbivores consume the plants. Other processes are 'bottom up'. An example is that the upper limit to kangaroo density is determined largely by the growth rate of edible plants. In 'trophic cascade' theory, top predators have alternating positive and negative effects on the trophic levels below (Hairston 1960) and indirectly increase plant biomass. An increasing number of studies have supported the theory, based on observations of predator reduction being followed by depletion of plant biomass and decline of species that depend on the vegetation for shelter or food (Berger et al. 2001; Hebblewhite et al. 2005, Letnic et al. 2009).

In the ACT, the concept of trophic levels relates to kangaroos and native grassy ecosystems in two ways. First, in natural conditions, eastern grey kangaroo populations in natural temperate grasslands are responsible for almost the entire function of the herbivore trophic level. Where the grasslands are exploited for pastoral use, introduced livestock largely replace the kangaroo function. Grassland where kangaroos have been replaced by livestock will fare much better than one left without herbivores for a long time, provided the stocking rate is appropriate. Thus, in grasslands where the eastern grey kangaroo is still the main herbivore, what happens to that kangaroo population is significant for the integrity of the natural temperate grassland. Second, in recent times the composition of the predator trophic level has changed, or more significantly, in some areas it has been removed partially or completely. Thylacines, Tasmanian devils, dingoes, and Aboriginal and European hunters no longer prey on kangaroos in most of the native grassy ecosystems of the ACT. Exceptions to this are the persistence of dingo/wild dog predation in some parts of Namadgi National Park and the culling of kangaroo populations on ACT rural leases. The removal of dingoes from semi-arid areas is associated with increased abundance of kangaroos and foxes and increased grazing pressure; reduced grass, groundcover, species richness of mammals and abundance of native rodents (Letnic et al. 2009). It is assumed that the same pattern applies in temperate areas.

3.4.2 Principal herbivore

Retention of a large grazing mammal is highly desirable to avert the risk of a cascade of plant species being lost from a site. Kangaroos generally fulfil this role in ACT reserves that conserve

native grassy ecosystems. Controlled stock grazing is also used in some places. Plant species in grasslands have a range of growth forms (e.g. tall tussocks, rosette forming flowers, tiny herbaceous plants). This structural variation provides habitat for a variety of plant and animal species. However, in the absence of some form of herbage reduction (grazing, mowing or burning), the dominant tussock grasses can become large and dense, to the extent that many other plant species are out-competed and disappear. In these circumstances, the natural diversity of plant species in the grassland and the structural diversity of the vegetation are reduced. The importance of herbage reduction was demonstrated in a large grassland grazing exclosure in Namadgi National Park where only seven plant species persisted inside the grazing-free exclosure, compared to 32 immediately outside in the grazed area (Ingwersen 2001).

Herbage removal, therefore, appears to be an important requirement for grassland conservation and can be achieved by grazing, mowing or burning. However, it seems likely that the nutrient cycling and physical disturbance caused by grazing animals would make grazing the preferred form of herbage reduction, or a combination of methods, rather than mowing alone or burning alone. In addition, the selective grazing of kangaroos is different to that of livestock, the latter often resulting in the loss of the inter-tussock palatable forbs. On a long time scale (tens to hundreds of years), it seems likely that kangaroo grazing would be preferable to livestock grazing to maintain grassland species diversity.

Prior to the introduction of European agriculture and pastoralism, fire and kangaroo grazing would have been the main forms of herbage reduction in grasslands in the ACT region. From the 1820s domestic stock grazing, and later, rabbit grazing and slashing became increasingly important while the role of kangaroos declined. From their reported low densities in the mid 20th century kangaroo numbers have increased, related to land use changes, and kangaroo grazing has again become significant in some areas for herbage reduction. Kangaroos should be regarded as important to retain, at appropriate densities, in grassy ecosystems. However, they have lost their top predators, so are very likely to have a major top-down influence on ecosystem processes.

3.4.3 Conservation impacts

Grazing by high density populations of eastern grey kangaroos can have effects on whether other species, such as ground frequenting birds, can persist on a site (Neave and Tanton 1989). In the latter study, kangaroos were found to be much more significant grazers than rabbits, and reduced the vegetation to such a degree that ground nesting birds could not persist. Habitat loss due to kangaroo overgrazing is also considered to be one of the emerging issues in relation to the decline of a broad group of woodland birds in the ACT and region (Bounds et al. 2007) (s. 3.7.3). A similar situation has occurred at the Majura Training Area, where heavy grazing in drought conditions severely changed the habitat of the endangered grassland earless dragon (*Tympanocryptis pinguicolla*) during which period the density of the dragons plummeted. Dragon numbers remained high on a less heavily grazed site in a nearby valley. Most likely the dragons need the longer grass to shelter from their predators and to provide habitat for the insects on which they feed. Where kangaroos were fenced out, the population of grassland earless dragons began to recover (unpublished data, ACT Parks, Conservation and Lands) (Figure 3.1). Some ecologists use the term ‘ecosystem engineers’ (Jones et al. 1994) for species such as eastern grey kangaroos, which change the habitat to such an extent, that its suitability for other species is significantly affected.

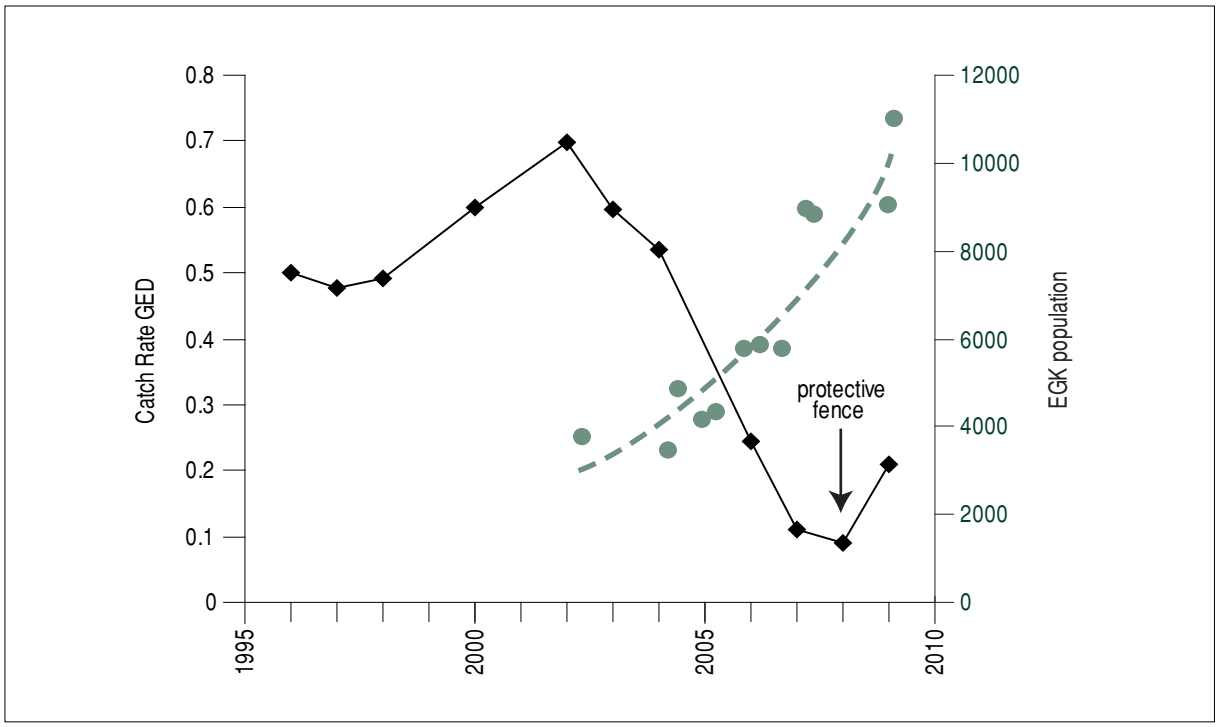
3.4.4 Exponential population growth: the herbivore irruption

The pattern of population growth that can be predicted theoretically from the interactions

between large mammalian herbivores and their environments is both complex and variable. The animal population will either irrupt, crash, and then converge to a more stable density; or it may oscillate indefinitely, the densities of plants and animals being locked into a stable limit cycle (Tyndale-Biscoe 1999). A major contribution to the understanding of these interactions was made by Caughley (e.g. Caughley 1970, 1976a, 1981), including for kangaroos (e.g. Caughley et al. 1987). This work continues to have a major influence on thinking and practice in vertebrate ecology and wildlife management (Tyndale-Biscoe 1999).

Kangaroos react to the standing crop of vegetation in two ways: they reduce its standing biomass by grazing, and they use that harvested energy to produce more kangaroos. The rate of increase of a population as a function of available food (or any other limiting resource) is called its *numerical response* (Caughley and Gunn 1996). Herbivore systems are 'interactive' in that consumption by the animals influences the rate of growth of the vegetation. Herbivores introduced into a new area or freed from previous population controls may increase dramatically to high densities, before their population crashes to lower levels. This increase and subsequent collapse is well known and documented in herbivore ecology and is called an *irruption*, and often occurs when food supply is good and there is an absence of predators (Caughley 1976b; Forsyth and Caley 2006; Leopold 1943). The collapse is due to starvation.

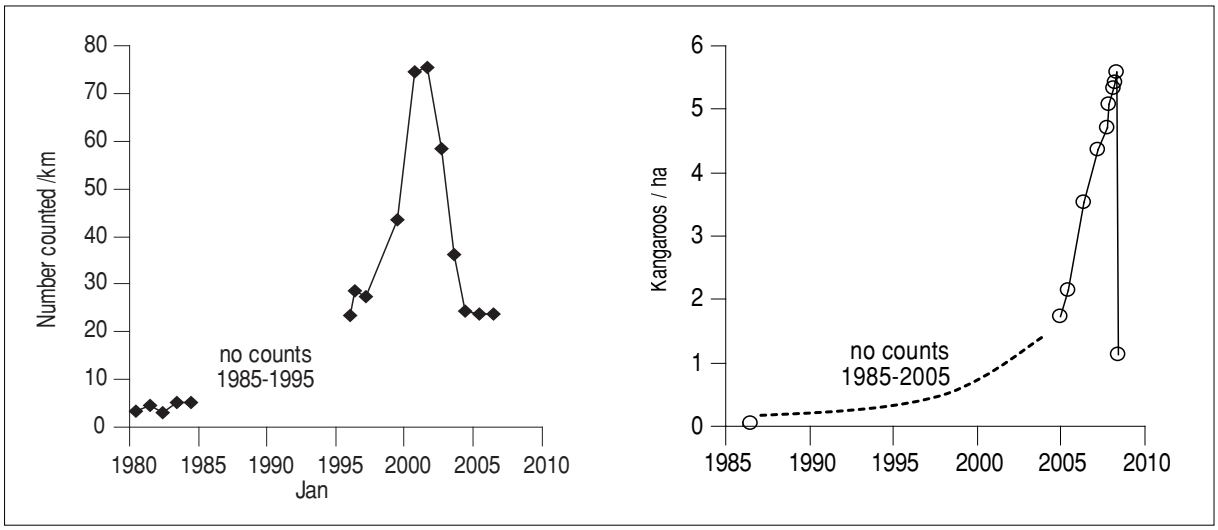
Figure 3.1: Abundance of grassland earless dragons (GED, left axis) and kangaroos (EGK, right axis) at Majura Training Area



Kangaroo counts (solid circles) by Defence contractors were commenced at Majura Training Area in 2002 in response to concerns about increasing kangaroo numbers and their grazing effects. The trapping of grassland earless dragons had been commenced earlier, in the summer of 1995/96, by ACT Parks, Conservation and Lands. The catch rate in Figure 3.1 is the number of unique individuals per trap. Dragon abundance declined from about 2002 until it showed an encouraging sign of recovery in 2009, after most of the dragon population (including all of the monitored area) was surrounded by a kangaroo exclusion fence which enabled the vegetation to recover.

Irruptions of kangaroo populations have been documented in the ACT and region over the past two decades. All instances involve populations on protected sites that have been freed from previous limiting factors. These sites include Government House (Yarralumla), Tidbinbilla Nature Reserve, Googong Foreshores and Belconnen Naval Transmitting Station. An irruption is not an effect of the weather, but a deterministic pattern arising from the different growth rates of plant and animal populations on the site, which is why the trends at Belconnen Naval Transmitting Station and Googong Foreshores were in opposite directions from 2002–05, although the sites experienced the same weather (Figure 3.2).

Figure 3.2: Herbivore irruptions: eastern grey kangaroos at Googong Foreshores and Belconnen Naval Transmitting Station



Googong Foreshores **Belconnen Naval Transmitting Station**

Like other large herbivore species, eastern grey kangaroo populations can exhibit herbivore irruptions characterised by a phase of herbivore increase, followed by a decline when the vegetation is gone and the animals are starving, and possibly a third phase of relative equilibrium: (**Left**) Following the removal of livestock grazing at Googong Foreshores the kangaroo population increased until 2001–2002 then declined steeply by starvation, reaching approximately its current level in 2004. The decrease phase was associated with concerns about soil erosion and loss of vegetation. As apparent from a close inspection of the chart, the decrease was genuinely due to starvation, not the culling of 800 kangaroos in July 2004 which was too late and too few to affect the pattern; and (**Right**) the fenced population at Belconnen Naval Transmitting Station increased to a maximum of 649 animals (559 per square kilometre/5.59 per hectare) when culling, evident as the vertical decline on the chart, was carried out in order to prevent a natural population decline and further impact on the native grassland ecological community in the area.

3.4.5 Overabundance

Overabundance is a value judgment that has a clear meaning only when placed in a specific context (McShea et al. 1997 in Côté et al. 2004). Caughley (1981) outlined a series of definitions to summarise the ecological and non-ecological criteria on which assessments of overabundance have been based. Animals are overabundant when they:

- threaten human life and livelihood
- are too numerous for their 'own good'
- depress the densities of economically or aesthetically important species
- cause ecosystem dysfunction.

With regard to kangaroos, the concept of overabundance is not universally accepted (e.g. Croft 2005a) and it has been argued that the management of native species described as overabundant is often largely influenced by social and political factors (Coulson 1998). The view is sometimes expressed that kangaroos, as native animals that have been part of a long evolutionary process with grassy ecosystems, are perfectly adapted to their environment and limit their numbers at times when their grazing would cause environmental impacts. Early modern writing on kangaroos such as Frith and Calaby (1969), which by their own admission (p. xii) refers mainly to free-ranging red kangaroos, notes the environmental adaptation of kangaroos, their lack of destructive impacts on food plants, and their ability to limit their numbers in dry times. This reference to rangeland kangaroo populations could not foresee how temperate native grassy ecosystems would become endangered, nor, as the foregoing sections of this plan have outlined, eastern grey kangaroos in the ACT are capable of reaching densities that have undesirable impacts in those ecosystems. It is these impacts which are the focus of this plan, not the densities *per se*.

3.5 Environmental considerations: native grassy ecosystems

Prior to European settlement, temperate grasslands and temperate eucalypt woodlands extended in a broad arc from south-eastern South Australia to northern New South Wales (grasslands) and southern Queensland (woodlands). Temperate grasslands and grassy woodlands occurred as part of a mosaic, with treeless grassland occurring at lower elevations as well as some higher elevation valleys, and the woodland merging with dry sclerophyll forests on the upper slopes of hills and ridges (Keith 2004; Lunt et al. 1998; Moore 1970; Yates and Hobbs 2000). The grasslands and woodlands and plant and animal populations were connected to varying extents across the landscape. Areas subject to disturbance such as fire could be recolonised from both within the area and from adjacent unburnt areas. Fragmentation is now a major issue for the conservation of these grassy ecosystems and the species within them. The focus of the following sections 3.6–3.8 is on grassy ecosystems that are of conservation value, related to the diversity of native plant and animal species, and the presence of threatened species (Table 2.1).

3.6 ACT grassy ecosystems

The main habitats for eastern grey kangaroos in the ACT are grasslands and grassy woodlands, extending from the plains around Canberra to the foothills and lower elevation valleys of the western and southern ranges. Grasslands in these areas range from those with a high component of native species (e.g. remnant areas of natural temperate grassland) to those containing only introduced species (e.g. the greens of golf courses).

While the definitions of different types of grassy ecosystems (e.g. natural temperate grassland) are expressed in terms of the vegetation, the ecological community comprises both the flora and fauna, the interactions of which are intrinsic to the functioning of grassy ecosystems.

3.6.1 Grassy woodlands of low hills and plains

ACT lowland woodlands are part of the Southern Tablelands grassy woodlands described by Keith (2004). Only a small amount of this grassy woodland survives in a relatively unmodified form (ACT Government 2004; Land and Water Australia 2002; Thiele and Prober 2000; Thomas et al. 2000).

The dominant ACT lowland woodland community is yellow box (*Eucalyptus melliodora*) – red gum (*E. blakelyi*) grassy woodland, which is declared an endangered ecological community under ACT legislation and together with white box (*E. albens*) under Commonwealth legislation (s. 2.4) (ACT Government 2004). With an open canopy, grassy woodland had a rich understorey dominated by native tussock grasses and forbs as indicated by the remaining high quality areas. In ACT yellow box – red gum grassy woodland, groundcover was structurally and floristically similar to adjacent natural temperate grassland.

About one-third of the estimated 32 000 ha of pre-1750 yellow box – red gum grassy woodland remains in the ACT in a partially or moderately modified form, as well as areas that are more highly disturbed (ACT Government 2004). Typically the woodlands contain yellow box or red gum trees over a variable understorey ranging from areas with a high native component to areas of mainly exotic pasture. These areas all provide suitable kangaroo habitat. The *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004) divides the ACT lowland woodlands into five complexes: Gungahlin, Majura–Kowen, Callum Brae, Tuggeranong–Naas, and North Murrumbidgee–Lower Molonglo (Appendix 3 this plan).

3.6.2 Lowland grasslands

Temperate grasslands are now one of Australia's most endangered terrestrial ecological communities with as little as 0.5 per cent of their estimated pre-1750 extent remaining (Kirkpatrick et al. 1995). While extensive areas of the former distribution of natural temperate grassland still contain grassland, most of this is dominated by exotic species (Keith 2004). Where native grassland exists, three major changes to the flora have occurred: a) replacement of grazing sensitive grass species with hardier, less palatable grass species; b) loss of forb species; and c) invasion by a wide range of mainly herbaceous weed species and introduced pasture species.

In the ACT, natural temperate grassland was the dominant ecological community across the lowland plains from Belconnen and Gungahlin in the north to Tuggeranong in the south (Benson and Wyse Jackson 1994; Pryor 1938; Wildlife Research Unit 1994). The remaining areas are part of the Temperate Montane Grasslands described by Keith (2004) that are found on the Southern Tablelands at an altitude from 600 m to 1500 m. Benson (1994) estimated that there were 20 000 ha of natural temperate grassland in the ACT prior to European settlement.

ACT native grasslands were surveyed and assessed for the preparation of the *ACT Lowland Native Grassland Conservation Strategy* (ACT Government 2005). Forty-two sites (covering 1534 ha) were found to contain 991 ha of natural temperate grassland, which is about 5 per cent of the estimated pre-European extent of the ecological community. All of the remaining native grasslands have undergone varying degrees of modification due to past land uses.

3.6.3 Grasslands in the western and southern ACT

In addition to the lowland grasslands, there are grasslands in valleys at elevations up to about 1200 m in the western and southern ACT, mostly in Namadgi National Park and Tidbinbilla Nature Reserve. The most extensive areas of these grasslands are in the Naas Valley, Boboyan Valley (Naas Creek), Grassy Creek, the Gudgenby area, Rendezvous Creek, Middle Creek, Bogong Creek, Nursery Creek, Orroral Valley, Booroomba Creek and the Tidbinbilla Valley (Tidbinbilla Nature Reserve). The grasslands are at a mid-level in the elevation range of the Temperate Montane Grasslands described by Keith (2004).

Grassland types identified are: wet tussock grassland and tablelands moist tussock grassland (Benson 1994) and sub-montane moist grassland (Rehwinkel 2007). The grasslands are a mix

of natural and semi-natural types as well as pastures that were improved for grazing (Ingwersen 2001). In some areas, the grassland has been extended or created by the clearing of woodland during the pastoral period (described as 'secondary grassland' (ACT Government 2005; Ingwersen 2001)). Examples of this are at Gudgenby (in the area of the former Gudgenby property) and the Tidbinbilla Valley.

These areas were grazed by stock at varying intensities in the past, but many areas retain a high level of natural integrity and are some of the largest remnants of natural temperate grassland on the Southern Tablelands. The sites have good connectivity with other vegetation communities. They are significant as probably the only large-scale examples on the Southern Tablelands where the spatial arrangement of the pre-European grasslands and associated vegetation types has been maintained (G. Baines, pers. comm.).

Together with adjacent woodland and open forest, these grasslands are ideal kangaroo habitat and some areas contain high kangaroo densities. However, they do not appear to be suitable habitats for the grassland species occurring at lower elevations in the ACT that are now threatened, such as the grassland earless dragon, golden sun moth and Ginninderra peppercress (Table 2.1).

3.7 Ecology of grassy ecosystem species

Natural temperate grasslands and the understorey of grassy woodlands contain a surprising array of plant communities and diversity of plant and animal species. However, this diversity of plants and animals is less conspicuous than in many other ecological communities. About 700 species of native plants have been identified in grasslands of south-eastern Australia, the majority of which are not grasses (Eddy 2002). In the Southern Tablelands, more than 600 native plant species (including trees and shrubs) have been found in lowland woodlands and grasslands (ACT Government 2004). Natural grassland and the grassy woodland understorey are structurally and floristically similar and are treated together in this section under the terms 'native grassland' and 'grassy ecosystems'.

3.7.1 The role of disturbance

Prior to European settlement, disturbance was an integral part of the ecology of the grassy ecosystems that had evolved as the Australian continent dried out over tens of millions of years. This disturbance included:

- fire regimes that involved lightning generated fires and, more recently, Aboriginal burning
- small-scale soil disturbance associated with digging by small to medium size mammals (e.g. bandicoots, bettongs)
- utilisation and husbandry by Aboriginal people of plant foods (e.g. the yam daisy or murnong *Microseris lanceolata*) that encouraged the maintenance of particular species in grassy environments
- many grazing and foraging species (herbivores) with kangaroos dominant
- dingo and Aboriginal predation of native herbivores.

(Lunt and Morgan 2002; Morgan and Lunt 1999).

A much more intensive level of disturbance followed European settlement including sheep and cattle grazing, pasture improvement, agriculture, use of fertilizers or other soil ameliorants, and the accidental or deliberate introduction of plants that are now weed species (ACT Government

2004, 2005). The resulting changes to lowland grassy ecosystems were swift. Generally, the dominant disturbance agent changed from burning under low grazing pressure by native species to grazing by stock with little burning (Lunt and Morgan 2002).

The remaining areas of native grassland can be considered on a continuum from those that appear largely intact (similar to their estimated pre-1750 state, though there are likely to be changes in component species) to those in a substantially modified state with only a few elements representing their origins. Typical changes are loss of inter-tussock forb species, invasion by weed species (both forbs and grasses), and replacement of palatable species such as kangaroo grass (*Themeda triandra*) with less palatable species e.g. speargrasses (*Austrostipa* spp.).

At the time of European settlement, lowland grassy ecosystems of south-eastern Australia supported a rich vertebrate fauna, including a wide variety of bird species, large and small marsupials, other mammals (e.g. bats, rodents), reptiles and frogs and a diverse invertebrate fauna (Osborne *et al.* 1995; Driscoll 1994). Disturbances to grassy ecosystems resulting in loss and degradation of grassland habitat were combined with introduced predators and hunting pressures leading to the sometimes rapid decline and/or extinction of grassland animal species from the mid-1800s.

For many vertebrate and invertebrate species, the complete loss, reduced extent, fragmentation and degradation of grassy ecosystem habitat has had major deleterious impacts, with some species now existing only in correspondingly small and fragmented populations. Compared with the megafaunal extinctions of the late Pleistocene, the extinctions that occurred after the expansion of European pastoralism were of the wallabies and small mammals that lived on the ground and were dependent on a thick layer of herbs and grasses for cover (Caughley 1987a). The changes to grassy ecosystems meant that the eastern grey kangaroo rapidly lost its previous predators, while tree clearing increased the area of grassland. The species became part of ecological systems that were 'changed beyond recognition' (Caughley 1987a). While occasional fire, droughts and seasonal disturbances still remained, over most of the lowland native grasslands, kangaroos were now the main pre-European animal disturbance agent—a role shared with domestic stock and from the second half of the 19th century with rabbits.

3.7.2 Flora of grassy ecosystems

Native grassland is characterised structurally by perennial tussock grass species that form the upper stratum. In the ACT, kangaroo grass (*Themeda triandra*), spear grasses (*Austrostipa* spp.), wallaby grasses (*Austrodanthonia* spp.), red grass (*Bothriochloa macra*) and *Poa* spp. are the dominant species. A second lower stratum may contain shorter perennial and annual grasses, and forbs, growing in the spaces between the tussocks. These are not obvious in all seasons and all years. The forbs include orchids, lilies and broad-leaved herbs such as daisies. For much of the year many of these species are not readily noticeable, because they emerge from underground organs, flower, set seed and then die back in autumn or earlier. Many of these plants disappear from grasslands as disturbance increases. At ground level, there may also be a third discontinuous stratum of dwarf forbs and grasses, with occasional bryophytes (e.g. mosses), lichens and fungi also present on 'bare ground' forming a 'cryptogamic crust' (Costin 1954; Lunt et al. 1998).

In surveys undertaken in ACT lowland native grasslands since 1991, 50 species of grasses, over 200 species of native forbs and about 150 introduced species have been identified (ACT Government 2005).

A number of plant species found in natural temperate grasslands and grassy woodlands in the Southern Tablelands region are listed as threatened under Commonwealth, New South Wales

or ACT legislation (ACT Government 2004, 2005; Environment ACT 2005) (Table 2.1). Many other grassland plant species are rare or uncommon, or have suffered dramatic declines in their frequency and abundance. They now occur at low densities within sites, or in very few sites in the region. The abundance and distribution of many of these species is poorly known, but surveys indicate that they have only small populations or low population densities at sites where they occur. Palatable forbs can be lost, even at low grazing intensities, with little obvious effects on the dominant grasses (Lunt 1991). Where there is a major reduction of the dominant grasses through overgrazing, this represents a threat to many plants and animals that depend on their shelter, such as the grassland earless dragon.

3.7.3 Fauna of grassy ecosystems

Grasslands provide habitat for animals and are a source of food for both herbivores and predators. Invertebrates are particularly important in grasslands (Driscoll 1994), and many reptiles, small mammals and birds are associated with well-developed ground cover in grassy ecosystems (Martin and Green 2002). This provides shelter, cover from predation and a source of food such as invertebrates. Ecosystems with a complex 'architecture' support more species than ecosystems that have been simplified, and many species require a complex vegetation structure to meet their habitat requirements (Mac Nally 1995). Figure 5.2 illustrates relationships between these ecosystem components that are hypothesised to be important.

Invertebrates

Insects, other invertebrates and micro-organisms account for much of the species diversity in grassy ecosystems; however, less ecological information exists on invertebrates than other faunal groups (Driscoll 1994; Farrow 1999; Greenslade 1994; Sharp and Dunford 1994; Yen 1995).

Two threatened insect species occurring in the ACT region, the Perunga grasshopper (*Perunga ochracea*) and golden sun moth (*Synemon plana*), are grassland specialists (Table 2.1). Many other insect species and invertebrates in general may have undergone similar declines, but there is insufficient baseline data for such an assessment. Insect species known to have declined include the Canberra raspy cricket (*Cooraboorama canberrae*), Lewis's laxabilla (*Laxabilla smaragdina*), and Key's matchstick grasshopper (*Keyacris scurra*).

Mammals

Grassy ecosystem habitat for mammals is enhanced where there is a combination of grassland and grassy woodland. Mammals found in grassy habitat include the eastern grey kangaroo (*Macropus giganteus*), common wallaroo (*Macropus robustus*), red-necked wallaby (*Macropus rufogriseus*), swamp wallaby (*Wallabia bicolor*), common wombat (*Vombatus ursinus*), echidna (*Tachyglossus aculeatus*) and common brushtail possum (*Trichosurus vulpecula*). Smaller ground-dwelling mammals recorded in ACT woodlands include the yellow-footed antechinus (*Antechinus flavipes*), common dunnart (*Sminthopsis murina*) and native bush rat (*Rattus fuscipes*). There is good evidence that these small mammal species have declined to the point where some may no longer be present in ACT urban reserves (Buckmaster 2005).

Historical records and studies of recent bone deposits (from the last 200 years) indicate a much more diverse small/medium mammal fauna in the ACT at the time of European settlement, including bandicoots and potoroos (F. Ford, pers. comm.). For example, plentiful numbers of small hopping animals (described as 'rat-kangaroos'—probably bettongs) were present in historical times (Schumack and Schumack 1977), but were part of the widespread extinctions of smaller mammals that followed the advance of European pastoralism (Caughley 1987a). Unlike woodland

in some other parts of Australia, the ACT now lacks small and medium-sized ground-dwelling marsupials such as bettongs, potoroos or bandicoots.

At least ten bat species occur in ACT open grassy woodlands and are likely to use adjacent grasslands and areas where isolated trees provide suitable roosting sites. Introduced domestic and feral mammal species occur throughout the grassy ecosystems.

The dingo (*Canis lupus*) is a recent addition to the mammalian fauna and was brought to Australia by humans. Based on a study of mitochondrial DNA (see **Glossary**), the founding of the dingo population in Australia has been estimated at approximately 5000 years ago, pre-dating the earliest substantiated evidence in the archaeological record from approximately 3500 years ago (Savolainen et al. 2004). Most dingoes have been eliminated from the grassy lowlands of south-eastern Australia (Corbett 2008). However, dingoes are found in remoter habitats in the ACT, such as parts of Namadgi National Park.

None of the mammal species remaining in ACT lowland grassy ecosystems are declared threatened under ACT legislation.

Birds

Woodlands and grasslands provide habitat for the majority of Australian land bird species (Olsen 2008). At the time of European settlement, ACT lowland grasslands supported populations of the emu (*Dromaius novaehollandiae novaehollandiae*), bush stone-curlew (*Burhinus grallarius*), brolga (*Grus rubicunda*) and bustard (*Ardeotis australis*)—all now locally extinct. Complex understorey including grassy areas is a very important habitat requirement for many woodland birds which are insectivorous, seed eating, and ground or near-ground feeding species. About fifty bird species occur as residents or summer migrants in ACT grassy woodlands and for many of these species, nearby grasslands are an important component of their habitat, Many species found in grassy woodlands have declined, and few of these are found in simplified habitats that have little understorey other than exotic pasture (Freudenberger 2001). Habitat loss is the single greatest threat to birds, both because of the legacy of past clearing and continuing overall loss and degradation of what remains through inappropriate fire regimes; overgrazing (especially by livestock but also feral animals and over-abundant macropods); human pressures (urbanisation, recreation and other uses); predation, competition and habitat change by feral animals and weeds (Olsen 2008).

There is good evidence that a broad group of woodland birds are in decline in south-eastern Australia. The *State of Australia's Birds 2008* report (Olsen 2008) indicates that the hooded robin, as well as a number of other robins, thornbills, and other small insectivorous birds which feed on or near the ground, are decreasing in this region. These conclusions are supported by the Canberra Ornithologists Group's Woodland Monitoring Project which has 142 monitoring points at 15 grassy woodland patches in the ACT (10 years of data) and a six year study of birds in the Cowra region—many species occur in both areas (Bounds et al. 2007; Cunningham and Rowell 2006; Reid and Cunningham 2008). While habitat loss due to urban expansion continues to impact on birds in the ACT, overgrazing by kangaroos, weed invasion and inappropriate fire regimes are considered to be emerging issues in remaining grassy woodland areas (including those that are protected) (Bounds et al. 2007). For example, observations by Canberra Ornithologists Group indicate an absence of ground feeding finches such as the diamond firetail and double barred finch from one of the largest grassy woodland reserves in the ACT (Mulligans Flat) where kangaroo densities have increased, grassy understorey and adjacent grassland have been heavily grazed, and seeding of grasses suppressed. Diamond firetails have been recorded in small numbers in neighbouring Goorooyarroo Nature Reserve in and around a paddock enclosed by a kangaroo exclusion fence (COG 2009).

The conservation of bird species (some of which are threatened) that utilise floristically diverse and well-structured grassland and grassy woodland understorey is an important reason for managing herbivore grazing pressure in those environments. Grassy understorey is a critical habitat feature for four of the woodland bird species declared threatened in the ACT: hooded robin (*Melanodryas cucullata*), brown treecreeper (*Climacteris picumnus*), white-winged triller (*Lalage sueurii*) and superb parrot (*Polytelis swainsonii*) (Table 2.1). The hooded robin and brown treecreeper are dependent on the ground layer for insect food. Both of these species are in decline in the ACT. Other ground layer dependent species are:

- scarlet robin (*Petroica multicolor*): showing significant decline
- jacky winter (*Microeca fascinans*): in very low numbers locally and prefers more open woodland and woodland–grassland edges
- speckled warbler (*Chthonicola sagittata*): in low numbers, reliant on ground for food and nests on the ground
- diamond firetail (*Stagonopleura guttata*) and double barred finch (*Taeniopygia bichenovii*): seed eaters reliant on seeding native grasses
- white-fronted chat (*Epthianura albifrons*): insectivorous, regionally declining
- restless flycatcher (*Myiagra inquieta*): uncommon in the ACT. Occurs in grassy woodlands and feeds on insects close to the ground
- painted button-quail (*Turnix varia*): very uncommon. Occurs in grassy woodlands with good ground layer complexity.

Five bird species in the ACT are grassland specialists and are considered to be dependent on this habitat, namely stubble quail (*Coturnix pectoralis*), brown quail (*Coturnix australis*), singing bushlark (*Mirafra javanica*), brown songlark (*Cinclorhamphus cruralis*) and richard's pipit (*Anthus novaeseelandiae*). Others are closely associated with grassland habitat e.g. masked lapwing (*Vanellus tricolor*), rufous songlark (*Cinclorhamphus mathews*) and golden-headed cisticola (*Cisticola exilis*) (ACT Government 2005).

Reptiles and amphibians

Native grasslands and grassy woodlands in the ACT provide habitat for many lizard species and four snake species, with their abundances varying geographically. Many species are also found in other habitats such as dry forest. Three reptile species that are grassland specialists, the grassland earless dragon (*Tympanocryptis pinguicolla*), striped legless lizard (*Delma impar*) and pink-tailed worm lizard (*Aprasia parapulchella*), are declared threatened under ACT and Commonwealth legislation (s. 2.4).

Widespread and common species include a number of skink species, eastern blue-tongue lizard (*Tiliqua scincoides*), eastern brown snake (*Pseudonaja textilis*), red-bellied black snake (*Pseudechis porphyriacus*) and eastern snake-necked turtle (*Chelodina longicollis*). Less commonly seen lizards include the shingleback (*Trachydosaurus rugosus*) and bearded dragon (*Pogona barbata*) (ACT Government 2005). Frogs occur in wetter areas or at waterbodies and may use burrows and cracks in the soil, logs, rocks and thick grass for shelter. Some species remain common (e.g. common eastern froglet *Crinia signifera*), while others have declined (e.g. brown toadlet *Pseudophryne bibronii*), or are now thought to be locally extinct (green and golden bell frog *Litorea aurea*, warty swamp frog *Litorea raniformis*, yellow-spotted tree frog *Litoria castanea*).

Introduced Species

The European rabbit (*Oryctolagus cuniculus*) is a widespread pest in grassy ecosystem environments. Hares (*Lepus capensis*) occur in smaller numbers. Deer (mainly fallow deer *Dama dama*) are emerging pest species but numbers are low at present. Important predators are the fox (European red fox *Vulpes vulpes*) and domestic and feral cats. The common myna (*Acridotheres tristis*) and common starling (*Sturnus vulgaris*) use tree hollows in peri-urban woodlands.

3.8 Conservation of grassy ecological communities and species

As is evident from the foregoing, in the ACT and throughout their former south-eastern Australian distribution, the remaining native grasslands and grassy woodlands have been reduced to fragments and are subject to ongoing threats. In the ACT and region, some plant and animal species have been lost from grassy ecosystems (e.g. Australian bustard, brolga, brush-tailed rock-wallaby). Others survive, in mainly small populations, in isolated patches of habitat (e.g. golden sun moth, small purple pea). In some instances, species may be reasonably common in habitat where they occur, but there are only one or a few areas of habitat (e.g. Ginninderra peppercress, pink-tailed worm lizard). With the exception of the large and easily identifiable animals, it is difficult even to ascertain what species have been lost. Such assessments are even more difficult for plants, due to the lack of early detailed botanical surveys.

3.8.1 Extinction processes

A large number of species in an ecological community such as natural temperate grassland that is reduced to small and fragmented remnants potentially face the threat of extinction. Extinction processes in lowland grasslands and grassy woodlands can be grouped into three categories:

- **Alienation** of habitat is the most serious of the threats, meaning conversion of areas of native grassland to uses such as housing, infrastructure, and farming. Large areas of native grassland have been transformed to varying degrees by grazing and cropping. Urban development has had a significant impact on ACT grassland and remains an important threat. Of the estimated original ACT lowland grassland, 95 per cent has been alienated and about 5 per cent remains.
- **Fragmentation** refers to the spatial distribution of the remaining grassland and is explained further below. Fragmentation of remaining native grassland has resulted from the alienation process and the types and intensities of land uses and management. Further fragmentation is a significant threat to the areas that remain, particularly the larger remnants that have the highest conservation value.
- **Degradation** refers to processes operating within a fragment that reduce its natural integrity and conservation value. Some form of degrading disturbance threatens all grassland remnants, even those in permanent reserves (ACT Government 2005). Examples of these threats are weed invasion, overgrazing, inappropriate burning, fertilizer application, feral animal activity and physical disturbance.

Fragmentation warrants further explanation. When habitat is reduced in area and fragmented into small disconnected patches, animals and plants dependent on that habitat face a high risk of extinction. This is because small populations are more vulnerable to environmental events such as wildfires and local drought, and may suffer inbreeding, or fall below some critical size (Lindenmayer and Burgman 2005). These populations conform to the 'small population paradigm' (Caughley 1994), which is supported by numerous empirical studies that provide evidence for the

theoretical conclusion that low abundance increases the likelihood of extinction. Often these remnant populations have limited environmental tolerance and specific habitat requirements. There is also likely to be variation in the quality of habitat fragments and this will affect survival and breeding rates.

Widespread populations occupying connected habitat can recolonise areas affected by factors such as fire, localised drought, human disturbance or overgrazing, whereas fragmented habitats are not recolonised after the species is lost from each part. Even if loss of habitat is halted, in the absence of recolonisation, the continued loss of small populations of a particular species from small habitat patches will eventually result in extinction. This is a key aspect of a process ecologists call the 'extinction vortex'. Thus, small populations of grassland species occupying fragmented habitat are highly vulnerable to extinction. The conservation of some of the remaining species of the natural temperate grassland will need to be given exceptional priority if those species are not to follow the others which have previously disappeared. This is exemplified by the dramatic range-reduction of the grassland earless dragon in the last few decades.

The remaining fragments of natural temperate grassland and lowland grassy woodland deserve special conservation protection. In general, management should be conservative. Extremes of fire frequency, mowing, and grazing pressure should be avoided, and management changes undertaken cautiously.

3.8.2 Conservation management

In recent times, governments, with the support of the community and landholders, have made commitments to the conservation of lowland grassy ecosystems. This is expressed in the declaration of the ecological communities and component species as threatened under state, territory and Commonwealth legislation, the preparation of recovery and action plans, and the establishment of conservation reserves such as the grassland and woodland reserves in the Gungahlin and Jerrabomberra areas of the ACT.

Since the early 1990s, considerable attention has been given to understanding the management requirements for long-term conservation of grassland remnants in the ACT. This is a complex matter as all grassland areas have been subject to degrading disturbances (e.g. weed invasion) but most have lost the type of disturbances that maintained them in the past (e.g. fire). This means that while more general principles and understanding can provide a starting point, management regimes for particular sites need to take into account current and previous land uses and management, the extent of degradation, and management objectives for the area (including the conservation of threatened and uncommon species).

3.8.3 Herbivores and grassland habitat

There are a number of factors to be considered in the conservation management of native grasslands (Eddy 2002). Defoliation and fauna habitat management are the main concerns for this kangaroo management plan. ACT grassy ecosystems evolved under the influence of grazing herbivores, macropods in particular. The population size of grazing animals is determined largely by the seasonal abundance of the grassland food source. In turn, species composition and abundance of grassland vegetation are affected by the population size of grazers (grazing intensity) and seasonal conditions (rainfall and temperature). Thus grazers and grasslands are linked in a feedback loop driven by the weather.

The diet of eastern grey kangaroos is 99% grass (Jarman and Phillips 1989) and they graze both the native and introduced species that occur in ACT lowland areas. This general grass diet compares

with the habitat requirements of many other grassland species that are now rare and/or threatened, which are found only or mainly in native grassland and are wholly dependent on this vegetation community and intact grass tussock structure for their survival. The relationships between the habitat requirements of ACT threatened species and kangaroo grazing are summarised in Table 3.3.

Table 3.3 Habitat requirements for threatened species in ACT native grassy ecosystems and significance of kangaroo impacts

Grazing impacts from all herbivores, as well as other potential threats, are considered in managing habitat for these species. Assessment of the significance of kangaroo grazing impacts derives from knowledge of grazing impacts generally, current understanding of the habitat requirements of grassland species, data collected for some species, and field observations as part of survey, monitoring and research undertaken by ecologists within ACT Parks, Conservation and Lands and by researchers from other institutions. For threatened species reliant on grassland or grassy understorey, the precautionary management response is to avoid overgrazing from any source. In ACT reserves where there is no grazing by domestic stock (or limited stock grazing in particular locations for fire fuel reduction) overgrazing is mainly by kangaroos and rabbits.

(See Table 2.1 for threatened status under ACT and/or Commonwealth legislation)

Threatened Plant Species in ACT Native Grassy Ecosystems		
Species	**Habitat Requirements**	**Significance of Kangaroo Grazing Impacts**
Tarengo Leek Orchid (*Prasophyllum petilum*) (ACT Woodland Strategy, pp. 31–32)	Native grassland/grassy woodland on moister sites. ACT and NSW distribution suggests the species does not survive under constant stock grazing.	Hall Cemetery contains the only ACT Tarengo Leek Orchid population. This is not currently threatened by kangaroo grazing.
Small Purple Pea (*Swainsona recta*) (ACT Woodland Strategy, pp. 32–33)	Open grassy woodland. Species appears to not survive under heavy or constant stock grazing pressure.	There is no evidence that the ACT populations have been threatened by kangaroo grazing pressure, but studies are lacking. Indirect impacts possible (e.g. overgrazing facilitating weed invasion). A potential impact of high kangaroo density (e.g. Mt Taylor) is kangaroos resting on the remaining plants.
Austral Toadflax *(Thesium australe)* (ACT Woodland Strategy, pp. 33–34)	Strongly associated with kangaroo grass dominated herbaceous understorey. ACT populations should be managed to retain an open vegetation structure (e.g. limiting tree/shrub cover).	Heavy grazing pressure (stock, rabbits, kangaroos, grasshoppers) is a threat to species. Indirect impacts (e.g. overgrazing facilitating weed invasion) also possible.
Hoary Sunray (*Leucochrysum albicans var. tricolor*) (ACT Woodland Strategy, pp. 34)	Open areas in grassy woodland, large numbers sometimes colonise disturbed sites. Usually found in ungrazed or lightly grazed areas. Appears to tolerate mowing.	Species appears to be very sensitive to grazing, but responds to disturbance as a colonizer. Studies are lacking to estimate the threat posed by kangaroo grazing pressure.
Canberra Spider Orchid *(Arachnorchis actensis)*	Species occurs in transition zone between grassy woodland and open forest, amidst grasses, forbs and low shrubs.	It is not known if kangaroo grazing has a deleterious impact in some circumstances. Fencing is proposed for the remaining orchid populations.

Threatened Plant Species in ACT Native Grassy Ecosystems		
Species	**Habitat Requirements**	**Significance of Kangaroo Grazing Impacts**
Button Wrinklewort *(Rutidosis leptorrhynchoides)* (ACT Grassland Strategy, pp. 24–27)	Occurs on margins of open grassy woodland with ground layer of native grasses and forbs. Prefers open habitat and is poor competitor amongst dense sward-forming grasses. The species is a tall palatable herb that is lost under stock grazing.	There is no evidence that the ACT populations have been threatened by kangaroo grazing. Low to medium intensity kangaroo grazing is likely to be beneficial in helping to maintain an open grass cover. This needs to be considered in terms of total grazing pressure.
Ginninderra Peppercress *(Lepidium ginninderrense)* (ACT Grassland Strategy, pp. 28–29)	At the one site where species occurs, it grows well where competing grass tussocks are short and open. The species appears to be susceptible to overgrazing as well as competition from other plant species.	Limited kangaroo grazing may be beneficial in removing competitive growth of grass species; however, heavy kangaroo grazing is likely to have deleterious impact. Site is protected by a fence.
Golden Moths (*Diuris pedunculata*) (ACT Grassland Strategy, pp. 24)	Occur on moist grassy slopes or flats on peaty shale or fine granite and among boulders.	There is no evidence that the ACT populations have been threatened by kangaroo grazing but studies are lacking.
Tuggeranong Lignum *(Muehlenbeckia tuggeranong)* (ACT Riparian Strategy, pp. 40–42)	Known only from a very small population near the Murrumbidgee River. Current habitat is highly disturbed and weed invaded riparian shrubby woodland.	It is not known whether grazing animals such as kangaroos pose a threat to the survival of remaining plants or whether such grazing may benefit the species by keeping competing grass tussocks and other plant growth open and short.
Threatened Animal Species in ACT Native Grassy Ecosystems		
Species	**Habitat Requirements**	**Significance of Kangaroo Grazing Impacts**
Grassland Earless Dragon *(Tympanocryptis pinguicolla)* (ACT Grassland Strategy, pp. 38–39)	Key habitat for the three remaining populations is well drained and relatively undisturbed natural temperate grassland dominated by *Danthonia* and *Stipa* spp. The species shelters within grass tussocks and in arthropod burrows. The rocks used for shelter in other areas are not a characteristic of ACT sites.	The species and its habitat appear to be maintained under stock and/or kangaroo grazing at low intensities. Heavy grazing pressure by stock, kangaroos and/or rabbits reduces and/or degrades this habitat. Kangaroo grazing pressure (exacerbated by drought conditions), with resultant loss of tussock grassland structure, has impacted on the dragon population. Three of the populations are now within kangaroo exclusion fences.
Striped Legless Lizard *(Delma impar)* (ACT Grassland Strategy, pp. 39–40)	Key habitat is native grassland dominated by kangaroo grass, spear grasses and wallaby grasses. Species is also found in adjacent areas dominated by exotic grasses. An important habitat characteristic appears to be tussock structure, though little is known about how the habitat is used. Soils with moderate to high clay content, often producing cracks in summer are another habitat feature.	The species and its habitat appear to be maintained under stock and/or kangaroo grazing at low intensities. Grass tussock structure, important for this species, is lost under heavy grazing pressure by stock, kangaroos and/or rabbits.

Threatened Plant Species in ACT Native Grassy Ecosystems		
Species	**Habitat Requirements**	**Significance of Kangaroo Grazing Impacts**
Golden Sun Moth *(Synemon plana)* (ACT Grassland Strategy, pp. 40–41)	On current knowledge, this species appears to be dependent on a narrow range of native grasses (commonly a wallaby grass *Austrodanthonia carphoides* in the ACT), but has been found to utilise the introduced Chilean needle grass (*Nassella neesiana*) when native grasses have been significantly depleted (Braby and Dunford 2006). *Austrodanthonia* is low growing with tussocks usually separated by bare ground.	Native grasslands that support golden sun moth populations in the ACT are subject to low intensity management activities that apparently benefit low growing wallaby grasses and hence maintain habitat quality for the species. These activities include light grazing by stock and/or kangaroos.
Perunga Grasshopper *(Perunga ochracea)* (ACT Grassland Strategy, pp. 41–42)	Key habitat appears to be natural temperate grassland dominated by wallaby, kangaroo and spear grasses with forb food plants located in the inter-tussock spaces. Species also occurs in open woodland with a grassy understorey. Grass tussocks appear to be essential habitat, being used to escape predators and shelter from wind, low temperatures and frost.	The species persists in lightly grazed areas where tussock structure remains. When it has been recorded from heavily grazed areas, it was still associated with nearby grass tussocks. Observations to date suggest that heavy grazing pressure by stock, kangaroos and/or rabbits have the potential to reduce and/or degrade the habitat of this species.
Pink-tailed Worm Lizard *(Aprasia parapulchella)* (ACT Riparian Strategy, pp. 56–59)	Habitat in ACT is native grassland usually dominated by kangaroo grass, with numerous partially embedded rocks. Likelihood of occurrence of the lizard increases with increasing cover of kangaroo grass and decreases with increasing cover of other species that are indicative of disturbance.	Livestock grazing and agriculture have probably had the most impact on this species through loss and degradation of habitat. Kangaroo grazing has not been specifically identified as a threat but could contribute to loss of habitat, in the context of total grazing pressure.
Hooded Robin *(Melanodryas cucullata)* (ACT Woodland Strategy, pp. 43–54)	Woodland understorey of tall tussock grasses, low shrubs and fallen logs, which support insects and other invertebrates on which the species feeds, is critical habitat.	Intensive grazing which reduces the complexity of understorey habitat is a threat and in some important ACT woodlands (e.g. Mulligans Flat) this grazing is mainly by kangaroos. Rabbits are also important in some areas.
Brown Treecreeper *(Climacteris picumnus)* (ACT Woodland Strategy, pp. 43–54)	Critical habitat is relatively undisturbed grassy woodland with native understorey, especially grasses.	Intensive grazing which reduces the complexity of understorey habitat is a threat and in some important ACT woodlands (e.g. Mulligans Flat) this grazing is mainly by kangaroos. Rabbits are also important in some areas. Areas with short grass are also favoured by the species and its precise habitat requirements remain uncertain.
White-winged Triller *(Lalage sueurii)* (ACT Woodland Strategy, pp. 43–54)	Critical habitat in the ACT is grassy woodland, with intact grassy understorey and fallen timber that support insects and other invertebrates on which the species feeds.	Intensive grazing which reduces the complexity of understorey habitat is a threat and in some important ACT woodlands (e.g. Mulligans Flat) this grazing is mainly by kangaroos. Rabbits are important in some areas.

Threatened Plant Species in ACT Native Grassy Ecosystems		
Species	**Habitat Requirements**	**Significance of Kangaroo Grazing Impacts**
Superb Parrot *(Polytelis swainsonii)* (ACT Woodland Strategy, pp. 43–54)	Main habitat in the ACT region is box woodlands. Species prefers to feed on ground on seeds of grasses and herbaceous plants associated with yellow box –red gum grassy woodland.	Intensive grazing of understorey of box woodland with loss of structure and diversity is identified as a threat to the species. Such grazing pressure could derive from stock, kangaroos and/or rabbits.

Note: Abbreviated titles have been used for ACT nature conservation strategies which contain information and action plans for declared threatened species and ecological communities: ACT Woodland Strategy (ACT Government 2004); ACT Grassland Strategy (ACT Government 2005); ACT Riparian Strategy (ACT Government 2007a).

The sustainable management of native grassland requires sufficient plant material be maintained to provide habitat for the range of species associated with it. This plant material provides food for herbivores ranging from large grazers to invertebrates, the latter in turn providing a food source for other organisms in the grassland food web. The grass sward protects the soil surface and provides the physical structure necessary for the shelter, foraging and breeding requirements of all grassland species (Braid et al. 2008).

Grassland structure is influenced by the grazing effects of large herbivores. Plant species composition varies under different grazing pressures because plants exhibit a range of grazing tolerances (McIvor 2002a). The animals and uncommon plants living in the grass sward also vary in their requirements, and variation in grassland structure provides a means by which the maximum number of species can persist. Little or no grazing allows for the accumulation of herbage mass and results in dominance by tall-growing grazing-intolerant plant species (e.g. kangaroo grass *Themeda triandra*). Moderate grazing allows herbivores to graze selectively, and in native grasslands, this creates patchiness with areas of both tall and short grass swards. Heavy grazing pressure results in non-selective grazing, so the herbivores eat virtually all plants on offer and the resulting grass sward is very short and lawn like. Under these 'marsupial lawn' conditions, bare ground is exposed, especially in drought conditions. Plants that become dominant under heavy grazing pressure (e.g. wallaby grass *Austrodanthonia carphoides*, windmill grass *Chloris truncate*, red-leg grass *Bothriochloa macra*) are grazing-tolerant and short growing, even when ungrazed (Braid et al. 2008; McIvor 2002a).

Management of herbivore grazing pressure is an important factor in efforts to rehabilitate areas in poor condition due to past land uses. An example is Mt Painter Nature Reserve where high densities of kangaroos, as well as rabbits and hares, are hindering rehabilitation work.

It is sometimes suggested that grazing in conservation reserves should be undertaken using native herbivores (e.g. eastern grey kangaroos) rather than grazing stock. The practicality of native herbivore management varies greatly, largely according to reserve size and location. Kangaroo and grassland conservation might be seen as complementary; however, kangaroos are particularly difficult to control in small isolated grassland and woodland remnants, especially in urban areas. Stock can be easily moved or sold when not needed. Regardless of differences in grazing behaviour, the key difference between grazing with stock and with kangaroos, from a management perspective, is that stock grazing can be controlled to achieve desired ecological outcomes, whereas this cannot be done easily with kangaroos (Lunt 2005).

3.8.4 One native animal species negatively impacting upon another

There are a number of factors that contribute to the probability of a population becoming extinct, in particular, environmental and demographic variables, loss of genetic variation and loss of social structure. Small isolated populations are highly at risk simply due to their size (Caughley and Gunn 1996). Destruction of habitat, hunting, and the impacts of introduced species such as pigs, cats and foxes are all implicated in the recent rise in extinctions e.g. for Australian mammals (Caughley and Gunn 1996).

In the context of the presence of high kangaroo numbers and densities in some native grassland areas of the ACT that support threatened grassland species, it has been claimed that there is no precedent for the concept of a native species deleteriously impacting upon another native species to the point of extirpation. However, most native species are impacted by many other native species. The relationships that cause these impacts are fundamental and well known in ecology, involving competition, predation and parasitism. While broad-scale factors such as global climate change are implicated in mass extinctions, it is highly likely that the interactions between component populations of ecosystems have not always been benign.

For those species in Australia that are currently considered to be threatened with extinction, that threat arises from multiple causes. In general, some widespread factor such as habitat loss and fragmentation reduces the remaining fragmented population to low levels and divides it into sub-populations. Specific factors may then result in the death of the last animal on each site and those factors may differ between sites. Rarely can they be specifically identified. In grasslands, excessive kangaroo grazing pressure that destroys the specialised habitat of threatened species is not the proximal cause of death (which may be starvation or predation by raptors or feral cats), but one of the ultimate causes—primarily habitat loss and degradation.

Over the past 200 years, many Australian ecosystems have been altered, reduced and fragmented to the extent that they no longer retain all the ecological process that existed before European settlement. In fully-functioning ecosystems with a complete complement of co-evolved species whose populations are widespread and well-connected, it is less likely that one species could cause the extinction of another. This threat is much greater when habitat is fragmented and some species exist only in small and separated populations.

The most authoritative recent book on wildlife damage control, Hone (2007), notes that introduced species are not the only vertebrates that affect biodiversity and require management intervention for conservation. Many examples are provided by Goodrich and Buskirk (1995), including kangaroos (Australia), and coyotes (*Canis latrans*), American badgers (*Taxidea taxus*), striped skunks (*Mephitis mephitis*) and corvids (*Corvidae*) in North America. Studies have shown that fragmented and simplified woodlands in Australia may be dominated by native fauna species that are disturbance tolerant, widely distributed, abundant and often aggressive (Majer et al. 2000). The presence of such species (e.g. the noisy miner *Manorina melanocephala*) can have a negative impact on other woodland fauna. Nest predation in urban areas by the former altitudinal migrant, the pied currawong (*Strepera graculina*), is well documented (Major et al. 1996).

There are similarities in the ecological effects of overabundant deer (browsers) and kangaroos (grazers), where foraging on vegetation by deer results in cascading effects on animal species (summarised in Côté et al. 2004). Ecological impacts of deer have been much better studied than those for kangaroos. McShea et al. (1997) noted the importance of moving deer management beyond a population based approach to one that considers the ecosystem as a whole. This

comment is equally relevant to high density kangaroo populations in native grassy ecosystems, especially those containing rare and threatened species.

3.9 Economic considerations

McLeod (2004) estimated that kangaroos cost the nation about $76 million annually, of which vehicle collisions accounted for $30 million. The presence of kangaroo populations in the ACT can have both positive and negative economic impacts and these are often difficult to quantify. Positive economic effects are associated mainly with nature-based tourism. Negative economic effects are associated mainly with rural leases, some other land areas, and vehicle collisions and collision avoidance. Commercial kangaroo harvesting is not undertaken in the ACT. The area surrounding the ACT has recently been incorporated into the NSW harvesting program.

3.9.1 Nature-based tourism

The kangaroo is a key symbol for tourism promotion and imagery generally of Australia, as well as being an important component of nature-based tourism (Cousins 2005; Tourism Australia 2008). In the ACT, kangaroos feature in tourism promotion literature and websites, e.g. kangaroos grazing on the lawns of Parliament House, photographs to accompany publicity for wilderness tours, and information about nature reserves, especially Tidbinbilla.

The identification of the kangaroo with Australia cannot be simply translated to mean that all tourists coming to Australia wish to, or expect to see kangaroos as part of their experience or that this will decide whether or not they come to Australia. While two-thirds of all international visitors to Australia in the years ending June 2007/June 2008 undertook a broadly defined nature based activity (Tourism Research Australia 2008, 2009), international visitor surveys have indicated that the proportion of international visitors coming to Australia partly to experience native animals is about 18 per cent. Less than one per cent indicated that this would be a deciding factor in the decision whether or not to travel (Higginbottom et al. 2004).

Kangaroos are part of 'wildlife tourism' (any tourism involving wild animals), which in turn is a subset of nature tourism (Higginbottom et al. 2003). Such non-consumptive use of wildlife has attracted increasing numbers of recreational users and created substantial economic activity around the world. Until recently, there has been limited information on the role of kangaroos in the Australian tourism industry in general and nature tourism in particular. This has been addressed as part of a number of related projects undertaken by the Cooperative Research Centre for Sustainable Tourism and is the first published research on management of kangaroos in relation to tourism (Higginbottom et al. 2004). The potential role of kangaroos in non-consumptive wildlife based tourism has been raised also in the context of kangaroo management, especially commercial harvesting, in western New South Wales (Croft 2000; Higginbottom et al. 2004) and elsewhere (Croft and Leiper 2001). Wildlife based tourism is also promoted by some animal rights organisations as an alternative to kangaroo culling and commercial harvesting (see, for example, 'The Kangaroo Trail' <http://www.rootourism.com> and Australian Wildlife Protection Council (2008)).

Some pertinent points from the research referred to above (Higginbottom et al. 2003, 2004; Croft 2000; Croft and Leiper 2001) regarding the role of kangaroos in wildlife tourism include the following:

- The opportunity to see a kangaroo (and wildlife in general) is a pleasant addition to the visitor experience rather than a primary motivation to travel to Australia. While there is a market for

specialised kangaroo tourism experiences, it is likely to be small. There is currently insufficient evidence of unmet demand that would justify significant investment in new kangaroo tourism enterprises.

- While Asian and European visitors both express a preference for seeing animals in the wild, the former are far less likely to travel outside international gateways. Areas such as western New South Wales that rate highly for viewing wild kangaroos are generally distant from such gateways, away from preferred travel routes, and have limited facilities. These facilities are more suited to the independent domestic travellers that make up the bulk of visitors in such areas.
- In 2003, at least 192 tourism operators in Australia included kangaroo viewing in their operations; 154 of these are based mainly on free ranging populations. The eastern grey kangaroo is the species most commonly used in promotional material.
- A range of deficiencies in the operation of the industry are identified, including knowledge and interpretative skills of operators, links with protected area management agencies, and planning and management of encounters with kangaroos (including managing visitor and kangaroo behaviour).
- As well as the important role of national parks and other protected areas for kangaroo related tourism, there may also be potential for well-placed landholders to exploit their kangaroo populations or mammal introductions (King et al. 2007) as a tourist attraction. This is more likely to be near major cities than in the remote inland.
- Revenue from non-consumptive use of wildlife may be inadequate to meet management costs.
- Pastoralists and farmers adjacent to tourism enterprises involving large mobs of kangaroos are unlikely to be supportive due to the impacts upon their operations.
- Management issues and problems may arise with regard to kangaroo tourism and are recognised by some in the industry. These include:
    - road kills (often by tourists)
    - kangaroo densities that are too high for the available pasture with resultant malnutrition, starvation and death of kangaroos. In such instances there will be an incongruity between kangaroo tourism publicity and the ecological reality (visitors seeing emaciated or dead kangaroos)
    - stresses suffered by animals from repeated contact with wildlife tourists
    - inappropriate handfeeding and harassing behaviours by visitors
    - aggressive behaviour by some kangaroos habituated to visitors
    - over-use of particular areas by the presence of too many operators.

Nature-based and wildlife tourism in the ACT is a minor, low-key activity compared with visits to the national institutions, and nature-based tourism to other Australian destinations (Environment ACT 2000; Tourism Research Australia 2009). However, tourist information (including websites) about the parks and reserves in the ACT, especially Namadgi National Park and Tidbinbilla Nature Reserve, typically includes references to kangaroos. Photographs of eastern grey kangaroos are more likely to be used in such information than any other animal. This is similar to other material of this type Australia-wide. Historically, Tidbinbilla Nature Reserve, currently visited by more than 100 000 people annually of which about one-quarter are from overseas, has been a popular destination to see kangaroos. Other favoured sites include Red Hill, Government House

(Yarralumla), Weston Park and the Royal Canberra Golf Club (MARS 2008; Micromex 2008). The wildlife spectacle provided by free-ranging kangaroo populations in some of the grassy valleys of Namadgi National Park is probably the best to be seen in the region, particularly along the Yankee Hat walking track at Gudgenby. However, these areas are further from the city than the popular Tidbinbilla, may require walking to see the animals, have fewer and basic facilities, and potentially expose visitors to starving and dead animals, including those killed by dingo/wild dog predation.

3.9.2 Rural lands

Management of kangaroo populations is a significant and contentious issue across much of rural Australia, especially in those areas where the larger and more common species are found. In these areas kangaroos may be culled under licence, and depending on location, may be included in commercial harvesting. The overall justification is one of 'damage mitigation' (effectively 'pest control') linked to (usually assumed) competition for pasture, and the concepts of 'total grazing pressure' and 'carrying capacity'. These and other considerations have been the subject of research and review in recent years resulting in some of the previous ideas and assumptions being challenged.

There are 150 rural leases in the ACT, covering 39 500 hectares or 17 per cent of the Territory. 'Rural areas' is one of the land use categories in the General Policy Plan contained within the *National Capital Plan* (NCA 2008) which states that these areas 'should be retained and utilised on a sustainable yield basis whilst providing a distinctive rural landscape setting for the National Capital' (p. 125). The *Territory Plan*, Vol 1 (ACTPLA 2008: s. 9.1) contains specific objectives for the Rural Zone (NUZ2) covering landscape setting, ecological integrity, biodiversity conservation, rural productivity and sustainability, land parcel sizes and lease periods.

Management of kangaroos on rural lands was considered by the former ACT Kangaroo Advisory Committee (KAC 1996a), which proposed that conservation of the species and damage mitigation should be the dual aims of any kangaroo management program on rural lands in the ACT. Given the relatively high densities of kangaroos on ACT rural leases, the committee gave particular attention to the potential for excessive grazing pressure to occur on rural lands deriving from grazing by livestock, kangaroos and vertebrate pests. Rural lessees considered the critical time for competition between kangaroos and livestock to be the colder months (March to October) when green herbage mass (see **Glossary**) is at its lowest. Another issue for farm management is unregulated kangaroo grazing of spelled paddocks, sown forage, and new spring growth. Where there were demonstrated impacts of kangaroos on the economic viability and ecological sustainability of rural leases, then damage mitigation by localised culling (shooting) was recommended.

Key considerations for rural lands are competition, damage mitigation, dry sheep equivalent (DSE), the concepts of total grazing pressure and carrying capacity, and kangaroo culling.

3.9.2 (a) Competition, damage mitigation and dry sheep equivalent (DSE)

Assumed competition between domestic livestock (especially sheep) and kangaroos for pasture, and an associated management approach of damage mitigation have been fundamental to rural land management throughout Australia. Most studies of dietary competition between livestock (mainly sheep) and kangaroos have been conducted in the arid and semi-arid rangelands, including studies of eastern grey kangaroos (e.g. Dawson et al. 2004; Witte 2002). In these areas, rainfall, which is unpredictable, is the main factor in pasture condition, and because pastoralism

is a marginal economic activity, kangaroos only need to affect sheep occasionally for them to be perceived as a pest (Tyndale-Biscoe 2005). Much of the rangelands has been degraded by stock grazing and the resultant vegetation changes mean that competition for available herbage may be severe in dry periods and persist for longer (Dawson and Munn 2007).

For competition to be demonstrated, one species must have a deleterious effect on another and though a dietary overlap is known to exist, the interactions between sheep and kangaroos in relation to pastures and seasonal conditions are complex (Dawson 1995; Edwards et al. 1995, 1996). The question of competition between sheep and macropods has been reviewed by Olsen and Braysher (2000), Olsen and Low (2006) and Pople and McLeod (2000). There has been limited research in temperate Australia.

Drawing mainly on rangeland research, Olsen and Braysher (2000) stated that competition between sheep and macropods is less than commonly supposed. Macropods prefer grass, whereas sheep have a more varied diet of which grass is only occasionally the main component. Competition is only considered substantial when kangaroo numbers are high and pastures poor and is not an issue when vegetation conditions are good in the rangelands (Dawson and Munn 2007), though degradation of these areas means these conditions are now less likely to occur. In reference to the rangelands, Pople and McLeod (2000) concluded that competition seldom occurs, either because food is not limiting, or because food choices or feeding sites differ.

The situation with regard to dietary competition has been less well studied in moister temperate areas. In many of these areas, the pasture contains a high grassy component. This contrasts with natural pastures of the rangelands. Also, eastern grey kangaroos are more specialised in feeding on grass than the kangaroo species of the rangelands. This means that more of the temperate pastures comprise species favoured by both kangaroos and livestock. Critical grazing exclusion studies have not been undertaken to assess the impacts of the various grazing species on pastures and sown fodder crops, partly because it is unlikely that results would be obtained that have a level of certainty to justify the cost and effect on land holders. Rather than such adaptive management experiments, understanding has been obtained from the ecological studies (Fletcher 2006a) applied to the culling records, and other observations on ACT grazing properties.

Of significance for the question of dietary competition is the reassessment of the assumption that kangaroos have 70 per cent of the food requirements of sheep (a dry sheep equivalent (DSE) of 0.7; see **Glossary**) (Olsen and Low 2006). While calling for more research, Grigg (2002) suggested that a DSE of 0.15–0.25 would be more realistic. Fletcher (2006a) noted that no single DSE value can represent well the true comparison of sheep and kangaroo consumption rates. This is because sheep eat at a lower rate than eastern grey kangaroos when the pasture is at low herbage mass and at a higher rate than kangaroos when herbage mass is high. Based on local (i.e. ACT region) measurements in both native and exotic pastures, there is support for DSE values in the range from 0.4 for harvested populations to 0.6 for unharvested ones (Fletcher 2006a). Dawson and Munn (2007) found that a DSE of 0.4 is the most relevant given that most populations in rural areas are culled or commercially harvested.

3.9.2 (b) Total grazing pressure

The ‘total grazing pressure’ concept has been used widely in both the sheep rangelands and temperate areas to consider the effect of all vertebrate herbivores on available pastures. These herbivores comprise mainly domestic stock, feral animals and kangaroos, and the DSE (discussed above) has been the means of converting their relative pasture consumption to a common unit. The grazing pressure expressed in DSE for the population of each grazing species becomes

the basis for strategic and economic decisions such as whether to harvest particular species or control them as pests (Freudenberger 1995; Grigg 2002). Olsen and Braysher (2000) concluded that total grazing pressure theory is a useful concept as it focuses on the desired outcome of amelioration or avoidance of damage to pastures. Problems with the application of the concept include the complex and dynamic nature of grazing systems, uncertainty as to the accuracy of the DSE applied, and its lack of recognition of food resource partitioning by different grazers (Croft 2000; Fletcher 2006a; Olsen and Low 2006).

The concept was adopted by the ACT Kangaroo Advisory Committee (KAC 1996a) and consideration of total grazing pressure has formed part of ACT rural Land Management Agreements, providing for a proportion of the total grazing pressure (based on DSE) for rural properties to be allocated for kangaroo grazing. Rural landholders whose leases adjoin reserves may consider that the DSE–based kangaroo grazing allocation does not make sufficient allowance for movement of kangaroos from the reserve lands on to their properties.

Despite its limitations, total grazing pressure is considered to be a useful conceptual framework for considering herbivore grazing impacts in the ACT. This is supported by the conclusions of Olsen and Braysher (2000) and Olsen and Low (2006) that management of total grazing pressure may have more applicability where damage mitigation (rather than commercial harvest quotas) is the goal of management and management is at a more confined scale, such as rural properties and reserves, where there is greater control by the manager over herbivore grazing.

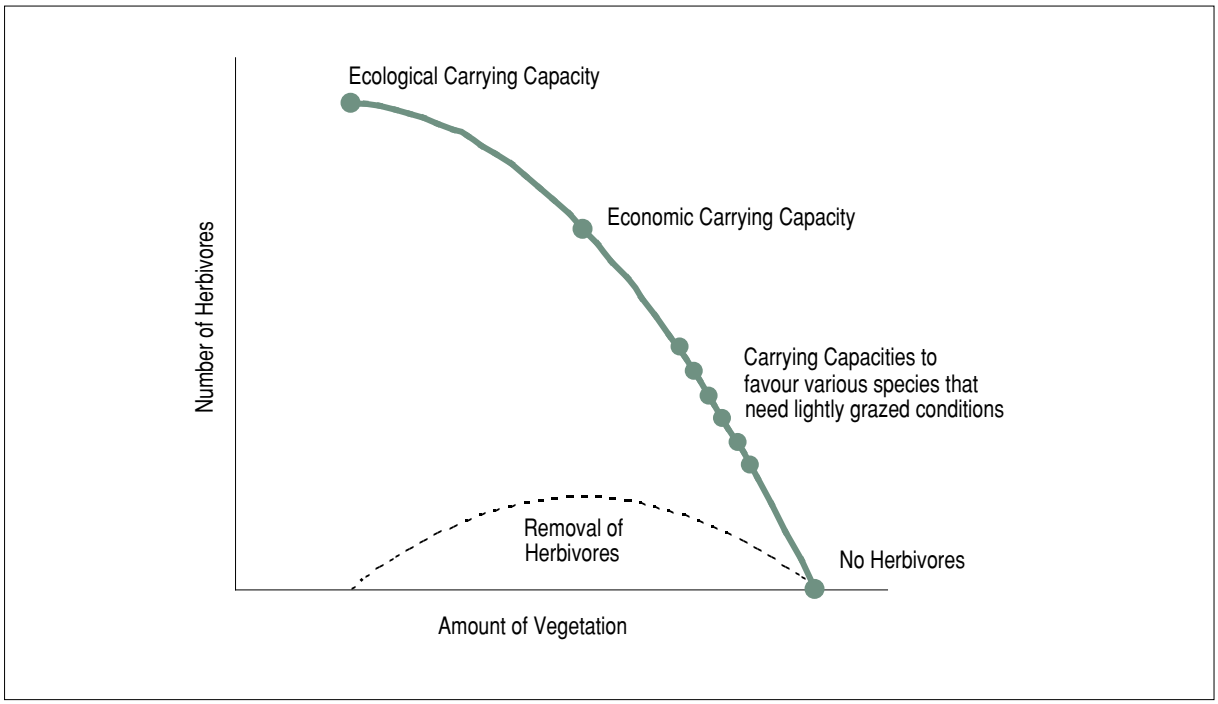
3.9.2 (c) Carrying capacity

'Carrying capacity' is defined as the number or weight of animals of a single or mixed population that can be supported permanently on a given area (Sharkey 1970 in Krebs 2001). The concept of 'carrying capacity' is appealing, but its interpretation and application is problematic even for stable environments (McNab 1985; McLeod 1997; Olsen and Braysher 2000) and many users of the term fail to appreciate the difficulty of determining and achieving it in practice. Out of the many possible interpretations of the term, Caughley (1976b, 1979) defined two that are significant in herbivore–pasture dynamics, namely:

- Ecological carrying capacity is the maximum density of animals that can be sustained in the absence of harvesting without inducing negative effects on vegetation.
- Economic carrying capacity is the density of animals that enables maximal sustained harvesting.

Ecological carrying capacity is the point that will eventually be reached by a herbivore population that is not culled or harvested and is not limited by predation. All other carrying capacities have fewer herbivores and more vegetation. Economic carrying capacity refers to a density of stock that provides maximum sustained yield and is always lower than the ecological carrying capacity. These two states are represented in Figure 3.3. Other kinds of carrying capacity can be defined, depending on the management objectives. If the aim were to maintain long grass to preserve a population of endangered reptiles, the herbivore carrying capacity, and the corresponding harvest required to achieve it, would be lower than for economic carrying capacity (Figure 3.3).

Figure 3.3 Representation of different kinds of carrying capacity



The solid line is the zero isocline of vegetation, marking the position of all possible equilibria between vegetation and herbivores. The dashed line indicates the level of culling or harvesting that is required to achieve the equilibrium. An unculled herbivore population naturally rises to the so-called 'ecological carrying capacity'. All other forms of carrying capacity are imposed by humans periodically removing animals. See text for explanation.

Ecological carrying capacity represents a natural accommodation between the growth rates of the vegetation and the herbivores. It is a long-term mean observed density of animals left to themselves i.e. it is a self-regulating system (Shepherd and Caughley 1987). Starvation will be a factor in the dynamic equilibrium of such a system. Witnesses to such a system tend to describe it as 'overgrazed' and 'beyond carrying capacity' but such terms are meaningless without reference to specific management objectives (McNab 1985). Economic carrying capacity refers to a level of vegetation where off-take of animals is maximised; however, most prudent farmers would operate below this level. It is in this context that dry sheep equivalents (DSEs) are used to determine stocking rates. A basic misunderstanding when attempting to apply the carrying capacity concept via DSEs to kangaroo management is that the type of carrying capacities recommended by regional NSW Livestock Health and Pest Authorities (for example) are only achievable through regularly taking animals to the sale yard (effectively a form of culling). Further misunderstanding is the application of a profit maximising carrying capacity to an ecosystem not managed for profit.

Economic carrying capacity has nothing to do with wildlife management unless the goal is to maximise the long-term profit from harvesting the animals. Those familiar with managing land and specifically pastures for economic carrying capacity are likely to view similar areas in a national park as either out of control or underutilised, because the yardstick is what a well-run grazing property looks like. In these circumstances, economic carrying capacity (a specific level) comes to be viewed as a generic carrying capacity (i.e. applying in all circumstances), which if it was the desirable goal, would be unattainable without continual culling (Shepherd and Caughley 1987). A further point worth noting is that early comparisons showing a higher ecological carrying capacity for wildlife rather than livestock have been found to be in error (Krebs 2001).

With regard to carrying capacity, rainfall, and in particular rainfall variability, is the crucial factor in herbivore grazing systems and nowhere is this more apparent than with kangaroo populations (Caughley 1987b; Krebs 2001; Olsen and Braysher 2000; Pople and Grigg 1999). In the ACT, temperature is also an important influence on pasture growth (Fitzpatrick and Nix 1970). In eastern Australia, during the 25 years that kangaroos have been commercially harvested and monitored, populations, especially in the rangelands, have undergone huge fluctuations and shown a corresponding capacity for recovery (2009a). Based on aerial survey data, numbers in eastern Australia have fluctuated from 14.5 million in 1984 to almost 32 million in 2002, whence they have been affected again by drought, which was the main, but not the only cause of fluctuations in the population (Olsen and Low 2006). In 2008, the population estimate for the four harvested species within the commercial harvest zone was about 26 million (DEWHA 2009b).

In marked contrast to the picture of kangaroo population dynamics in the arid and semi-arid zone (Caughley et al. 1987), kangaroo populations in the ACT have demonstrated considerable resilience to drought. For example, during the drought of 2002–03, a great reduction in food supply had little effect on kangaroo density. The reason for this may be simply the much higher herbage mass than in the rangelands, combined with the success of kangaroo survival mechanisms that allow them to bridge many of the troughs in food availability in this temperate environment (Fletcher 2006a).

3.9.2 (d) Culling

As noted earlier, kangaroo numbers in the ACT increased from the 1960s to the 1990s following a reduction in the previous levels of shooting. In response to concern by rural lessees about the economic impact of this increase, rental rebates were provided to a number of lessees, and electric fences constructed at reserve boundaries. In 1994, the ACT Parks and Conservation Service developed a policy for management of eastern grey kangaroos on rural lands that provided for limited culling. During the 1994–95 drought a few lessees took up the option, but controversy over culling kangaroos in enclosed areas in the urban area at the time resulted in the Minister not renewing culling licences. The former Kangaroo Advisory Committee investigated the matter, recommending that damage mitigation by localised shooting be permitted on rural leases (KAC 1996a). A culling program for rural leases based on an annual licence system commenced in 1998.

The Committee also noted that there were no reliable long-term data on kangaroo numbers and it was essential to develop a program of ongoing research, including population surveys, to determine long term trends in kangaroo numbers in the ACT. ACT Government supported research and survey effort since 2001 has been devoted to an ecology research project. As part of this, kangaroo density was monitored intensively at three sites in reserves over two years and methods of estimating density assessed (Fletcher 2006a). There has been no recent survey of densities on rural lands.

3.9.3 Other lands

These areas include ACT Government managed land, leased Territory Land and Commonwealth managed National Land (see s. 2.2). Management of kangaroo populations on these lands can be expensive, controversial, and require methods that take account of the proximity to urban populations. Some of the areas have large numbers and/or high densities of kangaroos. Government horse paddocks are one category of land use for which there are many parallels with rural leases (KAC 1997). There are 17 paddock complexes in the ACT covering 1038 hectares of mostly unleased Territory Land and located mainly on the margins of the urban area. Damage mitigation (see **Glossary**) is the main consideration, with horses and kangaroos competing for pasture. Kangaroo populations in these areas are free-ranging (see s. 6.3).

In some areas, which may be relatively large, kangaroo populations are effectively captive due to their location inside boundary security fences. These populations require site based management if it is decided to maintain them at the location (see s. 4.4.4).

3.9.4 Vehicle collisions and collision avoidance

The presence of free-ranging kangaroos along roadsides has a significant adverse economic impact in the ACT due to collisions between kangaroos and motor-vehicles (including motorcycles) and accidents derived from collision avoidance. These also have animal welfare and social impacts. Throughout Australia, there is a lack of consistent, systematically collected data on kangaroo–vehicle collisions, but there is enough data to form a general picture of kangaroo related road trauma. The Queanbeyan, Yass and Goulburn triangle is identified as a 'hotspot' for kangaroo-vehicle collisions across the ACT and New South Wales as a whole (Ramp and Roger 2008). In a survey of Canberra residents in 2008, of the respondents who had ever owned an ACT registered vehicle, 17 per cent stated that the vehicle had hit a kangaroo on an ACT road (Micromex 2008). Canberra is unique among Australian cities in having large populations of free-ranging kangaroos within and on the margins of the urban area. The situation most similar to that of the ACT, with the presence of a large wild herbivore in close proximity to urban populations, is that of deer in North American cities.

Collisions often result in serious injury to, or death of the kangaroo, costly damage to the vehicle, and may involve death, trauma and/or injury to the occupants of the vehicle, motorcycle riders and cyclists. Most accidents occur after dark or during the dawn/dusk periods. The main issues arising from, and factors contributing to, vehicle–kangaroo collisions are summarised below:

- Kangaroos struck by a vehicle may be killed outright, injured but able to leave the site (to recover or die elsewhere), or injured and immobilised. Those that leave the site are only occasionally found. Immobilised animals invariably need to be destroyed. The euthanasia of a large, injured kangaroo may be dangerous and to do this in a public place requires skilled handling, taking account of public sensitivities and safety.
- Data from the ACT Parks and Conservation Service and the NRMA show that there are 'hot spots' for collisions. These are typically freeways and major urban arterial roads that have higher speed limits and traverse areas separate from residential areas.
- There are a range of factors that contribute to the prevalence of vehicle–kangaroo accidents in the ACT. These include: high kangaroo numbers and the extensive open space areas of Canberra; major roads bisecting natural movement corridors; attractive roadside herbage; high speed roads with frequent traffic; driver inattention and ignorance of potentially high risk road sections; the funnelling effect of some roads with central concrete and vegetation barriers; climatic conditions (e.g. drought) that result in kangaroos moving at night into suburban areas to feed.
- Motorcyclists are inherently vulnerable to injury. Data from a north Queensland study showed a statistically significant higher proportion of motorcyclists involved in reported animal road crashes than all other road crashes (Rural and Remote Road Safety Study data analysed in Rowden et al. 2008).
- There are no simple solutions to the problem. Mitigation methods can be expensive (e.g. fencing), of doubtful efficacy (e.g. wildlife reflectors), difficult to retrofit (e.g. underpasses) or not favoured by motorists (e.g. lowering speed limits).

Worldwide there has been considerable effort to develop strategies and techniques to reduce the incidence of vehicle–wildlife collisions (Mata et al. 2008; Ramp 2010; van der Ree et al. 2006). The closest parallel to the Australian situation with kangaroos is deer–vehicle collisions in North America and Europe, and mitigation techniques used there have been considered in Australian approaches. There are three broad factors that contribute to the potential for collisions: the attributes of the road; the behaviour of the animal(s); and the behaviour of the driver (Bender 2001). Mitigation strategies may focus on modifying one or more of these factors. In Australia, drought is also a contributor to rates of road-kill (Coulson 1989; Lee et al. 2004). In recent years more attention has been given to integrating the mitigation of wildlife road-kill into the planning, design and maintenance of major roads (e.g. Department of Infrastructure, Energy and Resources, Tasmania, 'Code of Practice' in Magnus (2006); Pacific Highway upgrade work (NSW RTA 2008); Gungahlin Drive Extension in the ACT, (Roads ACT, Department of Territory and Municipal Services)).

The range of potential techniques to manage the conflict between motorists and free-ranging kangaroos is briefly reviewed below and summarised in Table 3.4. Electronic animal detection and animal warning systems are not considered here as only a few of these systems have been installed, all in North America and Europe. Reliability, technical and maintenance issues have been reported with these systems, which are relatively new technology (Gordon et al. 2004; Huijser and McGowen 2003). *Animal detection systems* detect animals as they approach the road e.g. when animals break infrared beams. When an animal is detected, signs are activated that warn drivers that animals may be on or near the road at that time. These are reported to have been successful in reducing accidents in Finland (Taskula 1997 in Clevenger et al. 2001). *Animal warning systems* detect vehicles and alert animals through a range of audio and visual signals from stations placed in the right-of way (Huijser and McGowen 2003). In a review of these systems, Huijser and McGowen (2003) conclude that they have the potential to be an effective mitigation tool but require further research and development.

3.9.4 (a) Attributes of the road

Various road-kill mitigation measures based on modifying the attributes of the road and/or its surrounds have been trialled, installed, or are recommended for roads in different parts of Australia. These include fencing, underpasses, overpasses (fauna bridges), escape routes, table drain management, traffic slowing devices, odour repellents, roadside lighting and light coloured road surfaces (Magnus 2006; Abigroup n.d.). Underpasses and overpasses are generally applicable only to new road design or major upgrades of existing roads. To date, no study has linked the installation of a physical road structure with a reduction of macropod fatalities or the facilitation of movement where none was previously possible, though evidence has been obtained for other species in Australia and elsewhere (Ramp 2010).

Fencing to exclude animals from roads and guide fences associated with underpasses and overpasses are being used increasingly along major highways and motorways in Australia and overseas, especially where roads traverse habitats of rare or threatened species (Abigroup n.d.; HCCREMS 2009; NSW RTA 2008; Queensland Department of Main Roads 2000; Rowden et al. 2008). Fencing of sections of the Trans-Canada highway in Banff National Park, Alberta, is reported to have resulted in a decline of 80 per cent in ungulate–vehicle collisions (Clevenger et al. 2001). Design is important as fencing can have serious implications for the movement of kangaroos and other wildlife and may trap animals on the wrong side.

It is appropriate to reappraise the use of fencing in higher risk areas (hotspots) as part of new or upgraded roads in the ACT, in association with the installation of underpasses. For kangaroos,

fences need to be high (1.8 m) and of chain-wire construction. Wing fencing and underpasses have been installed on sections of Gungahlin Drive in the ACT and numerous kangaroo movements take place through the underpasses. Fencing against kangaroos needs to be strategically placed, as it is not feasible to attempt to fence off all roads.

Underpasses for wildlife have been studied for some time in Australia and overseas (Bennett 1998) and included in new roadworks and major upgrades (e.g. Gungahlin Drive Extension (ACT), F3 Freeway and Pacific Highway upgrades (NSW), East Evelyn Road upgrade, Atherton Tablelands (Qld)) (AMBS 2002; Goosem et al. 2001; NSW RTA 2008; van der Ree 2006). Generally, funnel or wing fencing is also necessary to guide animals through the underpass (Magnus et al. 2004). There are two purposes of underpasses: a) to maintain habitat connectivity for movement, dispersal and genetic linkages; and b) to mitigate road-kill at collision hotspots and areas with high biodiversity values and/or habitat for threatened species. Larger animals of open forest and grassland habitats, such as kangaroos and wallabies, are unlikely to use underpasses unless the opening is large, as smaller structures may act, or appear as, a predator trap or simply be too small for their body size (Hunt et al. 1987; Rodriguez et al. 1996). It has been suggested that larger animals prefer shorter lengths with clear lines of sight from entry to exit (Goosem et al. 2001; Magnus et al. 2004); though use of longer underpasses has been recorded (AMBS 2002). No rigorous evaluation has been published to date of the effectiveness of underpasses generally for reducing road trauma in Australia (Rowden et al. 2008).

Overpasses (fauna bridges) serve the same purposes as underpasses but have been less used or investigated in Australia due to the high cost of building and maintaining bridge type structures, or tunnelling roads through hilly areas. Overpasses are generally most appropriate where a road is constructed through a cutting or tunnel in hilly terrain. If canopy vegetation is to be planted or maintained, a substantial depth of soil has to be maintained on the structure compared with other types of overpasses (Abigroup n.d.; HCCREMS 2009). Similar to underpasses, fences are generally necessary to guide animals to an overpass. Initial surveys of the use by animals of overpasses in north-east New South Wales (Hayes and Goldingay 2009) and south-east Queensland (Bond and Jones 2008), indicate that macropods use overpasses and may favour these over underpasses (Hayes and Goldingay 2008).

The following techniques have been trialled in other parts of Australia with the aim of reducing road-kill. They are likely to have only limited application to the broad-acre management of free-ranging kangaroos in the ACT. *Escape routes* (e.g. paths of lower gradient cut into roadside batters or cuttings) are designed to allow the exit of animals that have become trapped on the road where there are banks, cuttings or fences. They have been trialled in Tasmania and are considered to be highly successful (Magnus et al. 2004). *Table drain management* involves the management of road verges to make the areas less attractive to grazing herbivores. The presence of cleared, grassed areas and slashing and mowing of verges that encourage the growth of new shoots attract grazers such as kangaroos (Osawa 1989). However, grass cutting on verges is undertaken for reasons such as motorist safety (providing a visible road verge should a vehicle need to move off the road), reduction in fire risk, improved visibility generally, and road/highway aesthetics. Traffic speed is a major factor in wildlife road-kill. While *traffic slowing devices* are appropriate for roads such as those in protected areas such as national parks, they are inappropriate for major roads and highways. *Odour repellents* (that mimic canine urine) have been trialled for macropods with some initial success (Ramp and Croft 2002). There is insufficient information to evaluate their use, for example, in collision hot spots. *Roadside lighting* has been suggested as a road-kill mitigation measure aimed at discouraging wildlife from loitering on the road due to their increased visibility to predators (Magnus et al. 2004). Many of the major roads in the ACT where

kangaroo–vehicle collisions occur have lighting and the animals may be habituated to this, as well as having reduced sensitivity to predator threat. Lighting also improves the detection of animals by car drivers. It has been suggested from observations in Tasmania that *light-coloured road surfaces* may result in decreased road-kill (Jones 2000). This has not been trialled and would only be applicable to significant hotspot areas.

3.9.4 (b) Modifying animal behaviour: wildlife warning reflectors and 'ultrasonic' devices

Reflectors and vehicle mounted 'ultrasonic' devices are intended to deter animals from venturing onto the road when a vehicle is approaching. Both are available as proprietary products. On current knowledge, there is no unequivocal evidence that these products are effective. Many studies into these devices have been criticised for lack of statistical rigour, and research results show that manufacturers may make unfounded assumptions or assertions about animal behaviour.

There has been more research into the responses of deer to these types of products than for kangaroos. This deer research indicates the caution necessary in accepting unsupported statements about animal behaviour (e.g. Gilsdorf et al. 2004a, 2004b; Van Cauteren et al. 2003, 2006). Ramp (2010) suggests that a more fertile area of research would be to explore the response of kangaroos to natural sounds derived from themselves (e.g. foot thumps) or predators, as long as the repellent sound could be heard above normal vehicle sounds (see also, Bender 2005; Rose et al. 2006). Another potential line of enquiry is animal reactions to different types of headlights. In North America, certain types of commercially available headlights have been found to cause white-tailed deer on roadsides to move away sooner from approaching vehicles. These are lights producing illumination more closely matching the visual sensitivity of the species (Blackwell and Seamans 2009). Although this study was small and affected by design limitations, the topic may be a productive one for research in relation to eastern grey kangaroos, particularly if the result of the deer study is validated by other studies.

Wildlife warning reflectors were developed by the Austrian company Swareflex® in the 1970s to prevent collisions with large ungulates (especially deer) in Europe, and were modified and marketed in the USA and Canada by Strieter Corporation® (Strieter-Lite) in 1994. The reflectors are placed at fairly close spacing (< 38 m) to solid guide-posts (e.g. timber rather than the more modern pressed metal or plastic posts) on both sides of the road and reflect light into the eyes of animals either on the road or on the verge. This reflection is designed to result in animals fleeing the road before the vehicle arrives and to create an 'optical fence' that deters animals from approaching the roadway until after the vehicle has passed (Lintermans 1997; Ramp and Croft 2006).

Despite their use for about 30 years in North America and Europe, the results remain equivocal. Early studies reported opposite effects (e.g. a significant reduction in deer road-kill (Schafer and Penland 1985) and no effect (Reeve and Anderson 1993)). A review by Danielson and Hubbard (1998) noted the poor statistical design of studies and also that there was little evidence supporting the claim that deer can distinguish red as a colour. The latter conclusion is supported by more recent research showing that deer cannot detect wavelengths in the red portion of the spectrum (VerCauteren et al. 2003) nor can they detect green or blue (VerCauteren et al. 2006). An extensive review of deer-vehicle collision counter-measures by Knapp et al. (2003) was also unable to provide a conclusion about their effectiveness. D'Angelo et al. (2006) studied deer responses to four colours of wildlife reflector and concluded they were ineffective in changing deer behaviour such that deer-vehicle collisions would be avoided.

There has been interest in using the reflectors in Australia and trials have been conducted, including one established in 1995–96 on Mt Ainslie Drive in the ACT (Lintermans 1997). Though reduced animal fatalities with use of reflectors in Australia have been reported (e.g. Johnson et al. (1993) and O'Rourke (1990) in Ramp and Croft (2006)), the results are not conclusive. The Mt Ainslie trial was too limited to be scientifically valid and it was noted that many of the assumptions underlying the purported operation of the reflectors were untested (Lintermans 1997). To avoid the pitfalls of field trials, Ramp and Croft (2006) undertook a rigorous captive study with red kangaroos and red-necked wallabies. The result of this was that the reflected light failed to evoke a sufficient alerting or evading behavioural response that would result in fewer collisions. They concluded that 'installation of wildlife warning reflectors on highways at hotspot locations must be treated as a dubious solution to the problem of wildlife-vehicle collisions in Australia' (p. 589). Magnus (2006) also states that amongst the range of road-kill mitigation measures, reflectors are not recommended at this time. As well as the doubt about effectiveness, the high costs of placement and maintenance, and the need for solid mounting posts, are significant issues.

Ultrasonic devices are of two types: small whistles or similar devices that are attached to the outside of a vehicle and are activated by the air flow past the moving vehicle; and electronic devices powered from the vehicle battery that emit a sound through speakers attached to the unit normally mounted on the front of the vehicle. The whistles are cheap (from about $4 a pair) while the electronic form is much more expensive (approximately $500 plus fitting). Manufacturers of these products make a range of claims about their effectiveness based on testimonials, statements about animal behaviour, sound frequency (e.g. ultrasonic), sound pressure levels (decibels), and signal spread and strength.

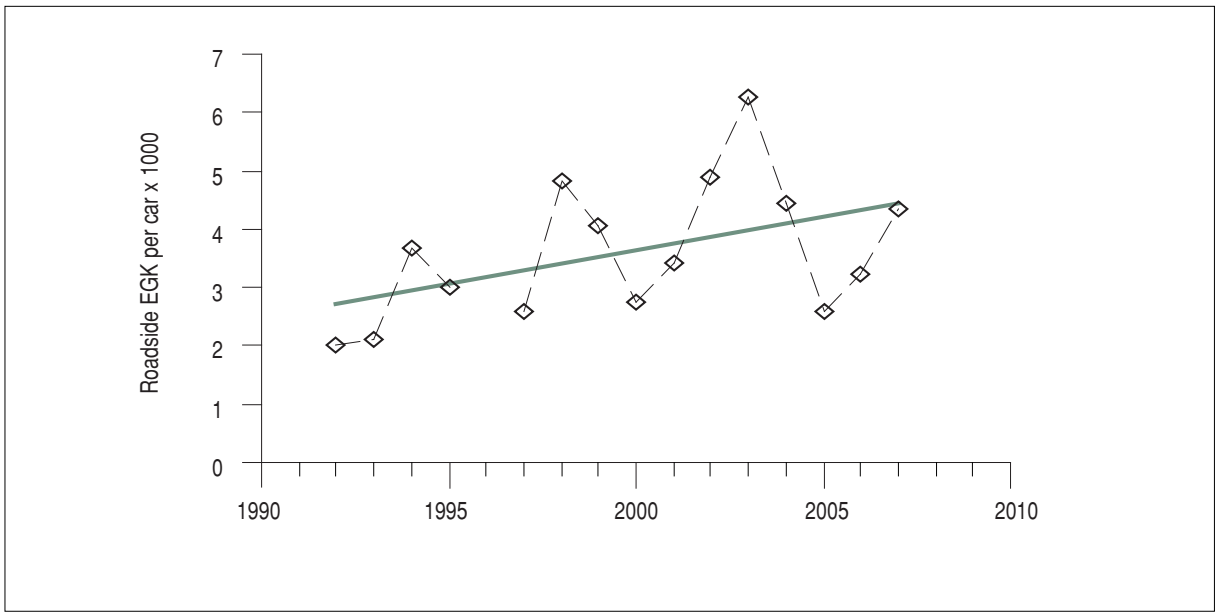
Scientific studies based on laboratory and field trials (including tests by transport operators) have found that these products generally do not match manufacturers' claims, that there is no evidence for statements about animal behaviour, and that there is no statistically significant difference in animal–vehicle collisions whether or not the devices are fitted/activated (Bender 2001, 2003; Magnus et al. 2004; Muirhead et al. 2006). Kangaroos have evolved flight in an unpredictable direction along an erratic path to deal with high-level threats, as opposed to stationary vigilance behaviour for lower level threats. If ultrasonic devices do provoke a flight response and encourage animals to move away, this could be counterproductive for kangaroos as their unpredictable movement may be into the path of the oncoming vehicle (Lee et al. 2010). Nevertheless, many individuals and organisations (e.g. businesses) believe these products are effective, often based on whether vehicle–kangaroo collisions have occurred before and after fitting, or on vehicles traversing the same road with and without the device fitted. While these observations would generally not stand up to statistical testing, prospective purchasers are able to make their own decisions regarding effectiveness and the claims of manufacturers. Bender (2001) suggests that the fitting of an electronic device combined with the manufacturer's advice about reducing speed in higher risk areas, may have an effect in modifying driver behaviour, and therefore the owner's assessment of the effectiveness of the device.

3.9.4 (c) Modifying driver behaviour

The three most significant risk factors for kangaroo–vehicle collisions in areas where kangaroos are likely to be encountered are driving in the period between dusk and dawn, driving at high speed, and driver inattentiveness. Of the intervention actions examined by the former Kangaroo Advisory Committee (KAC 1997), its highest estimation of practicality was for an education campaign to modify driver behaviour.

Kangaroo road-kill data for the ACT urban area is derived from two main sources: records of ranger attendance at accident sites to deal with dead or injured animals; and data from motor vehicle insurers related to claims for vehicle damage following collisions or collision avoidance (when the vehicle hits something else or runs off the road). Analysis of all available data from ranger attendances over a seventeen year period (1990–2008) using a Poisson rate model (P Caley pers. comm.) shows there has been a significant increase in the rate per car of vehicle collisions with kangaroos (collisions/1000 vehicles registered). Thus the increase in the number of collisions (Figure 3.4) is not merely a result of there being more suburbs and more motor vehicles in Canberra. In addition, the risk per car of hitting a kangaroo has increased. Other factors which may be responsible for the wide variation that is apparent around the general trend of increase in Figure 3.4 include pasture availability, ranger availability, and changes in the demand for other ranger work such as bush fire suppression.

Figure 3.4 Ranger attendance at sites of kangaroo–vehicle collisions in Canberra per 1000 motor vehicles registered in the ACT (See text for explanation)



From the same data, collision 'hotspots' have also been identified, which are roads that have the most kangaroo carcasses per kilometre of roadside. These are typically road sections with a high level of traffic flow adjacent to bush and grassland areas (Woodward 1994).

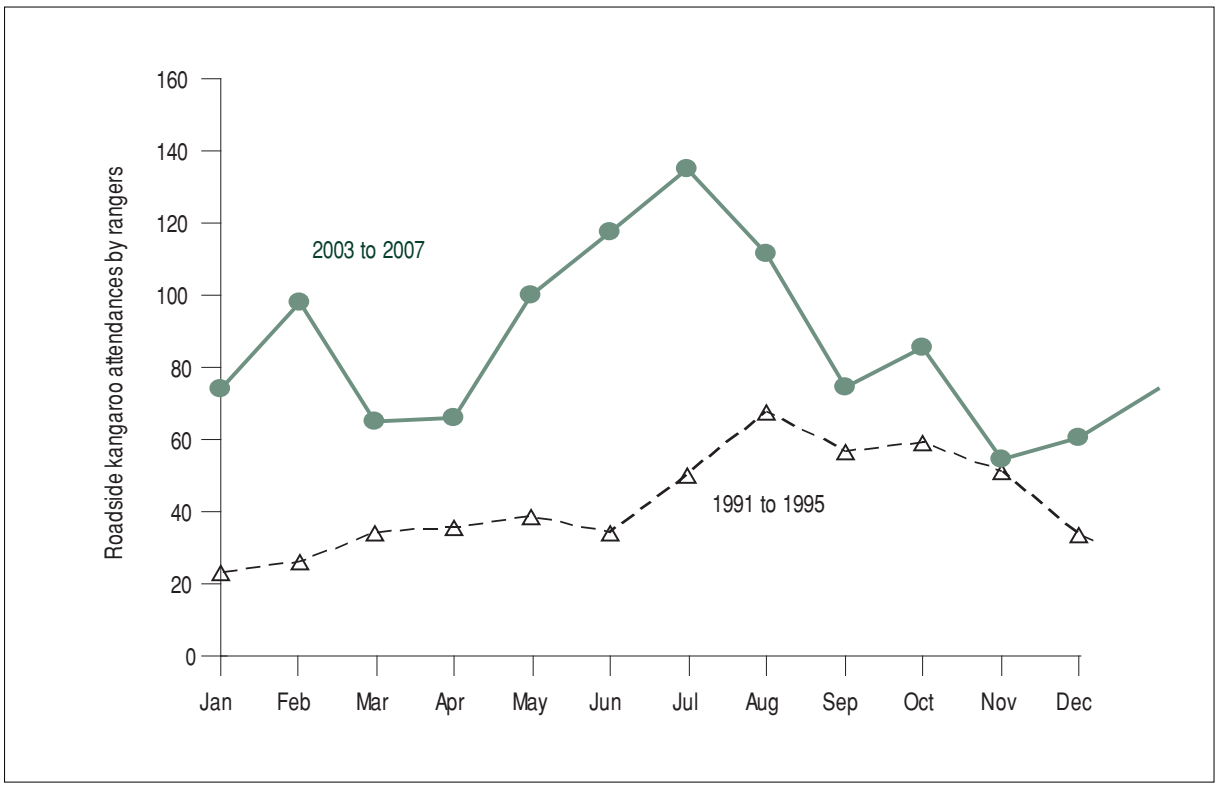
Based on the records from 2003 to 2007:

- *Hotspots* were Limestone Ave, Sulwood Drive, William Hovell Drive, Antill St, the former Caswell Drive (now part of the Gungahlin Drive Extension), Woodcock Drive, Monaro Hwy, Long Gully Lane, Yamba Drive, Athllon Drive, Tuggeranong Parkway, Tharwa Drive and Erindale Drive.
- *Exceptional hotspots* were Fairbairn Avenue, Hindmarsh Drive, Mugga Lane and Majura Lane.

It should be noted that Parks, Conservation and Lands does not have a policy of leaving kangaroo carcasses by the side of the road to warn motorists of the collision potential. However, the priorities in collecting 'reported' or 'discovered' carcasses mean that carcasses may remain on the roadside for a period of time and serve a warning function. Unreported carcasses may remain for some time, as there is not a dedicated 'carcass patrol' operating on Territory roads.

The same data also suggest that the seasonal timing of collisions with kangaroos has changed, the peak months for collisions with kangaroos now occurring earlier in the year (Figure 3.5).

Figure 3.5 Seasonality of kangaroo roadkill in Canberra suburbs based on roadside ranger attendance: (a) 1991–1995; (b) 2003–2007



a) 1991–1995 (hollow triangles and dashed line)
b) 2003–2007 (solid circles and continuous line)

In the colder months, but not in the spring months, the number of attendances in 2003–2007 is higher than in 1991–1995 to a statistically significant degree. There are several hypotheses which could explain the change, but in any case it has clear implications for the driver education campaign which was previously conducted in August–September. Future campaigns might do better to target the whole year, or start in autumn. From data collection and analysis in the ACT, New South Wales and some other states, the following observations can be made about collisions with kangaroos and most of these have implications for driver behaviour and education:

- The peak time for crashes is between 5 pm and 10 pm.
- The rate of crashes is higher from late autumn to early spring and this correlates with the increased length of darkness.
- Poor weather conditions do not play a role in causing collisions.
- Collision avoidance responses by drivers result in collisions with other objects (though this may be overstated in insurance claims).
- Collisions with animals do result in human fatalities and kangaroos account for the highest proportion of these. Motor cycle riders are very vulnerable.
- There is evidence for an inverse relationship between the seasonal frequency of road-kills and rainfall in the previous season.
- There is evidence for higher road-kill levels during the full and last moon phases. This is most likely related to changes in kangaroo behaviour associated with illumination levels.

- A higher proportion of male kangaroos, especially immature males, are killed in vehicle collisions.

(Abu-Zidan et al 2002; Coulson 1982, 1989; KAC 1997; Lee et al. 2004; Lintermans and Cunningham 1997; Ramp and Roger 2008; Rowden et al. 2008; unpublished data, Parks, Conservation and Lands)

The cost of kangaroo–vehicle collisions is significant for motor insurers and one response on their part is to issue media releases in winter/early spring to warn drivers of the risk. Information and data obtained from NRMA Insurance and AAMI indicate the high proportion of ACT/NSW 'hit animal' claims in the Canberra area. In recent years, NRMA has recorded around 600 kangaroo accident claims annually, which is almost 90 per cent of their animal collision claims in the ACT. AAMI, another major insurer, has about 30 per cent of its ACT/NSW 'hit animal' claims based on Canberra (this includes accidents occurring outside the ACT but claims settled through the Canberra office). The average cost of these collisions is in excess of $3000.

Following the recommendation of the former Kangaroo Advisory Committee, a community awareness program was run in 2000–2002 focussed on driver awareness and behaviour ('Kangaroos Cross Roads'). A more substantial campaign was run in 2004 by the ACT Government in conjunction with, and financial support of, the NRMA involving 'Give kangaroos a 'brake'!' publicity and the installation of advisory signs at road 'hot spots'. Hotspots were identified in the publicity, which included brochures, bus back advertising, radio, television, website and newspaper articles.

Following the awareness campaigns, assessments were undertaken of their effectiveness. Surveys of 200 households showed a high level of awareness of the advertising at 54 per cent (2002), 54 per cent (2003) and 70 per cent (2004) (MARS 2004). *The Canberra Times* newspaper was the most effective type of media in raising awareness, identified by 34 per cent (2002), 29 per cent (2003) and 39 per cent (2004) of respondents. Recall by respondents of the *specific* messages was limited: in 2004, 28 per cent for 'Slow down' and 7 per cent for 'Give Kangaroos a Brake' (declining from 45% and 17% respectively in the previous year). However, the majority of respondents who were aware of the campaign considered it to be effective. Awareness of the 'Kangaroos near Roadways' message was weakest in under-29 age group.

It is much more difficult to estimate the effectiveness of such campaigns in terms of actual collision reduction because conclusions are potentially confounded by other factors such as climatic conditions. As shown in Figure 3.4, ranger attendance in the urban area indicates that the number of kangaroo collisions with vehicles has not decreased.

Worldwide, road warning signs are a widely used technique aimed at modifying driver behaviour and are often recommended together with other measures. Their effectiveness in terms of collision reduction is uncertain and their benefits may be small in relation to the cost involved. In a Victorian study, Coulson (1982) found kangaroo warning signs to be ineffective in reducing the incidence of road-kill. A five-year Queensland study found that vehicle speeds did not reduce and mortality of koalas did not decline following the placement of signs (Dique et al. 2003). Alternatively, Sullivan et al. (2004) concluded that there is evidence that temporary, prominently displayed signs are effective in reducing deer–vehicle collisions in North America. It has been suggested that signs have an effect on some individuals and that erecting signs can be regarded as fulfilling a 'duty of care' (Magnus 2006). Magnus et al. (2004) have developed a protocol for determining and prioritising black spots for treatment, noting that signs should be at genuine 'black-spots' and avoid 'sign clutter'. The use of eye-catching graphics rather than text is another consideration.

3.9.4 (d) Summary assessment of potential interventions

In a review of road crashes involving animals in Australia, Rowden et al. (2008) concluded that:

No broad-scale effective countermeasure has been identified to date that reduces the occurrence or severity of animal-related crashes, highlighting the need for a multifaceted approach to the problem with regard to driver behaviour, road design, animal behaviour, and related environmental influences.

A summary assessment of potential interventions to manage conflicts between motorists and kangaroos is contained in Table 3.4, including assessments from the former Kangaroo Advisory Committee (KAC 1997).

Table 3.4 Current assessment of potential intervention actions to manage conflicts between vehicles and kangaroos in the ACT

Type of Intervention	Current Assessment of Expected Practicality/Effectiveness
Attributes of the Road	
1. Kangaroo-proof fences along roads that traverse kangaroo habitat	Consider for high-risk areas as part of new roads and upgrades, in conjunction with underpasses (or overpasses). It is not feasible to fence off dispersed kangaroo populations that interface with long sections of roads.
2. Underpasses	Evaluate in high-risk areas as part of new roads and upgrades, in conjunction with fencing, including 'wing' fencing. Underpasses may be combined with bridges over drainage lines.
3. Overpasses	Less suited to the ACT due to lack of hilly terrain where major roads are constructed. High cost of construction and maintenance.
4. Other: **a)** Escape routes, table drain management ..... **b)** Traffic slowing devices, odour repellents, roadside lighting, light coloured road surfaces	 **a)** Could have specific local application. ..... **b)** Not considered to have any practicality for ACT roads that have high levels of kangaroo–vehicle collisions.
Modifying Animal Behaviour	
1. Wildlife warning reflectors	Research has failed to demonstrate effectiveness. High cost of placement and maintenance. Need for solid mounting posts. Impractical unless shown to be effective.
2. Ultrasonic devices fitted to vehicles	Research has failed to demonstrate effectiveness. Impractical unless shown to be effective.
Modifying Driver Behaviour	
1. Education and awareness campaigns	Have been undertaken, though results in terms of collision reduction are uncertain. Periodic driver awareness programs are appropriate.
2. Signs placed at 'hotspots'	Has been undertaken, but results in terms of collision reduction are uncertain. Appropriate and 'duty of care' to continue using signs.
3. Leaving kangaroo carcasses on road edge	Results in terms of collision reduction are unknown. Not current policy, though some carcasses may be on roadside for some time as collection/removal depends on reporting of presence.
Other	
1. Bull bars and nudge bars fitted to vehicles	While individual vehicles may have protection this is not a practical solution for all vehicles. Potentially serious effects on other road users and pedestrians.

2. Vehicle driving lights	Not suitable for urban areas. Professional drivers suggest effectiveness outside the urban area (Magnus 2006).
3. Culling in habitat areas adjoining high speed roads.	Likely to be ineffective at a localised scale (e.g. 200m either side of road). Potentially effective at a larger scale but impractical in many areas. Issues: public safety, community acceptance, costly. In some instances, roadsides may benefit indirectly from culling on nearby land (e.g. rural culling).

3.9.5 Commercial kangaroo harvesting

3.9.5 (a) The harvest Australia-wide

Commercial kangaroo harvesting is based upon the taking of wild, free-ranging kangaroos to realise an economic value. Kangaroo products are meat (human and pet food) and skins, hides and leather. This is distinguished from kangaroo culling which refers to manipulating kangaroo populations to achieve other objectives, such as reducing grazing pressure on pastures, but does not realise a direct economic value from the culled animals. The origins of the commercial harvesting industry trace to rural support for it as self-funding pest control (AWMS 2004a). The industry commenced in the late 1800s based on kangaroo skins and developed slowly. By the 1950s, the trade had extended to meat (for pet food) following the collapse of rabbit numbers due to the spread of myxomatosis. The network of refrigerated 'chiller boxes' formerly used for rabbits became available for use for kangaroos. From 1955 to 1969, meat was exported for human consumption, but this ceased in the 1970s when poor meat quality resulted in importing countries closing the trade. There was also a Commonwealth ban on the export of kangaroo products (1973–1975) and an import ban by the United States Government (1974–1981), the latter following claims that the large kangaroos were in danger of extinction (Hercock 2004; Poole 1984; Pople and Grigg 1999; Shepherd and Caughley 1987).

These events resulted in greater Commonwealth involvement in, and regulation of, the kangaroo trade from the 1970s, the setting up of enquiries to review aspects of the trade, and the preparation of a *Code of Practice for the Humane Shooting of Kangaroos* (CONCOM 1990), revised in 2008 (see s. 2.1.3(a)). The Commonwealth and state frameworks for the operation of the industry have been progressively developed since that time. Commonwealth control over the industry is currently under the provisions of the *Environment Protection and Biodiversity Act 1999* (EPBC Act). Commercial harvesting operates under state-based management plans that are approved by the Commonwealth. Victoria, the ACT and the Northern Territory are not participants at this time in the industry.

The mainland commercial harvest currently comprises four species: red kangaroo, eastern grey kangaroo, western grey kangaroo and common wallaroo or euro. Wallabies but not kangaroos are commercially harvested in Tasmania (Bennett's wallaby *Macropus rufogriseus rufogriseus* and the Tasmanian pademelon *Thylogale billardierii*) and this is confined to Flinders and King islands. Nationally, the red kangaroo and the two grey kangaroo species comprise 90 per cent or more of the harvest. Their combined populations Australia-wide have fluctuated between 15 and 50 million animals over the past 25 years, depending on seasonal conditions (DEWHA 2009a). In 2005, the total value of the industry to the Australian economy was estimated at $200 million dollars annually and it is a significant contributor to the economy of rural areas, employing 4000 people (Thomsen and Davies 2007).

Though its origins derived from a view of kangaroos as pests, the modern commercial industry is based on treating kangaroos as a resource to be managed sustainably (DEWHA 2009a; Pople and Grigg 1999). This approach is expressed in the current NSW commercial harvest plan, which states the following goal (NSW DEC 2006):

> To maintain viable populations of kangaroos throughout their ranges in accordance with the principles of ecologically sustainable development.

The principles are those defined in the EPBC Act. The NSW plan is based around seven supporting aims directed to achievement of the goal. In line with the approach that treats kangaroos as a resource rather than a pest, the NSW plan discontinues damage mitigation as grounds for harvesting. As in other states, some landholders still perceive damage mitigation to be the main reason for harvesting and call for greater quotas especially during drought years (Olsen and Low 2006; Pople and Grigg 1999). A commercial quota that met the damage mitigation expectations of every landholder would be much higher than the sustained yield based quota and would prevent the harvesting industry being economically sustainable in the long-term. Non-commercial culling may be undertaken by landholders both inside and outside the commercial harvest zone, enabling them to achieve damage mitigation objectives. In New South Wales and South Australia, 'special quotas' allow for the commercial utilisation of these kangaroos, but in recent years, these have not been used (DEWHA 2009c).

There is now a vast amount of information on the harvested kangaroo species including estimates of population numbers, which are assessed annually (Pople 2004; Pople and Grigg 1999). The harvest strategy in all states is based on a percentage of the population considered appropriate to harvest and therefore requires an estimation of total population. Methods of estimating kangaroo density on a large scale have a long history and are reasonably well understood. Strip-counts from fixed-wing light aircraft date from the 1960s and are generally used, though line transect surveys using helicopters have increased in recent times (Olsen and Low 2006) (Appendix 1). Estimates are still considered to be conservative, providing a further buffer against over-harvesting (Pople 2004).

There are now long-term data, over 20 years in some cases, on numbers, harvest off-take and composition for each of the commercially harvested species in regions throughout Australia (Pople 2004). These show that population numbers have been maintained for all the harvested species (Olsen and Braysher 2000; Payne 2007). The major determinants of population levels are not off-take, but changes in land use and in particular, seasonal conditions that determine pasture levels (NSW DEC 2006; Payne 2007). While quotas have been generally in the range of 15–20 per cent of the population depending on species, the actual off-take is less than this, averaging 70 per cent of the quota in the period 2001–2007. For example, in the period 2001–2005 the harvest was 63 percent of the quota, while the long-term trend is about 80 per cent (DEWHA 2009c; Pople and Grigg 1999).

The high level of scrutiny and the detailed scientific analyses that have been applied to the commercial harvesting industry show that in terms of the ecologically sustainable development framework, the industry is ecologically and economically sustainable. However, the social dimension remains intractable due to the lack of cultural acceptability of kangaroo products (Hercock 2004). In addition, animal rights arguments will always remain outside the framework of analysis used to assess the commercial kangaroo industry. Animal rights based arguments that cross to the suggestion that the harvested species are in some way threatened (see, for example, Thorne 1998, and papers in Wilson and Croft 2005) clearly are without foundation when considered against the accumulated evidence.

Concern has been expressed that commercial harvesting of kangaroos selectively removes individuals with certain traits from the population, which may eventually result in the loss of adaptive genotypes or genetic diversity, and a decline in evolutionary fitness (see **Glossary**) (Olsen and Low 2006). This concern is featured in literature opposing commercial harvesting often with a focus on 'alpha' males (e.g. Croft 1999; Rogers 2005; Australian Wildlife Protection Council 1999). Since 2000, several studies have addressed this issue via molecular genetics and predictive modelling (e.g. Hale 2004).This is summarised by Olsen and Low (2006) who conclude that there is an absence of theoretical, empirical or modelled evidence of genetic effects at current levels of harvesting. Hale (2004) suggests that fitness in large males is unlikely to be greater than in smaller males because all males will have been subject to viability selection by the time they are old enough to breed. Nevertheless, Olsen and Low (2006) conclude that there is an argument to maintain harvest refugia, such as occur in national parks and inaccessible areas. Such refugia exist throughout the ACT where densities are much higher than in surrounding New South Wales. Hacker et al. (2004) indicate that such refugia have also happened as a result of harvesting economics, because areas at a greater distance from towns are not harvested.

3.9.5 (b) Commercial harvest: south-eastern New South Wales

The question of commercial kangaroo harvesting in the ACT has been considered previously (KAC 1997). At the time, kangaroo harvesting (as opposed to kangaroo culling) in New South Wales was restricted to the inland sheep-wheat belt, western pastoral areas and the Northern Tablelands. Following representation by landholders in south-eastern NSW who shoot kangaroos for damage mitigation purposes (up to 20 000 per year (Cairns 2004)) and leave the bodies in the field, a four-year (2004–2007) commercial harvest trial was undertaken in that zone with the approval of the Commonwealth. Following the trial, the South-East Kangaroo Management Zone (Zone 16) has been included in the NSW Commercial Harvest Plan (2007–2011) (NSW DEC 2006). The zone covers the NSW Livestock Health and Pest Authorities' areas of Goulburn, Braidwood, Gundagai, Yass and Cooma which completely encircle the ACT.

A helicopter based line transect survey in 2003 estimated an eastern grey kangaroo population for the zone of 292 396 (Cairns 2004; Pople et al. 2006) and a quota of 43 868 was determined (15% of the population). A second survey was undertaken in 2006, which doubled the length of helicopter transects (to 1495 km) and gave a population estimate of 415 721 (Cairns 2007). Improved survey method and population recovery after the extensive bushfires of 2003 are the two main factors likely to have contributed to this documented increase in kangaroo numbers (Payne 2007). The 2007 quota was set at 62 291 and the resultant harvest was 49 353 (79%) (Payne 2008a). This quota was maintained for 2008/2009 (Payne 2007, 2008b). Based on the 2003 and 2006 data, kangaroo density estimates are 11.95 and 14.07 per km^2 (0.12 and 0.14 per ha) respectively.

Whether commercial harvesting remains viable in the South-East Zone depends on a number of factors including maintenance of population numbers. There may be little decline if harvesting replaces the previous culling (Pople et al. 2006). About 30 per cent of the zone comprises national park and state forest in which culling does not occur. These areas serve as refuges, in which densities are likely to be lower than in the cleared grazing country due to the terrain and tree cover. Regular monitoring is a key element of the commercial harvest program with population estimates for the zone being undertaken every three years (2003, 2006, 2009).

3.10 Social considerations

Social considerations in relation to kangaroo management have been outlined briefly in s. 1.4.3. These considerations are heightened in the ACT due to its unique position of having a large kangaroo population within and on the margins of the urban area. It is a premise of this plan that to maintain the natural integrity (see **Glossary**) of grassy ecosystems in the ACT, where there are kangaroo populations, management interventions may be required. Underlying such interventions should be a high quality synthesis of the available scientific knowledge of kangaroos and grassy ecosystems. A range of other government policy decisions will also need to be made e.g. in relation to kangaroo–vehicle collisions and kangaroo populations on rural lands.

There will often be controversy about the basis, type and scale of these interventions, which is driven by underlying beliefs and values, and the opportunity to project those beliefs and values in the National Capital. Controversy is not a sign of weak science (Krebs 2001), but reflects the fact that most environmental issues involve a mix of scientific understanding and policy considerations—the latter concerned with negotiating a compromise between competing interests.

Welfare considerations, outlined in s. 1.4.3, are central to this plan and the policies herein. Application of welfare considerations may not be as straightforward as it might seem. The focus of ecology is the 'population', which is defined as a 'group of organisms of the same species occupying a particular space at a particular time' (Krebs 2001). In contrast, welfare considerations for kangaroos apply to individual animals as well as to the population as a whole, and at the two scales the approaches may differ. For example, in natural populations, individuals may suffer violent deaths from dingo attack or lingering deaths from starvation in droughts or cold winters (as in the ACT) when there is insufficient quantity and quality of pasture.

It would be clearly inappropriate to allow such conditions for individuals in a captive or enclosed population. However, it is entirely appropriate to allow the operation of these factors in a natural free-ranging population (as in Namadgi National Park). It is well understood that populations of the larger common species such as grey and red kangaroos are highly dynamic, and that seasonal fluctuations and episodic population 'crashes' do not affect the sustainability of the populations as a whole. This has been demonstrated in the population monitoring associated with the commercial harvesting program over a 25 year period (DEWHA 2009a; Payne 2007).

3.11 Kangaroo impacts: summary

As noted in s. 2.5, the impacts of high densities of kangaroos, rather than their densities *per se*, are the appropriate focus for management (ACT Government 2002). If high densities are having no demonstrable current or likely future effect, then no intervention may be warranted. Nevertheless, in particular environments, based on management experience and knowledge of the environment, certain density levels will suggest (given weather and pasture conditions especially) that impacts are likely. As discussed previously, these thresholds are represented by ecological carrying capacity, economic carrying capacity and the ability of native grassy ecosystems to sustain habitat for other species (including threatened species) (Figure 3.3).

From the foregoing, it is evident that there is no simple calculation of an appropriate kangaroo density on non-rural lands. Recent research to estimate functional responses and numerical responses (see **Glossary**) of eastern grey kangaroos on a range of ACT sites and pasture types (natural and exotic) as well as modelling (Fletcher 2006a) (Table 5.1) suggest that damage mitigation shooting formulas can be devised which:

- hold kangaroo density to about 0.6 to 1.5 per hectare
- increase herbage mass significantly
- reduce the frequency and duration of crashes to low herbage mass (e.g. in droughts)
- after initial population reduction, require about the same number of kangaroos to be shot as in commercial harvesting.

Free-ranging and large area enclosed populations of kangaroos provide a wildlife spectacle that is part of the experience of the 'bush capital'. However, high kangaroo densities in parts of the ACT have a number of significant impacts. These are summarised below:

Environmental

1. Excessive grazing pressure on native grassy ecosystems resulting in degradation of the natural integrity of those ecosystems.
2. Excessive grazing pressure resulting in loss and degradation of habitat critical to threatened species of grassy ecosystems.

Economic

1. Effects on the economic viability of rural properties and increased management costs for other lands.
2. High cost of vehicle collisions and collision avoidance in the ACT and region compared with the remainder of NSW.

Social

1. Road accident trauma.
2. Controversy in the community over kangaroo management and actions taken to reduce kangaroo densities in some areas.

4 Principles and Policies

Kangaroo densities can reach high levels in parts of the ACT and remove most of the grassy vegetation. This can have a severe impact on groundcover and habitat for other species such as grassland earless dragons (trap, lower right). Compare with a different view of this site, taken when kangaroos were less abundant, page 15.

4.1 Introduction

This chapter sets out the *principles* that underlie kangaroo management in the ACT and the general *policies* that apply to management issues wherever they might arise. There are also policies for kangaroo populations that are effectively captive behind fences. Policies are considered in three categories:

- kangaroo welfare (s. 4.4)
- human welfare (s. 4.5)
- managing kangaroo densities (s. 4.6).

The principles and policies outlined below support the purpose and goals of the plan (s. 1.3).

The goals of kangaroo management in the ACT are to:

- **maintain populations of kangaroos as a significant part of the fauna of the 'bush capital' and a component of the grassy ecosystems of the Territory**
- **manage and minimise the environmental, economic and social impacts of those kangaroo populations on other biota, grassy ecosystems, ACT residents and visitors.**

4.2 Principles

The following principles form the foundations for the plan:

Environment	**a) Kangaroos are valued as an integral component of grassy ecosystems.** **b) Kangaroo management is based on the best available knowledge of kangaroo biology and ecology.** **c) The conservation of native grassy ecosystems and their constituent flora and fauna species is a legislative requirement and a high priority for the government.**
Economy and Society	**a) The economic and social impacts of kangaroo populations are taken into consideration in forming government policy, particularly in relation to free-ranging kangaroo populations on rural lands and along roadsides.** **b) Kangaroo welfare is a primary consideration in all kangaroo management and all kangaroos are to be treated humanely.** **c) Human welfare and the welfare of other grassy ecosystem species are key considerations in all kangaroo management.**
Managing Kangaroo Populations	**a) Intervention to manage kangaroo impacts is necessary in some instances and may involve culling.** **b) Population control policies and actions will be based on scientific knowledge supported by ongoing research, appropriate regulation and monitoring, and codes of practice.**

4.3 Policies

Policies are guides to decision making and represent an underlying management position with regard to the achievement of objectives. Policies provide a consistent basis to respond to changing circumstances and new issues. Kangaroo management, like other environmental controversies, involves a mixture of scientific facts and policy decisions. Krebs (2001, p. xix) notes that: 'scientific facts alone do not determine policy, but policy without a solid scientific grounding is doomed.' Kangaroo management in Australia is a good example of applied ecology, defined as 'the science of the application of ecology to contemporary problems in managing our biological resources' (Georges, Hone and Norris 2008, p. 227).

4.3.1 Evidence-based management

Scientific knowledge in a field such as ecology is never complete, so policy must be formulated in the face of uncertainty and revised as new knowledge is developed. Rather than relying upon the required knowledge to be developed by chance, an 'adaptive management' approach provides the opportunity to link ecological research to the management of natural resources, with the aim of providing a solid scientific foundation for future management policy. Under this approach, management intervention is conducted in a rigorous experimental framework where the intervention is implemented as a scientific experiment (Georges, Hone and Norris 2008).

The methods of applied ecology adapted to kangaroo management involve observation, experimentation and modelling. In doing this, researchers and managers are able to draw also upon a large body of biological and ecological information that has already been assembled through decades of scientific studies of kangaroos and comparable herbivores in other continents. This approach is described as 'evidence-based management'. It was the approach adopted by the Kangaroo Advisory Committee and is continued in this plan. Evidence comprises the best available scientific information at the time including ecological theory and principles, published papers and books, university theses, technical reports and unpublished data e.g. data collected as part of monitoring programs for management purposes rather than for research projects and subsequent publication.

4.4 Kangaroo welfare

Objective: Kangaroo Welfare	**Kangaroo management in the ACT is undertaken in a way that accords with ACT legislation, codes of practice and current Australian standards for animal welfare.**

Policies related to this objective are at:

- s. 4.4.1 (d) (Humane treatment)
- s. 4.4.2 (c) (Kangaroo populations on land adjoining residential areas)
- s. 4.4.3 (a) (Euthanasia of injured kangaroos)
- s. 4.4.4 (c) (Captive populations)
- s. 4.4.5 (a) (Wildlife carers)
- s. 4.4.6 (b) (Translocation of eastern grey kangaroos)

The RSPCA, a non-government organisation, which has a pre-eminent role in animal welfare, has prepared an 'animals charter' that defines set minimum standards of treatment and husbandry that should be provided by a compassionate and responsible community. An animal welfare approach stands for the ability of animals to have a positive life and to be treated by humans in a considered and humane way that minimises suffering, injury or distress (RSPCA 2009). Inhumane treatment is the opposite of an animal welfare approach and there is a legacy in Australia of such treatment of animals including kangaroos. There are also divergent community views, for example, some groups oppose commercial kangaroo harvesting because they consider it to be inherently cruel (see 'Animal welfare groups', Ch. 3.5 in RSPCA 2002).

In recent decades in Australia, legislation and codes of practice have been established for animal welfare and there has been particular attention to kangaroos, mainly because of the export-based commercial harvesting. Two key welfare issues are:

- compliance with the relevant codes of practice for the humane shooting of kangaroos
- the fate of dependent pouch young and young-at-foot arising from the shooting of kangaroos. This is probably the most contentious welfare issue in relation to the killing of kangaroos (see, for example, Ben-Ami (2009), Wilson and Croft (2005)).

4.4.1 Humane treatment of kangaroos in the ACT

In the ACT, animal welfare (which covers wild animals such as kangaroos) is defined in the *Animal Welfare Act 1992* to mean 'the health, safety and welfare' of animals in general, or one or more animals in particular. Information on kangaroos including animal welfare has been provided for the public by ACT Government agencies for many years, including brochures such as 'Living with Kangaroos' and 'Kangaroos in our Nature Parks and Reserves' (http://www.tams.gov.au).

4.4.1 (a) ACT legislation and codes of practice

Kangaroo management in the ACT must be undertaken in accordance with the provisions of the *Animal Welfare Act 1992*. This is the primary animal welfare legislation in the ACT and aims to ensure the welfare of all animals in the Territory. The Act makes cruelty to animals illegal, provides the framework for the use of animals in research, has a range of enforcement powers, and allows the appointment of inspectors for the purpose of enforcing the Act. Officers from within the RSPCA and Parks, Conservation and Lands have been appointed inspectors under the Act. The legislation provides the basis for criminal charges against those who act in cruel and inhumane ways towards animals including kangaroos.

The Animal Welfare Act (Part 3) defines acceptable animal welfare standards by the gazettal of codes of practice for various types of animal use or for different animal species. Codes of practice are generally regarded as a minimum standard that is acceptable for dealing with, or interacting with, an animal. There are two codes in the ACT that are applicable specifically to kangaroos:

- *Code of Practice for the Humane Destruction of Kangaroos in the ACT*

  (Gazetted under the Animal Welfare Act (DI1994–149)
- *Code of Practice for the Welfare of Kangaroos Maintained Intentionally in Captivity*

  (see s. 4.4.4 below). (Not gazetted)

National codes are also applicable to specific uses of animals in the ACT, such as the *Australian code of practice for the care and use of animals for scientific purposes* (NHMRC 2004). This is gazetted under the Animal Welfare Act (DI2005–188).

4.4.1 (b) ACT code of practice for the humane destruction of kangaroos

The humane killing of kangaroos was one of the most important issues addressed in the reform and regulation of the commercial kangaroo harvesting industry from the 1970s (s. 3.9.5). Whether the harvest, which is conducted by shooting under field conditions at night can be conducted humanely, has continued to be the subject of considerable focus (Pople and Grigg 1999). The matter was addressed in a report by the RSPCA to the (then) Australian National Parks and Wildlife Service in 1985 (RSPCA 1985). This report established a standard for humane killing of kangaroos, namely a single shot to the head, to achieve the primary objective of instantaneous loss of consciousness and rapid death without regaining consciousness (RSPCA 2002). Most of the recommendations in this report for changes and additions to the first *Code of practice for*

the humane destruction of kangaroos (1985) were adopted for the second edition of the code in 1990 (CONCOM 1990). The ACT code is adapted from the national one. As noted in s. 2.1.3(a), the 1990 national code was replaced in 2008 by two codes, which separate commercial and non-commercial shooting (NRMMC 2008a, 2008b). Both the ACT and national codes cover all circumstances under which kangaroos may be killed (commercial harvesting (not ACT), non-commercial culling, road or other injury, and include specific consideration of orphaned pouch young).

Part of the ongoing debate about commercial kangaroo harvesting concerns the level of cruelty associated with the killing of kangaroos and wallabies. In addition, control of export of kangaroo products is now under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) and a wildlife trade management plan to export products can only be approved if the animals are killed in a way which is generally accepted to minimise pain and suffering (NRMMC Working Group 2004). In this context compliance with the 1990 national code was again reviewed (RSPCA 2002) and the recommendations of the compliance report, where relevant, used in drafting the revised 2008 codes of practice (NRMMC 2008a, 2008b). The compliance report examined the commercial and non-commercial killing of kangaroos in the four mainland states involved in the commercial harvest (New South Wales, Queensland, South Australia and Western Australia).

While the RSPCA report (2002) was focused on the commercial industry and did not specifically include the ACT, the following welfare issues canvassed in the report are relevant to the ACT: a) non-commercial culling; b) shooter competency; c) orphaned young; and d) types of firearms and ammunition.

- **Non-commercial culling**

  Issues: The RSPCA report (Ch. 5) concluded that major welfare issues arise from the killing of kangaroos outside the commercial system. It noted that the incidence of cruelty (e.g. body shot and injured kangaroos) within the non-commercial sector is higher than that found with professional shooters. It states that cruelty is neglected by authorities and control over the number of kangaroos killed and methods used is ineffective. The report noted very high compliance with head shot requirements by the commercial industry that is achieved partly through self-regulation (zero-tolerance with regard to body-shot animals).

  RSPCA recommendations: The RSPCA report (Chs 5, 7) notes that all kangaroos should be killed humanely in accordance with the code of practice, whether shooting is done under a commercial or non-commercial licence. RSPCA Australia takes the view that in order to achieve the principle of humane shooting in the long-term, the existing damage mitigation licensing system should be phased out. All killing of kangaroos would be undertaken by commercial shooters and the carcasses sold to processors.

  Revised national codes of practice (NRMMC 2008a, 2008b): The proposed change would be a policy matter, rather than part of a code of practice.

  Relevance to the ACT: The bulk of regular culling in the ACT is on rural leases for damage mitigation. The question of commercial harvesting is addressed in s. 6.4. As noted below, the ACT has the strictest requirements in Australia for licensing of non-commercial kangaroo shooting. These requirements incorporate the most important of the commercial industry provisions for animal welfare, namely attention to shooter accuracy through biennial testing.

- **Shooter competency**

  Issues: As noted above, shooter competency and knowledge of humane killing methods is lower in the non-commercial sector than the commercial industry. This has raised ongoing animal welfare concerns.

RSPCA recommendations: While the current damage mitigation system continues, RSPCA Australia recommends that all non-commercial licence holders be required to successfully undertake the section of the game meat harvesting course covering humane killing, as well as a firearms competency course that includes a shooting accuracy test (Ch. 5).

Revised national codes of practice (NRMMC 2008a, 2008b): The national commercial code of practice (see s. 2.1.3(a)) requires commercial shooters to pass a competency test, set by the relevant state/territory government. The non-commercial code does not have this requirement, but encourages relevant government authorities to promote measures to ensure competence of shooters. Shooters still have the responsibility to ensure that they kill kangaroos humanely and in accordance with the national code.

Relevance to the ACT: The ACT has the strictest requirements for licensing of non-commercial kangaroo shooting in Australia. Kangaroo culling requires a special shooter's licence under the *Firearms Act 1996.* Holders are required to pass an accuracy test every two years as well as a macropod identification test. Compliance with the ACT *Code of Practice for the Humane Destruction of Kangaroos in the ACT* is a requirement for any person permitted to kill kangaroos in the ACT, as a condition of the licence under the Nature Conservation Act. Thus the ACT already surpassed the requirements recommended by the RSPCA (2002) and continues to do so.

- **Orphaned young**

Issues: The reproductive biology of kangaroos (s. 3.3) means that in temperate Australia, pouch young are present in the population at all times of year. Most births occur during the 12 weeks from the last week of November, so in the following spring and early summer most young reach the age when they leave the pouch permanently, which is 10.6 months on average (Poole 1975). They are then referred to as young-at-foot until they become independent (weaned at 18 months). This has two main management implications: a) shooters must deal with pouch young and young-at-foot whenever female kangaroos are culled; and b) there are animal welfare considerations arising from the seasonal timing of reproduction, as explained below.

The fate of dependent pouch young and young-at-foot is a significant welfare issue arising from the shooting of kangaroos and is widely raised in opposition to kangaroo culling and harvesting. Mobile young-at-foot are difficult for shooters to deal with and there is some repugnance on the part of shooters to killing large young (RSPCA 2002). Suggestions to avoid the shooting of female kangaroos are impractical where culls are intended to reduce populations. Such a program would be much less effective than removal of both sexes. For the commercial harvest, long-term data from New South Wales shows a male bias in the harvest (approximately 70% for red and eastern grey kangaroos, 67% for western greys and 87% for wallaroos) (Payne 2008b).

In tiny naked pouch young, functions such as thermoregulation and kidney function are rudimentary or not evident and their nervous systems are also rudimentary. Older pouch young, which are lightly furred with erect ears and eyes open, have acquired many of the adult body functions, including the ability to perceive pain. Given this level of development, they should be treated for animal welfare purposes the same as adult kangaroos. Pouch young older than 41 weeks (9.3 months: the time of first pouch exit) have the potential to escape the pouch and run away when the mother is shot. At this age their dependence on milk is high, therefore independent survival is also unlikely. Taking both considerations into account, pouch young are deemed by the ACT Government to be in an age of animal welfare concern (equivalent to adults) from eight months of age (Fletcher 2007a).

The early young-at-foot also have the potential to escape the shooter, but as they depend heavily on milk, independent survival is unlikely. However, their milk intake declines rapidly over the next few months, being replaced by grass. Thus, the age of animal welfare concern is defined as 8–12 months to encompass both the older pouch young and the younger young-at-foot.

RSPCA recommendations: The RSPCA report notes that humane killing of orphaned young is a long-standing issue and recommends that research be undertaken to determine the most appropriate method of disposing of pouch young. It also notes that the only way to avoid potential cruelty to pouch young would be to avoid shooting females, especially those carrying large pouch young. As noted above, there is a male bias in the NSW commercial harvest.

Revised national codes of practice (NRMMC 2008a, 2008b): The national codes (see s. 2.1.3(a)) require that all target females (including sick and injured animals) must be examined for pouch young. Euthanasia methods and conditions are prescribed for three categories of young kangaroos: small furless pouch young; small and large furred pouch young; and young-at-foot. This corrects the lack of distinction between pouch young and young-at-foot that was an important issue for the 1990 national code of practice (CONCOM 1990).

Relevance to the ACT: The ACT is the only Australian jurisdiction that restricts kangaroo culling to a defined season (March–July), which is timed to minimise the rate that shooters will encounter female kangaroos with young in the age of animal welfare concern. Where young are present, the *Code of Practice for the Humane Destruction of Kangaroos in the ACT* (s. 4.4.1(a)) states that pouch young and young-at-foot should be humanely killed immediately. Acceptable methods are described for two categories: 'very small hairless young' and 'larger young'. The results of inspection of kangaroo carcasses shot on ACT rural properties suggest that the timing of the season is effective in achieving its objective. The timing of the shooting season may be revised in the future, depending on collection of additional non-selective samples of pouch young. The ACT *Code of Practice for the Humane Destruction of Kangaroos* should be reviewed, given the changes to the national code (i.e. the inclusion of three categories of young kangaroos).

- **Types of firearms and ammunition**

Issues: The aim of achieving humane killing of kangaroos with a single shot to the head requires the use of an appropriate firearm and ammunition, of which only a small selection is suitable under most circumstances. A significant issue is the use of shotguns, mainly for wallabies in Tasmania. Shotguns are not permitted for the shooting of kangaroos taken as part of the commercial harvest in the five states with approved management plans (NRMMC 2008b).

RSPCA recommendations: The RSPCA report (Ch. 6) notes that there is now a larger range of ammunition and firearms available and recommends that a study be conducted into the relationship between ammunition types, firearm size and the efficiency of killing kangaroos. It also recommends removing any reference to the use of shotguns from the code.

Revised national codes of practice (NRMMC 2008a, 2008b): The national codes (see s. 2.1.3(a)) contain detailed minimum specifications of firearms and ammunition (calibre, cartridge size, ammunition type and maximum range) covering commercial and non-commercial shooting, and euthanasia of sick and injured animals and young-at-foot. Centrefire rifles are specified for the shooting of all the larger kangaroo species, except in special circumstances when this might not be safe or practical e.g. in proximity to suburbs. The use of shotguns for the commercial shooting of kangaroos and wallabies is prohibited. The non-commercial code permits the use

of shotguns in certain circumstances where it is not safe or appropriate to use centrefire or rimfire rifles, including the euthanasia of animals injured on the roadside and of orphaned young-at-foot.

Relevance to the ACT: The specifications for firearms and ammunition in the ACT *Code of Practice for the Humane Destruction of Kangaroos* need to be reviewed in relation to both the revised national codes and advances in technology. For example, attention has been drawn to the safety advantages and greater killing power of certain ammunition available for the 0.17 rimfire rifle that could replace some of the uses of the traditional 0.22 rimfire rifle.

4.4.1 (c) Illegal killing

In the ACT, native animals (including kangaroos) are protected under the *Nature Conservation Act 1980* (s. 2.1.1). A permit issued by the Conservator of Flora and Fauna is required under the Act to kill a native animal or to take and kill (where capture is required). Killing an animal without a permit is illegal.

Throughout Australia, cruelty towards kangaroos is often associated with illegal killing and in some instances these events have been well-publicised (RSPCA 2002). Such events are not common in the ACT, and as noted in s. 4.4.1(a), cruelty is an offence in the ACT under the *Animal Welfare Act 1992*.

4.4.1 (d) Humane treatment of kangaroos: policies

Humane treatment of kangaroos	
Welfare	· Animal welfare, including legislative requirements, will be a primary factor in all decisions and actions regarding kangaroo management in the ACT. · Information for the public on kangaroos and their welfare in the ACT will continue to be provided and made accessible e.g. at ACT Government shopfronts and on websites.
Code of Practice: Humane Destruction of Kangaroos	· Requirements for the humane destruction of kangaroos in the ACT will continue to be prescribed in a code of practice. · The *Code of Practice for the Humane Destruction of Kangaroos in the ACT* (1994) will be revised in relation to changes to the national codes of practice for the humane shooting of kangaroos and wallabies, advances in technology, and any other relevant considerations
Shooter's licence	· The special requirements for a kangaroo shooter's licence in the ACT will be maintained.
Shooting season	· A kangaroo shooting season for the ACT will be maintained. Timing of the season will be refined if appropriate, based on increased evidence of seasonality in reproductive patterns in a range of local populations. · Specific culling licences may be issued outside this season e.g. small supplementary male-only quotas on rural lands in spring.

4.4.2 Kangaroo populations on land adjoining residential areas

ACT residential areas have a large interface with Public Land and other categories of land (s. 2.2) that support kangaroo populations. It is in areas such as Canberra Nature Park, horse paddocks and golf courses that residents are able to gain the sense of the 'bush capital' and experience encounters with free-ranging kangaroos. Kangaroos graze at night on suburban nature strips, household lawns and parkland in areas adjoining reserves. Harassment of individuals or mobs of

kangaroos may occur, especially by domestic dogs. This has welfare implications in that stressed and disoriented kangaroos may flee across roads, into fences, or suburban backyards, where they can damage property, injure themselves, or end up in swimming pools.

4.4.2 (a) Urban wildlife

The ACT Government has a long-standing *Urban Wildlife Program* to manage issues associated with the presence of wildlife in the urban area. The program is established in Parks, Conservation and Lands and its main focus is to: a) aid injured, trapped, sick or orphaned wildlife in need of assistance; b) provide advice to help resolve conflicts between the community and local fauna; c) provide information about urban wildlife to the general public; and d) promote 'Living with Wildlife'. ACT residents are encouraged to keep an appropriate distance from kangaroos and to see them as a wild animal, the populations of which will fluctuate according to environmental conditions. The urban wildlife program undertakes the capture, relocation and euthanasia of animals, but not the actual care of sick, injured or orphaned wildlife. The latter function lies with licensed bodies such as the RSPCA and local vets. Guidelines have been prepared for the program, covering matters such as operating procedures, field attendance, handling wildlife, and euthanasia (ACT Parks, Conservation and Lands 2008).

Eastern grey kangaroos are the most commonly encountered species in the program, particularly in relation to motor vehicle collisions (s. 3.9.4). The majority of these calls require attendance by a qualified wildlife handler. The other common occurrence is the presence of kangaroos in the suburbs, often having been pursued by dogs. Field action is limited in these circumstances. Telephone advice is usually provided to residents to leave the animal alone to find its way back to bushland. Some animals become trapped in confined spaces, and capture and removal may be necessary if the animal has not been able to extricate itself after a period of time. In general, the handling of uninjured macropods is avoided, where possible, due to the risk of injury to people, and the stress caused to the animal.

4.4.2 (b) Attacks by dogs

Kangaroos and wallabies that live in interface areas are generally quiet and cryptic but may become alarmed if there is a dog in the vicinity. In those parts of Canberra Nature Park where dogs are allowed, it is a legal requirement that dogs remain on lead, and this information is provided in reserve information and at entry points to the reserves. Under the *Domestic Animals Act 2000* (Div. 2.6) it is an offence in the ACT for a carer with a dog to allow the dog to harass (hunt or torment) an animal, for the keeper of a dangerous dog to allow it attack or harass an animal, or for a person to knowingly encourage a dog to attack or harass an animal. Harassment or attack by dogs can result in injuries to the kangaroo that require its euthanasia. Some kangaroos, especially large male animals, will defend themselves, their offspring or their mates against dogs that harass them. In such instances, a kangaroo may fatally injure the dog or injure a person who tries to intervene between the dog and the kangaroo (s. 4.5.1). Another form of defensive behaviour is for a kangaroo (a competent swimmer) to retreat to a dam or other water body where the attacking dog is held under and drowned by the kangaroo.

From the 19th century, dogs have been used to hunt kangaroos, including in 'drives' (Dawson 1995) and this practice is reported to still occur in some parts of Australia today (RSPCA 2002). Such a practice does not conform to either the ACT or national codes of practice referred to in s. 2.1.3(a) and s. 4.4.1(b) and would be illegal in the ACT under both the *Animal Welfare Act 1992* and the *Domestic Animals Act 2000*. Dogs may also be used to chase kangaroos on rural properties and this is sometimes reported in the ACT. This practice is illegal under the Animal Welfare Act.

4.4.2 (c) Kangaroo populations on land adjoining residential areas: policies

Kangaroo populations on land adjoining residential areas	
Urban wildlife program	· A program that provides advice to the public on eastern grey kangaroos, ensures the welfare of kangaroos in urban situations, and undertakes euthanasia of injured animals where necessary will be continued in the ACT.
Living with kangaroos	· Advice will continue to be provided to ACT residents on 'living with kangaroos' and on the provisions of legislation relating to animal welfare and control of dogs.

4.4.3 Euthanasia of injured kangaroos

The aim of euthanasia is to relieve suffering by causing a rapid, painless and relatively comfortable death to animals with severe injuries, illness or debility. Methods of euthanasia should cause immediate and rapid loss of consciousness, followed by death, with a minimum of pain, discomfort or distress (Hanger and Tribe 2005). Kangaroos may suffer injuries as outlined in s. 4.4.2; however, the most common cause of injuries in the ACT is collisions with motor vehicles (s. 3.9.4). The ACT *Code of Practice for the Humane Destruction of Kangaroos* includes destruction of kangaroos in roadside and other situations (s. 4.2 of the code). This is also included in the *National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes* (NRMMC 2008b).

The main factors to be considered in dealing with injured kangaroos are: a) the welfare of the animal; b) public and ACT Government employee and contractor safety (in relation to the animal and its location—often on major roads); c) effectiveness of methods of euthanasia and their practicality in urban or near-urban locations; and d) public sensibility (given the potential distress at seeing the injured animal and its euthanasia). As noted in s. 4.4.2(a), guidelines have been prepared by ACT Parks, Conservation and Lands to be used in these situations. Standard operating procedures (SOPs) may be applicable also, such as the SOP in ACT Parks, Conservation and Lands for the 'Use, Transport and Storage of Firearms'.

4.4.3 (a) Euthanasia of injured kangaroos: policies

Euthanasia of injured kangaroos	
Euthanasia	· Euthanasia of injured kangaroos will be carried out according to the *Code of Practice for the Humane Destruction of Kangaroos in the ACT*, established guidelines for the management of urban wildlife, and relevant Standard Operating Procedures for staff and contractors of ACT Parks, Conservation and Lands.

4.4.4 Captive populations

Scale is an important consideration with regard to management responsibilities for captive kangaroo populations. The two extremes are a zoo and a large enclosure covering some square kilometres. The focus of this kangaroo management plan is enclosed populations in larger areas, rather than kangaroos kept in zoo or zoo-like conditions. Keeping the latter requires a licence under the *Nature Conservation Act 1980* and a management plan prepared by the licensee and approved by the Conservator of Flora and Fauna. Maintaining kangaroos in captivity requires an understanding of, and provision for the needs of, the particular species held, as well as trained staff, and attention to legal requirements and record keeping.

The manager has full ethical responsibility for individual animals in a small area such as a zoo or zoo-like setting. Where the enclosure is large and the kangaroos roam freely, relying on the available pasture, the management responsibility has more in common with the ethical responsibility for wild animals. In a zoo, it is appropriate that a kangaroo with a minor injury would receive veterinary care, but this would not be expected for an individual in an open-space population that might number some hundreds. In between, are spacious areas such as Government House (Yarralumla) where the population is essentially free-ranging, but also is managed, given the high profile and specific land management requirements of the location.

4.4.4 (a) Code of practice for captive populations

On the recommendation of the former Kangaroo Advisory Committee, a *Code of Practice for the Welfare of Kangaroos Maintained Intentionally in Captivity* has been prepared and effectively covers both intentionally and unintentionally captive populations in the ACT (ACT Government n.d.; KAC 1997b). The code has not been gazetted under the Animal Welfare Act. The code makes clear the requirement that those responsible for managing land that contains kangaroos in captivity are required by the *Nature Conservation Act 1980* to hold a licence to keep a native animal. A condition of such a licence is that there is a management plan for the captive kangaroos and this has been approved by the Conservator of Flora and Fauna.

Requirements for animals maintained in scientific/research facilities are outlined in one national code of practice and a guide:

- *Australian code of practice for the care and use of animals for scientific purposes* (NHMRC 2004)

  (Gazetted under the *Animal Welfare Act 1992* (DI2005–188))

- *A Guide to the use of Australian Native Mammals in Biomedical Research* (Sections 1–3, 1990 and Section 4, 1995) (NHMRC 1990, 1995).

  (Not gazetted in the ACT.)

Of relevance also for some captive populations is the Australasian Species Management Program (ASMP) of the Zoo and Aquarium Association, which aims ‘to plan and manage animal collections cooperatively, in ways that promote sustainability and contribute to species conservation’ and provides assistance to member institutions (www.arazpa.org.au).

4.4.4 (b) Enclosed populations in larger areas

These populations typically result from the fencing of areas which contain kangaroos, though in the case of Government House (Yarralumla) a small population was introduced to an existing fenced site. In some instances, the origins of the kangaroos are unknown. Examples of fenced areas are telecommunication towers (Bellenden Street (Crace); the Belconnen Naval Transmitting Station (Lawson)); Government House (Yarralumla); Royal Canberra Golf Club (Yarralumla); and the Mulligans Flat ‘Sanctuary’ with predator-proof fence (Gungahlin).

Management costs associated with these populations may include electric fencing, repair of fences, and culling and/or fertility control as at Government House (Yarralumla) (from 1992), Royal Canberra Golf Club (from 1994), and Belconnen Naval Transmitting Station (from 2008). There are several fenced areas from which all the kangaroos have been removed. The experience of Government House (Yarralumla) shows the long-term benefit of intervening to control kangaroo numbers in such situations, even though the proposed action created international media attention in 1992–93. The management of the enclosed population at the nearby Royal

Canberra Golf Club created similar attention in 1994 and even greater protests were made in 2007 and 2008 at Belconnen Naval Transmitting Station.

There have been three main responses to enclosed kangaroos in the ACT (KAC 1996b):

- They have been tolerated but no action taken to manage them.
- They have come to be seen as an asset maintained for aesthetic values.
- They have been discouraged but unable to be removed from the area.

Developers, lessees or government agencies have a responsibility to manage populations they enclose. Proposals to erect fences that inhibit kangaroo movement or enclose populations are dealt with in the statutory planning and development assessment processes to facilitate suitable solutions. Where captive populations remain, a population management plan is required in line with the code of practice. However, adequate provisions in plans and appropriate action to manage population growth has been lacking in some instances.

Kangaroo populations behind security fences are protected from mortality factors such as predation and vehicle collisions, and in the absence of population controls, their numbers have the propensity to rise exponentially (herbivore irruption) as has occurred previously at the Belconnen Naval Transmitting Station, Government House, and Royal Canberra Golf Club. Other significant issues that have arisen with regard to the management of these populations are:

- Some of the enclosed areas contain threatened natural temperate grassland and threatened grassland species.
- All the enclosed populations are in lowland areas. Unmanaged kangaroo populations in these areas have not reached a balance with their food supply (ecological carrying capacity) and are still increasing. Allowing populations to reach ecological carrying capacity is likely to have severe impacts on other animals that require substantial grass cover or intact tussock structure for habitat.
- The issue of overgrazing of some grasslands by kangaroos has shown a lack of understanding by some land mangers of the local environment, kangaroo biology, kangaroo/pasture interactions, the available methods of population control, the practicalities of achieving animal welfare, and the role of kangaroos in a dynamic grassland ecosystem.
- All the populations are located within or adjacent to the Canberra urban area which restricts culling by shooting.
- Some enclosed areas are National Land (s. 2.2.2) to which the provisions of the *Nature Conservation Act 1980* (ACT) apply. However, in practice, Commonwealth land managers may be reluctant to act in accordance with ACT policies.
- Kangaroo management in urban and near-urban locations is highly conspicuous and provides an ideal opportunity for opponents of population management actions (such as kangaroo culling) or other aspects of kangaroo management in Australia, to project those views in the National Capital.

4.4.4 (c) Captive populations: policies

Captive populations	
Code of Practice: Captive Kangaroo Populations	· Requirements for the keeping of kangaroos in the ACT will continue to be prescribed in a code of practice. · The *Code of Practice for the Welfare of Kangaroos Maintained Intentionally in Captivity* will be reviewed as to the adequacy of its provisions. The need for a more sophisticated approach will be considered, such as restricting the application of the code to places where the kangaroos are managed as individuals, rather than as populations of wildlife. · The code of practice will be gazetted under the *Animal Welfare Act 1992*.
Licence and management plan	· Maintaining a captive kangaroo population requires: (a) a licence under the *Nature Conservation Act 1980*; and (b) a management plan for the captive population prepared by the licensee and approved by the Conservator of Flora and Fauna. · The required scope of the management plan is outlined in the *Code of Practice for the Welfare of Kangaroos Maintained Intentionally in Captivity.* This code will be amended so that requirements for the 'protection of the environment' and 'public safety' are included in the scope of the management plan.
Removal of a captive population	· Removal of a captive population requires: o a permit from the Conservator of Flora and Fauna under the *Nature Conservation Act 1980* o actions in accordance with the relevant codes of practice o actions in accordance with relevant legislation including the *Animal Welfare Act 1992.*
Protection of natural and cultural heritage values	· Enclosed populations of eastern grey kangaroos will be managed in order to protect natural and cultural heritage values, ground cover and soil stability of areas in which they are contained. · In particular, kangaroo populations will be managed to protect native grassy ecosystems (Natural Temperate Grassland and Yellow Box – Red Gum Grassy Woodland) and flora and fauna species found in those grassy ecosystems.

4.4.5 Wildlife carers

The hand rearing and release of injured and orphaned joeys is an activity highly valued by many wildlife carers, underlain by a concern for animal welfare or animal rights. It involves a one-to-one relationship between the carer and the kangaroo which may be continued by observing the animal after its release. Wildlife carer organisations have developed techniques for kangaroo rescue, care and release (e.g. Zabinskas and Zabinskas 2005). Conservation biology is more concerned with populations and ecosystem interactions. In the ACT context of a widespread, abundant species that has high rates of natural increase even though juvenile mortality is high (Table 3.2), amounting to many thousands per year, hand rearing of orphaned young is irrelevant to the conservation of the species. There is likely to be conflict between these differing perspectives on kangaroos (see Perry and Perry 2008).

In the ACT, the RSPCA has the role of caring for sick, injured and orphaned wildlife and does not hand-rear young eastern grey kangaroos. It is an offence under the Nature Conservation Act to keep any kangaroo including young for more than 48 hours without a permit. A number of issues have been identified in relation to hand-rearing of eastern grey kangaroos (KAC 1997; Jackson 2003) as follows:

· There is no justification for hand-rearing and release on conservation grounds as the eastern grey kangaroo is an abundant species of which many thousands are culled and/or commercially harvested in the ACT and region annually.

- Eastern grey kangaroos are unsuitable as pets, on human safety and animal welfare grounds, due to their adult size, high mobility and potential for injury to themselves or people in the suburban environment. This is generally recognised by responsible wildlife carers.
- A precautionary note on hand-rearing of eastern grey kangaroos is that this can lead to future management problems if they are retained in human care for too long and released where human contact is likely (e.g. close to urban areas). Hand-reared kangaroos are known to habituate to humans and later may display pre-copulatory behaviour and aggression towards humans. This can create problems if animals are released where they are likely to have contact with humans, especially children. Based on considerable experience with management of captive kangaroos, Poole (1982b) noted that 'males hand-reared past the age of sexual maturity (about 2 years) and retained as pets are likely to become aggressive, and hence males of large species can be extremely dangerous and cause serious injury to inattentive attendants or handlers'. This is a precautionary note as it is unlikely that a verifiable connection between a particular instance of aggressive behaviour and hand rearing would be able to be made when they are separated in time or space as there is generally no long-term monitoring of released animals.
- If released to the wild (rather than protected environments), hand-reared animals have a much higher death rate than naturally reared animals. For example, they often fall prey to predators as they have not learnt an appropriate recognition and flight response from potential predators such as dogs and foxes, in particular, where they are raised alongside domestic dogs (Jackson 2003; Richards 2006). Some carer organisations have instituted predator recognition training (especially dingoes/wild dogs) for hand raised kangaroos (Richards 2006).
- The release of captive-reared animals may impact on existing resident populations.

4.4.5 (a) Wildlife carers: policies

Wildlife carers	
Hand-rearing	· Licences will not be issued for the hand-rearing of young eastern grey kangaroos or their release in the ACT. This is: o due to welfare concerns and the need for consistent management (kangaroo populations are managed mainly to reduce impacts and there is no need to supplement the population) o to reduce the risk of injuries from large male kangaroos that were originally hand-reared. · Young eastern grey kangaroos will not be exported from the ACT to carers in other jurisdictions for hand-rearing.

4.4.6 Translocation of kangaroos

Translocation has been defined as the 'deliberate and mediated movement of wild animals or populations from one part of their range to another' (IUCN 1996 in Fischer and Lindenmayer 2000) and more generally as the 'movement of living organisms from one area with free release in another' (NSW NPWS 2001). Translocation is a management approach commonly adopted with the aim of solving human–animal conflicts, though it may also be undertaken for conservation purposes. Introduction, re-introduction and supplementation refer to the placement of animals for conservation purposes (Fischer and Lindenmayer 2001). The latter actions (grouped together as 'translocations' by NSW NPWS (2001)) are normally only undertaken for species that are rare or threatened. *This section refers to the movement of adult wild kangaroos from one location to another, not to the hand-rearing of orphaned young kangaroos and their release at a location different to where they were sourced.*

Over-abundant local populations, the problems created by some common species, small populations isolated by urban development, and return to the wild of sick, injured, orphaned or displaced animals have resulted in translocations of individuals or small numbers of animals in Australia e.g. koala (Duka and Masters 2005; Tribe et al. 2005); common brushtail possum (Pietsch 1995; Tribe et al. 2005); eastern grey kangaroo (Higginbottom and Page 2010; Hanger 2008; B. Nottidge pers.comm.). In the case of koalas this has been done over a long period (Tribe et al. 2005). Translocation of common macropods has emerged as a management option when their habitat is destroyed by urban development (Higginbottom and Page 2010). The Ecological Services Unit from Australia Zoo (Queensland), for example, has translocated 'individuals or small numbers as a last resort', where poor planning has left them isolated or unable to move safely to the nearest habitat (B Nottidge pers. comm.).

Small numbers of macropods have also been translocated for conservation purposes e.g. forester kangaroo (eastern grey) (Tasmania); bridled nailtail wallaby; yellow-footed rock wallaby (DEWHA 2008; Lapidge 2000; Pople et al. 2001; Rudd and McCallum 1998; Roe 1998–99). Short et al. (1992) reviewed six recent attempts (as of 1991) to conserve threatened wallabies by reintroduction, all of which ended in failure mainly due to introduced predators. They also reviewed 19 other reintroductions to both islands (higher survival rate) and the mainland, which had variable results overall. More has been learnt about the requirements for such programs to be successful, including predator control and predator avoidance behaviour by the animals involved. The carefully constructed program to reintroduce bridled nailtail wallabies to parts of their former range in central Queensland has proved successful, with new populations being established. This program gives specific attention to predator control (DERM 2009; Fisher et al. 2000; Pople et al. 2001; Roe 1998–99). Such conservation based programs are resource intensive, rely on finding suitable land, and need long term monitoring and management. This is justifiable for endangered species such as the bridled nailtail wallaby which had been considered extinct for 30 years until a population was discovered near the central Queensland town of Dingo in 1973.

Translocation of problem urban wildlife is not supported by the Australasian Wildlife Management Society (AWMS) due to animal welfare considerations, as well as the cosmetic nature of such actions and potential to consume significant resources (AWMS 2004b). AWMS does recognise translocation as a valuable conservation tool, for the restoration of plant and animal communities and assessment of the extent of ecosystem dysfunction (AWMS 2004c).

There is now widespread discussion on the internet and other sources about translocation of eastern grey kangaroos, which is proposed as a solution to dealing with kangaroo densities at particular locations, with the suggestion that methods for doing this are well established, recorded and successful. The inference is sometimes made that zoos and other institutions successfully transport animals, and animals are transported for conservation programs, so this could be undertaken for movement of excess numbers of kangaroos. However, it is illogical to equate the movement of one or a small number of captive animals between institutions under a very high standard of veterinary care, or as part of specialised resource intensive conservation programs, with the movement of hundreds or even thousands of wild kangaroos (on a regular basis).

The situation in the ACT is different to areas such as south-east Queensland where some small isolated kangaroo populations or individuals have been moved from residual habitat in developing urban areas. The extensive open space planning of the city allows kangaroos to move throughout the ACT and establish resident populations in nature reserves and other undeveloped areas near the suburbs. The problem with excessive densities has arisen in some medium to large areas where kangaroos are effectively captive and also where the high densities are impacting on native grassy ecosystems. Removal to reduce densities would involve large numbers of animals.

The reasons why the ACT does not license the translocation of eastern grey kangaroos are outlined below. Based on these, there is little imperative to undertake research into the large scale translocation of eastern grey kangaroos as there would be little application of the research results. This is an entirely different proposition to the reintroduction, which may involve translocation, of individuals or small numbers of macropods for conservation programs where the large investment in terms of money, equipment and technical expertise can be justified.

4.4.6 (a) ACT policy of not licensing translocations of eastern grey kangaroos

Translocation of free-ranging animals can appear a deceptively attractive option for dealing with excess numbers, especially when it is suggested that large-scale, successful translocations have been carried out elsewhere. In fact, it is difficult to find any examples of scientific studies or other accounts (e.g. conference proceedings, websites of wildlife carer or rescue organisations) that document the capture and movement of *large numbers* of large-bodied, wild animals such as kangaroos, or that show the long-term survival of such animals in the wild (long enough for reproductive success, for example). The primary reasons for not undertaking or licensing large scale translocations of kangaroos in the ACT are:

- animal welfare considerations (in particular, the certainty that many animals would die, during and following the process)
- the illogicality of undertaking large scale, expensive movements of one of the most common animals in the ACT which has no known threats to its long-term survival
- even if translocation were to be considered, the difficulty of finding suitable release sites for large numbers of animals.

These matters are outlined in more detail below.

4.4.6 (b) Eastern grey kangaroos are not a threatened species

Translocation of marsupials is a skilled, expensive, labour-intensive activity that is viewed by most wildlife conservation professionals as being appropriate only for threatened species conservation programs, rather than as a general management technique (AWMS 2004b, 2004c; NSW NPWS 2001).

Despite some assertions to the contrary, eastern grey kangaroos are not threatened and are abundant across their range in eastern Australia. While densities are low in more intensively settled areas throughout their range, due to agricultural and urban development and past or present shooting, eastern grey kangaroos are present in very high numbers and densities in many parts of the ACT. Translocation is irrelevant to their conservation. If translocation was undertaken in any particular situation, it would not be to conserve the species.

4.4.6 (c) Translocation is ineffective for population control

There is limited but growing experience in translocating macropods, in particular, eastern grey kangaroos, which are one of the more nervous and excitable of the kangaroo species (Jackson 2003). The known examples of eastern grey kangaroo translocation involve small numbers of animals (less than 30 individuals) enabling a high level of care to be applied to each animal. These numbers are very small compared to the numbers required to match the breeding potential and to effectively reduce most source populations.

In the ACT, translocation has been proposed as a non-lethal way of dealing with high densities of eastern grey kangaroos in particular locations. If translocations were to be used for removing ACT kangaroo populations for damage mitigation purposes (ecological or economic), it would involve moving hundreds or, more realistically, thousands of kangaroos annually, depending upon the initial and subsequent numbers removed in relation to each population.

The most prominent examples are at Belconnen Naval Transmitting Station and Majura Training Area. At Belconnen (2008), the immediate movement of more than 550 kangaroos would have been required to reduce a population of 650 to the target level. A larger overall number would have been required if the translocation was gradual. At Majura (2009), thousands would have needed translocation.

4.4.6 (d) Animal welfare

There are significant animal welfare reasons for not translocating eastern grey kangaroos, including the stress associated with capture, transport and release; the possibility of releasing animals to an inappropriate site (e.g. one where there is high predation risk); and stress associated with a new social environment (for both the new and existing animals).

Translocation may be divided into four stages: capture, transport, optional acclimatisation ('soft release'), and acclimatisation to the release site. The expertise and technical means are available to undertake the capture, transport and soft release of small numbers of kangaroos at a high standard of animal welfare, but at a very high cost per animal. These costs and the logistical requirements of translocating adult kangaroos are generally grossly underestimated by those who propose large scale translocations. Such costs and logistical requirements include preliminary approvals (e.g. police, ethics committees, approval by state or territory wildlife authorities), skilled professional staff (including constant veterinary attendance, trained shooters for dart gun use, trained wildlife handlers experienced with adult kangaroos), portable fences and yards, vehicles (including suitable enclosed and air-conditioned transport vehicles), sedative and euthanasia drugs and capture equipment (dart guns and projectiles), soft release yards, security, and burial pits for animals requiring euthanasia. It would be very difficult to achieve the standards of care attainable when dealing with a few animals (e.g. for research purposes) when undertaking a translocation of hundreds or thousands of animals. There is now a much better knowledge of handling techniques for eastern grey kangaroos when capture and movement of small numbers are required. These techniques have been aided from the late 1990s by the application of drugs used in human psychiatry (Blyde 1999; Jackson 2003).

Without the expenditure of much money and effort, and without appropriate expertise, eastern grey kangaroos are likely to suffer severely from an operation to move them in large numbers. They are fast, lightly built animals that are prone to fractures of the long bones and feet, dislocated hips and other injuries requiring euthanasia, if they are not directly fatal. Eastern grey kangaroos are known to be a nervous, excitable species in captivity (Jackson 2003) and are prone to a range of debilitating or fatal conditions (Blyde 1999). The stresses associated with capture and movement can result in a number of conditions leading to post-capture losses, namely, capture myopathy, shock, hyperthermia and hypothermia, respiratory failure, cardiac failure, trauma (injury) and secondary infections (Keep (1976) in Hume et al. (1989)). The often mentioned capture myopathy (see **Glossary**) can occur weeks or months after the event that caused it.

The final stage of translocation is where animals have to fend for themselves in the wild. There is much less certainty about this stage. This is because even though there has been the release over time of thousands of hand-reared individual animals by wildlife carers (these are not translocations

as defined in this section), there has been little long term monitoring of released animals including eastern grey kangaroos. This is due to the cost, expertise, technical requirements and practical difficulties of carrying out such monitoring. Richards (2006) noted that this has resulted in unsubstantiated claims about the effectiveness of translocation. In discussing 'real time' global positioning system (GPS) based monitoring of kangaroos, Richards noted that it is surprising to find 'the repeated claims by wildlife carers that all of their rehabilitated animals were alive more than twelve months after release. This statement would be unbelievable even if it weren't for the fact that mortalities amongst wild populations of kangaroos are known to be significantly greater than zero'.

Significant advances are being made in the tracking of animals using GPS devices. This is very expensive (compounded by the loss of devices), prone to equipment failure, and requires varying levels of technical expertise, supporting equipment and commitment over a long period. GPS collars are being used in a project to track kangaroo movements in the ACT (updated information can be obtained from the website of the ACT Department of Territory and Municipal Services (Parks Conservation and Lands) see <http://www.tams.act.gov.au/play/parks_conservation_and_lands/wildlife>). Such tracking is extremely valuable for conservation programs involving translocation, but even there, may not be a feasible long-term option because of costs and logistics (Pople et al. 2001).

The longest period of monitoring of *hand-reared* eastern grey kangaroos reported in the scientific literature is for 20 hand-reared kangaroos released with radio-collars on a rural property near Mudgee (NSW). The kangaroos were tracked for varying periods, the longest being more than two years for one individual. In this study, four of the original number were not released due to death or injury; no mortality was detected during the term of the study of those released; and about one-third emigrated from the site over time (Campbell and Croft 2001). Higginbottom and Page (2010) recorded a translocation of eastern grey kangaroos on the Queensland Gold Coast, beginning with 13 animals (excluding pouch young). Three died of physical injuries in the capture process and of the ten remaining, which were tracked using radio collars, six were alive and apparently healthy after 12 months. The authors concluded that capture, release and monitoring are expensive in time and money for the few animals involved, and while feasible, translocation is not likely to be a widely applicable option for dealing effectively with the destruction of kangaroo habitat, associated with development.

In a review of published results of animal relocations internationally, Fischer and Lindenmayer (2000) found that of 116 reintroductions, 47% had unknown results, 26% were classified as successful and 27% as failures. For conservation based translocations, a major issue is that the limiting factor that resulted in the depletion or extinction of the species at the release site is likely to impact on the reintroduced population. Well funded and well organised translocations have failed, often because the released animals were killed by predators (Fischer and Lindenmayer 2000; Short et al. 1992), even in cases where predator control was carried out in advance. Predator recognition training is recognised as essential for captive bred populations, and in conservation programs, strong justification for establishing breeding populations at release sites rather than translocating captive-bred animals that appear to have poor predator avoidance behaviour (Griffin et al. 2000; Pople et al. 2001; Richards 2006). Reintroduction of macropods for conservation purposes has involved species less robust in some ways than eastern grey kangaroos, in that the latter are less affected by cat and fox predation. However, eastern grey kangaroos are a nervous and flighty species compared to many other macropods (Jackson 2003) and may have less chance of surviving a capture and movement process than some of the threatened species.

4.4.6 (e) Lack of suitable release sites

Proposals for the large scale translocations of excess numbers of kangaroos usually suggest rural properties or reserves where it is assumed these kangaroos will be safe. Unfortunately, these proposals usually indicate very limited knowledge of kangaroo ecology. If there is a proposed release site that is suitable kangaroo habitat, but is not already fully stocked with eastern grey kangaroos, there must be some reason for the reduced population. The number of kangaroos on every site (including none) is a result of the current or previous operation of ecological factors, such as food availability, shooting or predation risk. This is demonstrated by the failure of many translocations for conservation purposes, which have shown that the ecological factor that caused the species to decline on the release site needs to be remedied before translocation is attempted.

Finding suitable release sites for individuals or small numbers of animals using criteria based on factors affecting translocation success has been found to be difficult in urban areas (Higginbottom and Page 2010) but may be less of an issue where rural land is available (Campbell and Croft 2001). Presumably, on rural land, released animals that do not emigrate elsewhere have to contend with the same ecological factors as the resident population. There are no published data on the long term survival of eastern grey kangaroos in such circumstances. In the ACT and surrounding region of NSW, shooting is widespread and appears to be the dominant density limiting process in rural areas.

There is a welfare issue in relation to the selection of release sites. On rural lands in the ACT and surrounding New South Wales, kangaroos are culled non-commercially for damage mitigation as well as being harvested commercially in NSW (s. 3.9.5(b)). If substantial numbers of kangaroos (some hundreds or even thousands) could be translocated to properties in New South Wales, this would have to be to a property or a number of properties of substantial size. Even if kangaroos were not culled or harvested on these properties, some of the dispersing translocated animals are likely to be shot by neighbouring farmers or by commercial shooters, die on rural roads, or fall prey to predators such as wild dogs not present in their source environment. It will generally be more humane to shoot these animals in their home range and spare them the stressful processes of capture, transport, handling and acclimatisation to the release site.

It should be noted that it is an offence to 'liberate' a fauna species in NSW without a licence issued under s. 127 of the *National Parks and Wildlife Act 1974* (NSW). In order to import fauna into NSW a licence under s. 126 of the Act is required (NSW NPWS 2001). New South Wales landholders (rural lands) and government agencies (public lands) are unlikely to view favourably proposals to move excess populations of eastern grey kangaroos from the ACT to New South Wales, when there is a longstanding program to reduce kangaroo numbers or maintain them at sustainable levels on lands that they manage.

4.4.6 (b) Translocation of kangaroos: policies

Translocation of kangaroos or other macropods	
Translocation of eastern grey kangaroos	· Based on welfare concerns, lack of known conservation benefits, ineffectiveness in reducing large source populations, and the expense and logistical requirements involved, translocation of eastern grey kangaroos is not considered to be an appropriate management technique for reducing kangaroo numbers. Translocation will not be permitted for such purposes.
Translocation of threatened or locally extinct macropods	· The reintroduction of threatened or locally extinct macropods as part of a scientifically based conservation or recovery program may be supported. Translocation may be permitted for such purposes.

4.5 Human Welfare

Objective: Human Welfare	**Kangaroo management and community education minimise negative encounters between people and kangaroos in the ACT.**

Policies related to this objective are at:

- s. 4.5.1 (d) (Human welfare)

4.5.1 Reported kangaroo attacks on people

Reported kangaroo attacks include genuine attacks, as well as those that are defensive behaviour by kangaroos fending off dogs. In the latter, humans often sustain injuries when they intervene in the fight between the kangaroo and the dog (see, for example, O'Connor 2001; ABC Western Australia 2005). There is also a suggestion that, in a few cases involving aged male kangaroos, the behaviour perceived by the victim as an attack is more consistent with kangaroo courtship and mating behaviour. This is a particularly dangerous form of 'attack' with the kangaroo clasping a child's face from behind.

4.5.1 (a) Kangaroo attacks: risk factors and ACT situation

Kangaroo attacks on people are reported in the media on a regular basis throughout Australia e.g. Edwards 2009. Common locations are country towns, rural residential areas and the urban fringes of cities where human activities impinge on kangaroo habitat. Kangaroo populations have built up in some areas with green grass such as golf courses, sportsgrounds and even backyards (see, for example, Inwood 2006). Kangaroos are often portrayed as gentle, friendly creatures. Left alone they generally represent little threat to humans. However, people especially children, are often keen to approach and try to pat or cuddle the animals as they might a friendly dog. Even relatively tame kangaroos generally dislike such approaches from strangers and aggressive reactions can result. Hand-reared kangaroos may also be associated with an elevated risk of attack (see below). Kangaroo attacks are the most commonly reported 'negative wildlife encounter' by tourists to Australia, often occurring in areas where there is feeding of wildlife (Moscardo et al. 2006).

Large male kangaroos, in particular, are powerful animals and their claws and feet are able to inflict severe injuries. The following risk factors are commonly identified in avoiding a kangaroo attack:

- alteration or change to the natural habitat and feeding patterns of kangaroos (including hand feeding and kangaroo feeding in human modified areas close to where people live, exercise or walk their dogs)
- unrestrained dogs that harass kangaroos, resulting in a defensive response by male kangaroos or female kangaroos (where the dog gets between the female and its young). Experience shows it is dangerous and often ineffective to intervene in a confrontation between a kangaroo and a dog
- aggressive poses towards kangaroos or moving between a female and her young
- approaching male kangaroos involved in courtship/mating behaviour (males sniffing, touching or escorting females), dominance behaviour (sparring, showing off size and strength), or kangaroos making growling or clucking noises

- the feeding or hand-rearing and release of kangaroos which results in the loss of their instinctive fear of humans. In such circumstances the animals may become aggressive in seeking out food and may be particularly threatening to children.

There are no reliable data on kangaroo–human confrontations in the ACT and reported incidents are mainly related to dog harassment and intervention by the dog owner. However, the incidence of kangaroo 'attacks' (both attacks and defence) appears to be low even though the ACT has a high concentration of people and kangaroos. The reasons for this are not known but may relate to:

- community awareness about kangaroos, especially the need to keep dogs restrained in areas occupied by kangaroos (see *Dogs in Canberra Nature Park* and *Living with Kangaroos* and *Kangaroos in our Parks and Reserves* (<www.tams.gov.au>))
- the extensive open-space areas of Canberra including parks and reserves and urban open space with walking and bicycle paths that traverse kangaroo feeding areas. While these open-space areas encourage kangaroo grazing and kangaroos may move closer to residential areas during drought, their extent also allows greater separation of kangaroo grazing and potentially conflicting activities such as dog exercise
- the long-standing ACT ban on hand-rearing and release of kangaroos (though this occurs illegally to a small degree) (s. 4.4.5(a)). It is suspected that in old age, hand-reared kangaroos are prone to display aggressive and courtship behaviour towards humans. This is perceived as an attack and in one well observed case resulted in serious facial injury to a child. People who rear and release kangaroos are unlikely to identify such behaviour as being a result of their activities, if it commences 7–15 years later.

4.5.1 (b) Human welfare: policies

Human welfare	
Advice	Advice (signs, leaflets, website information) will continue to be provided about the risks in approaching free-ranging wild kangaroos. Particular attention will be given to the need to keep dogs restrained.

4.6 Managing kangaroo densities

Objectives: Managing Kangaroo Densities	• **Kangaroo densities in the ACT are managed according to the management objectives for the land on which populations occur.** • **Methods of managing kangaroo densities in the ACT are based on the best available scientific knowledge, humaneness, and cost-effectiveness.**

Policies related to this objective are at:

- s. 4.6.1 (f) (Culling)
- s. 4.6.2 (a) (Fertility control)
- s. 4.6.3 (d) (Environmental modification)

This section reviews current and potential methods for managing and reducing kangaroo densities in three categories: culling, fertility control and environmental modification. As outlined in s. 4.4.6, translocation is not considered to be an appropriate management technique for reducing kangaroo densities. In recent years significant attention has been directed across Australia to managing overabundant populations of kangaroos (Coulson 1998, 2001, 2007), especially those in

nature reserves (e.g. Morgan and Pegler 2010; Sluiter et al. 1997) and on land in close proximity to urban settlement (Inwood 2005). In some of these areas the use of lethal techniques raises public objection and culling via shooting is often logistically impossible (Herbert 2004). In contrast to earlier times, a framework based on scientific knowledge, animal welfare and government regulation has been developed to guide approaches to managing kangaroo densities. Any population regulation method should be feasible, cost-effective, humane, without side effects, and internationally acceptable (Cooper 2004). The practicality of currently available and possible future methods varies between their use with small contained populations and broad-scale control, as occurs under rural damage mitigation programs.

Management of kangaroo densities should be based on clear management objectives and kangaroo population data for particular areas. Without these, resources may be expended unnecessarily and other problems created. There are two key questions that need to be answered before undertaking population management, especially culling, namely:

- Is the density of kangaroos causing environmental, economic or social problems?
- Through intervention, especially by culling, will other problems be created?

(KAC 1997)

Clearly it is a better management approach to aim to maintain a population at a level consistent with the management objectives, rather than for the population to rise to unsustainable levels and then require large-scale culling. For this reason and because of the public objection to culling, considerable attention has been directed in recent years to fertility control techniques. Even a partially successful method could result in the need to kill fewer kangaroos over a given time period.

Population dynamics research is vital to the success of fertility control and is relevant to all control methods. The ACT Government has supported a research project to quantify the ecological relationships between weather, pasture and kangaroos in the ACT region (Fletcher 2006a). The population dynamics research suggests that for ecological reasons, fertility control would be effective in wild populations of kangaroos in temperate areas, only in particular circumstances. Work is continuing to refine the models derived from this research.

Population modelling also indicates that far fewer kangaroos are killed over the longer term by undertaking small regular (preferable annual) culls rather than allowing a population to build to unsustainable levels and then undertaking a large cull.

4.6.1 Culling

Culling involves the removal of a proportion of an existing animal population and may involve certain parameters (e.g. a culling season, age and sex of animals removed, and codes of practice). Shooting is the main culling technique for kangaroos. Lethal injection and poisoning are also discussed in this section.

4.6.1 (a) Shooting

Shooting is recognised by the Commonwealth, and all state and territory governments as target specific and the most humane way of culling and commercially harvesting kangaroos, based on a single shot to the head, using high energy ammunition. These conditions are specified in the national codes of practice for the shooting of kangaroos (NRMMC 2008a, 2008b). Shooting is similarly recognised by RSPCA Australia (2002, 2009). In their situational analysis reports for the NSW commercial harvest, Olsen and Braysher (2000) and Olsen and Low (2006) conclude that

shooting remains the most economical, effective and environmentally friendly technique to cull or harvest large numbers of kangaroos. The shooting that occurs in the ACT (all non-commercial) is undertaken to high animal welfare standards. This is due, in part, to the ACT setting a high standard for shooter licensing, as well as the imposition of a shooting season (s. 4.4.1(b)).

In the ACT, large numbers of kangaroos are found on land adjacent to urban and other occupied areas where human safety considerations often preclude the use of high powered rifles. Many of these areas border reserves, including the extensive grassland and woodland reserves, created in the Gungahlin, Jerrabomberra and Dunlop areas. These provide ideal kangaroo habitat and kangaroo populations are generally increasing in these areas.

4.6.1 (b) Capture darting and lethal injection

For enclosed populations, capture darting followed by lethal injection is an acceptable culling method when shooting is inappropriate e.g. areas in close proximity to residential areas. The captured kangaroos, which are rendered unconscious by the dart delivered capture drug, are hand injected with the lethal poison used for the euthanasia of domestic dogs and cats. Lethal injection is considered by animal welfare experts to be a humane way to kill animals, including kangaroos. The technique is expensive as it requires a number of trained personnel, veterinary involvement and specialised equipment and drugs. In addition, in some cases, capture darting needs to be undertaken with small batches of kangaroos whose movements are constrained e.g. in yards.

Capture darting and lethal injection was used by the Department of Defence to cull approximately 500 kangaroos from the Belconnen Naval Transmitting Site in the ACT in 2008, with groups of kangaroos being herded sequentially into a circular darting yard over a period of ten days. The method had been little used previously, and must be regarded as being at a pioneering stage, with potential for future improvement. The 2008 activity demonstrated: (a) that a number of beliefs about kangaroos are incorrect e.g. that they can not be herded into yards; and (b) that the technique, though expensive, and challenging to carry out correctly, could be developed for use on numbers of eastern grey kangaroos in areas where shooting is not appropriate. Roberts et al. (2010) have prepared a field-trialled darting protocol for free-ranging eastern grey kangaroos.

4.6.1 (c) Poisoning

Poisons have been used, sometimes on a large scale, to kill kangaroos and wallabies in pastoral areas of Australia (Dawson 1995; Poole 1984). Poisoning is used for wallabies in Tasmania. In mainland pastoral areas it is reported to occur, especially where graziers believe that licensed culling and commercial harvesting have not removed enough kangaroos from their properties (Grigg 2008; RSPCA 2002). Increased use of poisons is suggested as a likely response in pastoral areas should the ability to cull or commercially harvest kangaroos be removed (Olsen and Braysher 2000; RSPCA 2002). Poisons such as '1080' can be used for macropods, but they are non-selective and their use raises animal welfare concerns.

The effectiveness and humaneness of a poison in killing a target species needs to be carefully assessed, including: the difficulty of controlled delivery and dosage; the potential effects on non-target species including predator species; the properties of some chemicals allowing them to persist and enter food chains; and public safety considerations. The conclusion of the KAC (1997) remains valid that 'poisons are not a desirable method of reducing kangaroo numbers when more humane, safe and environmentally benign techniques are available'. Further research may identify poisons that satisfy welfare, safety, effectiveness and environmental impact criteria. Research of this type is being undertaken by the Invasive Animals CRC for some other vertebrates, including feral pigs and cane toads, but not, so far, for kangaroos.

9.6.1(d) Frequency of culls

Culling less often than annually requires more animals to be killed per year on average. This is because populations grow exponentially, meaning the number of new animals added to the population is greater in the subsequent year than the previous year. Thus to cull less often is worse for animal welfare and impact reduction, and it usually costs more.

9.6.1 (e) Size of culled population

It is a mistake to think fewer animals will be killed if a proposed population reduction (cull) is reduced in number. Subsequently, a greater number must be killed annually to maintain a population at a larger size, and can quickly outweigh the effect of a smaller initial cull.

4.6.1 (f) Kangaroo culling: policies

Kangaroo culling	
Shooting	· As the most humane and target specific technique currently available, shooting is the preferred technique for the reduction of kangaroo populations in the ACT. · Shooting of kangaroos to achieve land management objectives will be licensed subject to consideration of public safety, assessment of shooter competency, compliance with the *Code of Practice for the Humane Destruction of Kangaroos in the ACT*, and adherence to the defined culling season.
Capture darting and lethal injection	· Capture darting and lethal injection may be approved as a culling technique in the ACT, subject to compliance with relevant legislation and the *Code of Practice for the Humane Destruction of Kangaroos in the ACT*.
Poisoning	· Poisoning will not be approved as a kangaroo culling technique in the ACT, unless humane, safe, target specific and environmentally benign techniques are developed.
Research	· Research to develop alternatives to shooting will be encouraged, which are more suitable for urban and peri-urban areas.

4.6.2 Fertility control

The use of fertility control is often advocated in preference to lethal methods for controlling wildlife populations and to reduce real or perceived animal welfare and ethical concerns. The usefulness of a fertility control method depends on several factors including the duration of the effect; the ease of delivery, the ability to recognise previously treated individuals; cost; and the absence of harmful effects on target or non-target species (DeNicola et al. 1997 in Herbert 2004). In recent years major advances have been made in contraceptive methods of kangaroo population control (Herbert et al. 2010). Because of the relatively high costs per animal and the limited period of fertility control (except for surgical methods and chemical sterilisation) none of the methods is suitable for broad-scale kangaroo control (Olsen and Low 2006). A major attraction of fertility control for kangaroo populations in grassy ecosystem areas of the ACT is the potential to keep those populations at a level that maintains the natural integrity of the grassy ecosystems.

Fertility of eastern grey kangaroos can be successfully controlled already by a range of methods suited to small captive populations, such as surgery, or hormone implants lasting 1–3 years. In these cases, almost every kangaroo of one sex can be captured, and identified. To cause infertility sufficient to change the abundance of larger free-ranging populations, it seems likely to be necessary to find ways to deliver the fertility control agent in food. Population modelling suggests it is also desirable to find methods with an effective life of several years.

One promising way to cause infertility for a few years, with substances deliverable in food, is by vaccination (immunocontraception). Eastern grey kangaroos have been made infertile for at

least one year by injected vaccine based on either Zona Pellucida (ZP, egg coat) proteins, or the hormonal control of reproduction in the brain involving Gonadotrophin Releasing Hormone (GnRH) (Kitchener et al. 2008; Parks, Conservation and Lands unpublished data). Research on fertility control in eastern grey kangaroos in the ACT has been conducted under cooperative arrangements between ACT Parks, Conservation and Lands and either the University of Newcastle, or CSIRO staff funded by the Invasive Animals CRC.

The general aim of fertility control is to reduce the population growth rate. This means that lethal interventions would be needed less often. Modelling, using realistic scenarios involving kangaroo capture, indicates that the success rate of treatment in the range of published fertility values is less important than the life of the fertility treatment in determining how frequently the population must be re-treated to maintain it at set limits. For example, in some circumstances it would be more cost effective to use a method that had a 70 per cent success rate and lasted three years than one which blocked fertility in 99 per cent of females for one year. Alternative forms of fertility control for macropods are being investigated by at least three groups of researchers in Australia, but all approaches are still in the research and development phase and unlikely to be effective for large populations, or non-captive populations, for several years. Table 4.1 contains a brief summary of these alternatives. Brief reviews of fertility control options are contained in Olsen and Braysher (2000) and Olsen and Low (2006).

Following the recommendations of the former Kangaroo Advisory Committee, the ACT Government has been providing financial and in-kind support for research into kangaroo fertility control methods since 1998, a record unmatched by any other state or territory government. The senior research partner has been the Marsupial Research Laboratory, in the University of Newcastle. In terms of research grants and ethics committee approvals, there have been several separate projects since 1998, which are all focused towards the development of orally-delivered fertility control in eastern grey kangaroos using zona pellucida (ZP) vaccines (Table 4.1). More recently, a CSIRO group funded by the Invasive Animals CRC has also joined the research, to investigate GnRH vaccines. Research institutions generally do not have extensive tracts of land containing kangaroo populations and some ACT sites are ideal for this purpose. For example, Belconnen Naval Transmitting Station, where fertility control research is in progress, is exceptional because of its convenient size, open grassland vegetation, security fencing and urban location. As noted in s. 4.6, population dynamics research, essential to the success of fertility control, has also been supported by the ACT Government and a major study completed (Fletcher 2006a).

Table 4.1 Summary of macropod fertility control alternatives

Method	Estimated effective life	Notes
SURGERY: Summary Readily available but expensive, invasive, and requires capture and anaesthesia of animals. If vasectomy/castration of males only, then immigration of entire males must be closely monitored and tightly controlled.		
Castration of males	Permanent	Loss of male behaviours.
Vasectomy of males	Permanent	Retention of male behaviours.[1]
Ovariectomy of females	Permanent	Equivalent to castration of males but requires abdominal incision (major surgery). No record of use for eastern grey kangaroos.
Tubal ligation of females	Permanent	Equivalent to vasectomy but requires endoscopic surgery or abdominal incision. Has had limited use.

Method	Estimated effective life	Notes
CONTRACEPTIVE IMPLANTS: Summary Hormonal contraceptives can be divided into non-steroidal (GnRH agonists) and steroidal (synthetic progestins) types. Require capture and anaesthesia of animals. A single treatment is likely to reduce fertility for a few years. See Herbert et al. (2010).		
Non-steroidal agents (subcutaneous injection)	At least 1 year, possibly 15 months	Non-steroidal contraceptive Deslorelin®/ Suplorelin® recently registered as an off-the-shelf veterinary product. Research at University of New South Wales. Retreatment 1–2 years.
Steroidal agents (silastic implants)	3 years	Most common form of steroidal contraception used in zoos because of efficiency and low cost. Levonorgestrel® considered promising in tests with macropods. Research at University of Melbourne. Retreatment 3–5 years.
IMMUNOCONTRACEPTIVES (VACCINES):Summary Immunosterilisation or immunocontraception has potential for oral delivery, which is what makes this approach attractive. At the current stage of research (injected delivery) the method is comparable to the implant methods in performance. A single treatment is likely to reduce fertility for a few years.		
ZP (zona pellucida) vaccine	3 years (?)	Potential for future delivery in food. Potential for species specificity. Research by Marsupial Research Laboratory, University of Newcastle.
GnRH vaccine – e.g. GonaCon®	3 years (?)	Potential for future delivery in food. Research by Invasive Animals Cooperative Research Centre.
CHEMICAL STERILISATION		
Vinyl Cyclohexene Dioxide (VCD)	Permanent (?)	Potential for future delivery in food. Research by Invasive Animals Cooperative Research Centre.

Notes: 1. Examples of use are at Government House (Yarralumla, ACT) (Coulson 2001) and Sanctuary Cove Resort, Hope Island (Qld) (McDonald 2007). Maintenance of normal male behaviours following vasectomy results in mature males seeking to prevent breeding by invading males.

4.6.2 (a) Fertility control: policies

Fertility control	
Development of fertility control methods	· Cooperation between ACT Parks, Conservation and Lands and research institutions in the development of fertility control methods for controlling eastern grey kangaroo populations, especially immunocontraception (vaccines), will be continued. This support may include: o administrative and regulatory arrangements o funding o staff resources o assistance with access and use of sites for research and trials.
Advice to land managers	· Advice and assistance will be provided to managers of ACT leasehold land and National Land on the use of fertility control to manage kangaroo populations on their land.

4.6.3 Environmental modification

Three types of environmental modification were considered by the former Kangaroo Advisory Committee and are reviewed below.

4.6.3 (a) Vegetation manipulations

Past tree clearing on grazing properties in the ACT has increased the available habitat for kangaroos. Some of these cleared areas e.g. the Tidbinbilla Valley and Gudgenby are now in

conservation reserves. The Committee suggested that a long-term option for managing the high density kangaroo populations in such areas would be to reduce the available grazing habitat through reestablishment of native tree cover (KAC 1996a, 1997).

'Restoration of cleared valleys' has been included in the 'ecological restoration' and 'pest animal' sections of the *Namadgi National Park Plan of Management* (ACT Government 2010b). This restoration would be aimed at providing more habitat for arboreal mammals and their predators, as well as reducing kangaroo numbers, nevertheless kangaroos densities would be expected to remain high in other open valley areas.

Any such restoration would be a long-term project and given the costs involved would need to consider the objectives for particular areas and how a reduction in kangaroo density relates to those objectives. High densities of kangaroos and rabbits may also limit vegetation recovery in such areas. The potential for this has been shown in research into grazing and browsing of seedlings by macropods and rabbits in native vegetation restoration following removal of the pine plantation in the southern part of the Gudgenby area (Webb 2001). However, other limiting processes such as cold-induced photo-inhibition and the effects of rabbits at higher density were not evaluated. Thus it remains to be determined which processes are most important: rabbit browsing, wallaby browsing, kangaroo browsing (and trampling), or weather effects.

4.6.3 (b) Limiting water access

Restrictions on access to water and closure of artificial water points have been considered and assessed in the rangelands as a way of reducing kangaroo numbers (Montague-Drake and Croft 2004). Closure has been undertaken in some national parks that were formerly grazing properties with the aim of improving vegetation recovery. Over the limited time scales considered so far, only localised reduction in kangaroo numbers is evident and there has been no significant improvement in vegetation. Vegetation recovery has been influenced during this period by drought, which has also reduced macropod numbers (Fukuda 2006). The evidence so far suggests that water point closure is not a viable method for large-scale control of kangaroos, because kangaroos are highly mobile and able to travel to water (Olsen and Low 2006). The availability of food rather than water appears to be more significant for kangaroo distribution (Montague-Drake and Croft 2004; Pople and Page 2001 in Olsen and Low 2006).

Field observations suggest that, in most years, eastern grey kangaroos in the temperate environment of the ACT drink infrequently (Fletcher 2006a). Eastern greys have water conserving capacities equivalent to similar sized placental mammals that inhabit the arid zone (Blaney et al. 2000) and it is likely that most of their water needs in temperate sites are met from the vegetation (Fletcher 2006a). In the ACT, surface water is rarely more than a kilometre away from most kangaroo populations.

The former Kangaroo Advisory Committee concluded that limiting water access could affect other species, was not practical in areas where water supply is abundant, and was costly. For these reasons its efficacy in the ACT was rated as low (KAC 1996a, 1997).

4.6.3 (c) Reintroducing predators

Foxes and dingoes/wild dogs are predators of kangaroos in the ACT, mainly in Namadgi National Park. The influence of dingoes/wild dogs in the pasture–herbivore system is magnified by non-lethal effects (predation sensitive foraging) which may be more important than direct, lethal effects (Fletcher 2006b). Management decisions about dingoes and foxes should regard the predator as a component of the kangaroo–pasture system. Where kangaroo density is naturally

low, managers should only contemplate predator control with an awareness of the possibility that interference with the predators may release the kangaroo population from a low density state (Fletcher 2006a). Management of the dingo/wild dog population in Namadgi, especially in relation to neighbouring rural lands, is included in the plan of management for the park. It is not practical that predators such as dingoes/wild dogs be reintroduced elsewhere e.g. reserves bordering the Canberra urban area.

4.6.3 (d) Environmental modification: policies

Environmental modification	
Vegetation manipulation	· Vegetation manipulation to influence kangaroo densities will be considered in areas where this would support the management objectives for the land, especially where these objectives include the expansion of limited habitat and habitat for rare and threatened species.
Water access	· Limitation of access to water will not be undertaken by the ACT Government for managing kangaroo densities, as it is unlikely to be an effective technique.
Reintroduction of dingoes/wild dogs	· The reintroduction of dingoes/wild dogs will not be undertaken in lowland grassy ecosystems and rural areas of the ACT for the purposes of controlling kangaroo numbers.
Dingoes/wild dogs in Namadgi NP and Tidbinbilla NR	· The dingo/wild dog population that is present in Namadgi National Park and Tidbinbilla Nature Reserve will be maintained as a natural component of the kangaroo–pasture system.

5 Managing Environmental Impacts of Kangaroos

in Grassy Ecosystems

The Gudgenby area of Namadgi National Park is one area where dingo predation on kangaroos still occurs. A range of colouring is characteristic of these dingoes as in this photograph.

5.1 A management model

This chapter outlines the approach to managing the environmental impacts of kangaroos in grassy ecosystems and is applied to categories of land in the ACT (s. 2.2):

- Public Land (s. 5.3)
- Other ACT Government managed land (s. 5.4)
- Leased Territory Land (s. 5.5)
- National Land (s. 5.7).

Included in this chapter (s. 5.6) is Googong Foreshores which is Commonwealth Land in New South Wales leased to and managed by the ACT Government.

Many of the government managed areas have an interface with leased rural land and kangaroos move between the two. This may have an economic impact on rural lessees. The issue is discussed further in s. 6.2.2(d).

In managing kangaroo populations, the chapter makes a clear distinction between the lowland grassy ecosystems (including Googong Foreshores) and the lower elevation valleys of the western and southern ranges and Lower Cotter Catchment. While native grassy ecosystems have the highest priority when considering environmental impacts, areas that have a high exotic component are also included where they contain important species habitat.

While the primary focus of this chapter is on environmental impacts, economic considerations (e.g. cost of population control techniques) and social considerations (e.g. animal welfare) are also important to management decision making. The environmental impacts that may result from high kangaroo densities are summarised in s. 3.11, namely:

1. Excessive grazing pressure on native grassy ecosystems resulting in degradation of the natural integrity of those ecosystems.
2. Excessive grazing pressure resulting in loss and degradation of habitat critical to threatened species of grassy ecosystems.

The principles stated in s. 4.2 form a foundation for management of kangaroo populations in grassy ecosystem areas, in particular:

Environment	**a) Kangaroo management is based on the best available knowledge of kangaroo biology and ecology.** **b) The conservation of native grassy ecosystems and their constituent flora and fauna species is a legislative requirement and a high priority for the government.**

The other principles related to *economy and society*, and *managing kangaroo populations* (s. 4.2) are also relevant to managing environmental impacts.

Kangaroos are an important component of grassy ecosystems, but past experience shows that their densities can increase to the level where they have deleterious impacts on those ecosystems, namely:

- reduced biodiversity (number of indigenous plant and animal species) and impact on regeneration of native species
- reduced vegetation biomass
- heavy grazing creating a condition that gives rabbit populations the potential to increase (as rabbits prefer short grass)

- overgrazing leading to the spread of burgan (*Kunzea ericoides*)
- potential for erosion
- overgrazing leading to the spread of weeds.
- reduced abundance of significant (threatened) species.

(KAC 1997; Parks, Conservation and Lands unpublished data, 2009)

These impacts follow the loss and disturbance of native grassy ecosystems after European settlement and are of most concern where they threaten the few remaining high quality areas that have been the subject of much recent conservation effort.

The key consideration for the management of the land areas included in this chapter is the prevention of such undesirable impacts (s. 2.5). This will not be achieved by monitoring and recording impacts, and then taking action after the damage has occurred. Primarily, management of the conservation areas needs to be preventative, and therefore based on principles derived from separate research on the interactive relationships between grazed pastures and grazing animals, and research on the significant plant and animal species of the grasslands.

The ACT Government has contributed significantly to the knowledge of how to effectively manage a wild herbivore population for various conservation objectives. In particular, an ecological model of the interactions between weather, kangaroos and vegetation (Fletcher 2006a) based on that of Caughley (1987b), makes predictions of the outcomes of management, such as culling proposals, which are useful for guiding management strategies and research designs. The model is based on measurements of local pastures and kangaroo populations and will be continuously refined as additional data become available (Figure 5.1). A revised grassland monitoring program for this purpose has been established in Research and Planning (Parks, Conservation and Lands). This program gives explicit recognition to the role of natural herbivory in grassland ecology and will be closely integrated with any specific monitoring of grassland flora and fauna, including threatened species.

Figure 5.1 Interactive herbivore–vegetation model defined by Caughley (1976b)

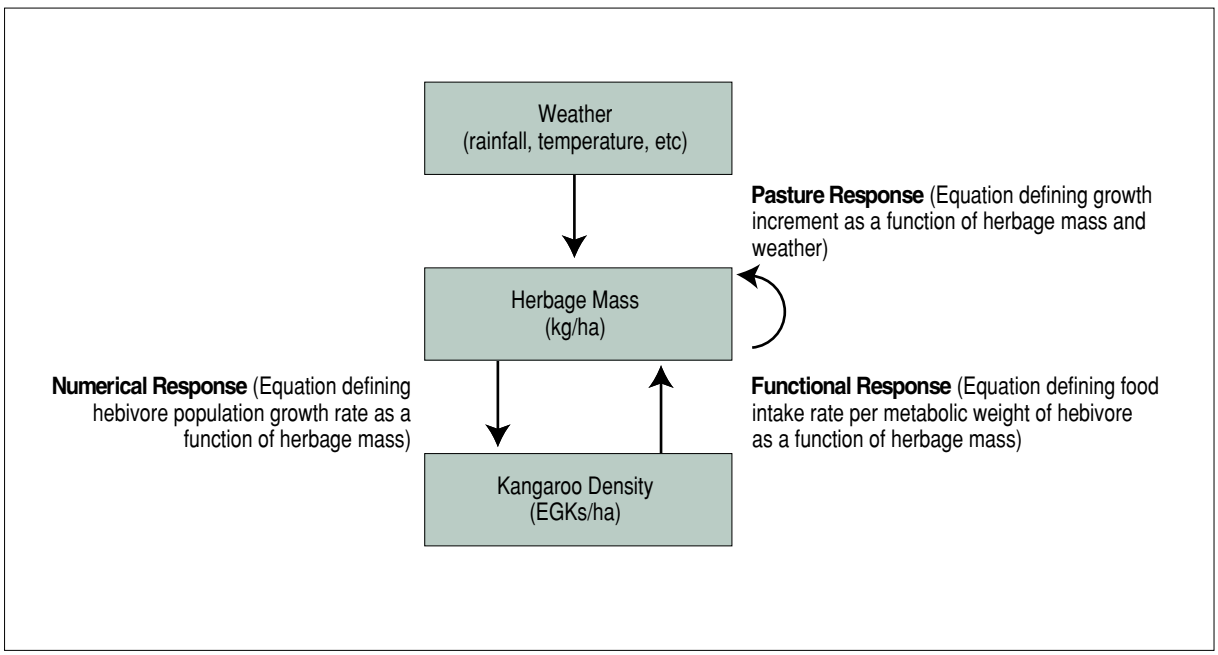


Table 5.1 provides outputs of the model for three alternative management scenarios, each based on 10 'runs' of 100 years, using Queanbeyan rainfall and temperature (for which there are long term records). In the first scenario, no management treatment is applied to the kangaroo population, which is limited by the natural variations in the weather as expressed through variable pasture (food) availability. The other two scenarios are two different management treatments that reduce the number of kangaroos, each according to different prescriptions. One management prescription is a version of the commercial harvesting process applied hypothetically to a kangaroo only grazing system, and the other is based on reducing impacts to vegetation. From the model (Table 5.1), the commercial harvest prescription provided a sustainable yield of kangaroos, but had marginal benefit for the vegetation, while the 'impact reduction' formula resulted in higher amounts of pasture.

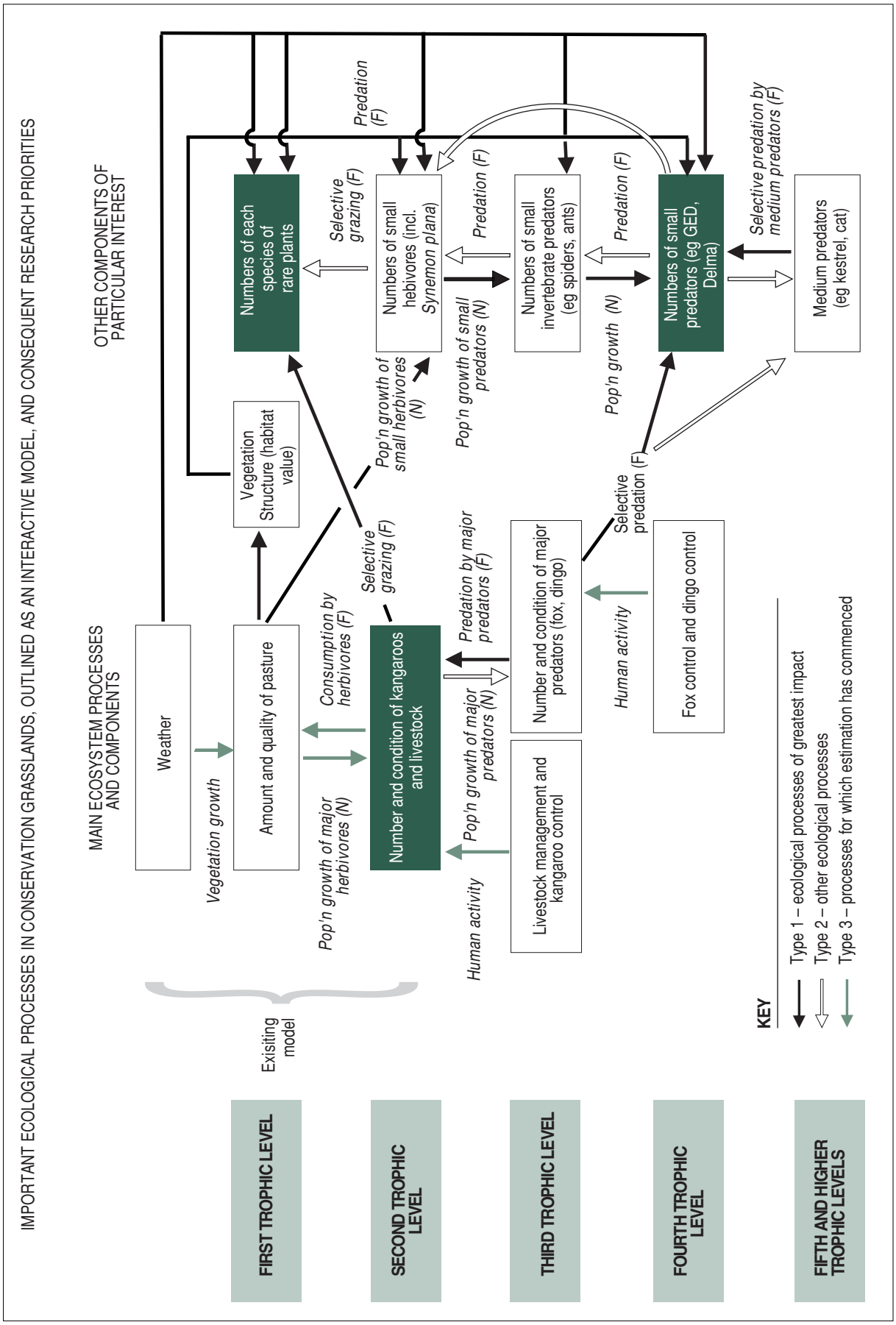
An advantage of using models such as this is that the interactions between kangaroo numbers and vegetation are observable and can be used to guide management. Which management alternative is best, such as the three examples shown in Table 5.1, depends on management objectives for kangaroos and/or vegetation and other species present in the grassy ecosystem. Further data from field research will enable refinement of the model. Another desirable activity is to test model predictions against real kangaroo and pasture populations, which will involve field-based research over a number of years under varying annual rainfall and therefore pasture growth conditions.

The condition of a declining pasture–herbivore system is likely to be detected first in the condition of the pasture and also in the absence of small animals such as lizards and insects, rather than the apparent condition of the herbivores (s. 3.3.8). However, it is the abundance of the large herbivores that is the variable of greatest utility for managers to influence the system. Where stock are used to manipulate pasture biomass, they can be readily introduced or removed by the manager, but this is a more difficult task with native free-ranging herbivores. Weather is the most significant variable through its effect on pasture growth, but is independent of management (Figure 5.2).

Table 5.1 Three alternative hypothetical management scenarios relevant to the ACT region, derived from the interactive herbivore–vegetation model shown in Fig. 5.1

	Management Strategy		
	No management intervention	**Hypothetical commercial harvesting**	**Vegetation impact reduction (e.g. for nature reserves)**
No. kangaroos shot/sq./km/yr (SE)	0 (0)	30 (4.4)	32 (1.5)
No. kangaroos left/sq./km (SE)	240 (27)	200 (38)	60 (0.67)
Green herbage density (kg/ha) (SE)	809 (225)	910 (276)	1858 (208)
Green herbage gained (kg/ha)	0	102	1050
Green herbage eaten (kg/ha/yr) (SE)	4483 (1035)	3846 (1767)	2143 (148)

Figure 5.2: Ecological relationships of particular relevance to grassland research and management



Coloured boxes enclose components of special public interest or legal status. The main flows of energy and materials in a grassy ecosystem have been estimated once in the local climate (left column) and represented in an interactive model (Fletcher 2006a). The state of these major components is likely to influence components on the right, but not the reverse. However, the right column includes items of particular interest. The ecological processes (arrows) are an important consideration for researchers, for example, there is no direct relationship between kangaroos and grassland earless dragons. Therefore it is desirable to estimate the relationships along the indirect pathways that link the two, and the alternative factors such as effects of weather. N= Numerical Response, F= Functional Response, Pop'n= Population, GED=grassland earless dragon, Delma= striped legless lizard.

5.2 Kangaroo density and ecosystem function in ACT lowlands

Determining an appropriate kangaroo density for a particular area or type of ecosystem depends crucially upon the management objectives for the land in question. Some other considerations are discussed in Chapter 3, especially s. 3.9.2(c) ('carrying capacity'). In particular, it is evident that the herbivore (e.g. kangaroo) carrying capacity would be lower than the ecological or economic carrying capacity, if suitable habitat in lowland grasslands for small fauna such as endangered reptiles is to be maintained (Figures 3.1, 3.3).

In the published literature on kangaroo and grassland ecology, there is little specific guidance on appropriate kangaroo densities that maintain ecosystem condition. As noted in s. 3.11, recent research to estimate functional responses and numerical responses of eastern grey kangaroos on a range of sites and pasture types (natural and exotic) in the ACT and at Googong Foreshores (Fletcher 2006a), as well as mathematical modelling, suggest that *a significant increase in herbage mass is associated with kangaroo densities that are in the range of approximately 0.6 to 1.5 per hectare in grassland areas*. This estimate is regarded as an initial approximation that requires further refinement. However, it accords with observations of the deleterious impacts of kangaroos on lowland native grasslands in the ACT when their densities are higher. While recognising the need for further research to better estimate appropriate densities, in the following sections the term *grassland conservation densities* is used to refer to densities that:

- relate to the management objectives for the land
- maintain suitable habitat for other grassland flora and fauna species (in particular, threatened species)
- recognise a mean kangaroo density of less than 1.5 per hectare as a likely requirement in order to maintain the natural integrity of lowland grassy ecosystems.

5.3 Public Land

Public Land is defined in s. 2.2.1(a) and includes the reserves and public open space areas of the ACT for which management objectives are prescribed in the *Planning and Development Act 2007* (Schedule 3). ACT Parks, Conservation and Lands is the primary 'custodian' (s. 320(1) of the Act) and land manager for this land. Public Land areas that contain native grassy ecosystems are mainly National Park, Nature Reserve, Urban Open Space, or Special Purpose Reserve. Kangaroos are not significant grazers in most of the small areas of Urban Open Space that contain grassland remnants and are bounded by residential areas or other urban land uses.

Public Land areas contain:

- the network of reserves that make up Canberra Nature Park; stretching from Mulligans Flat in the north to Rob Roy in the south
- the linear reserves making up the Murrumbidgee and Molonglo River corridors
- Namadgi National Park, Tidbinbilla Nature Reserve, and the Lower Cotter Catchment.

The ACT Government has given specific attention from the mid 1990s to the protection and management of the remaining areas of lowland grassy woodland and native grassland in the ACT. This is expressed in the reserves specifically established to protect these ecological communities such as Goorooyarroo Woodland Reserve, Gungaderra Grassland Reserve and the Jerrabomberra Grassland Reserves. These are part of Canberra Nature Park for which there is a management plan (ACT Government 1999b). More recently declared reserves are covered by the policies of the plan, even though they are not specifically shown in the plan.

Native grassy ecosystems also occur in the Murrumbidgee River and lower Molonglo River corridors for which there are management plans (ACT Government 1998, 2001). Management plans have been prepared for Namadgi, Tidbinbilla and the Lower Cotter (ACT Government 2010b, 2010a, 2006). Management of grassy ecosystem areas is guided also by management objectives and actions contained in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004) and the *ACT Lowland Native Grassland Conservation Strategy* (ACT Government 2005) and parts of the *ACT Aquatic Species and Riparian Zone Conservation Strategy* (ACT Government 2007a).

5.3.1 Lowland native grassland and grassy woodland

Objective: lowland native grassy ecosystems	**Kangaroo populations are maintained in lowland native grassy ecosystems at densities that conserve the natural integrity of the grassland ecological community and result in the maintenance of habitat for all grassland plant and animal species.**

Policies related to this objective are at:

- s. 5.3.1(g) (Lowland native grassland and grassy woodland)

This section refers to both lowland grassy woodlands and lowland native grasslands (see s. 3.5 to s. 3.8). Significant grassland sites are listed in Appendix 2, woodland areas in Appendix 3, and uncommon grassland flora and fauna species in Appendix 4. ACT lowland native grassland areas in Public Land are listed in Appendix 2. The largest reserves are in Gungahlin, the Jerrabomberra Valley and at Dunlop (North Belconnen). These areas contain varying amounts and proportions of natural temperate grassland, native pasture and exotic pasture (see Botanical Significance Rating in **Glossary**). Most contain populations of threatened species, which are grassland specialists (e.g. grassland earless dragon, striped legless lizard). The grassland nature reserves are all categorised as Core Conservation Sites (Category 1) due to their large size and presence of key threatened species habitat, rather than a high BSR rating (Appendix 2).

Lowland woodland areas in the ACT are found in the approximate altitudinal range of 600–1000 m, and before widespread disturbance, they intergraded at lower altitudes with natural temperate grassland. Broadly, the distribution of lowland woodland in the ACT is in a north-south pattern along the hills and ridges that flank the urban and rural areas of the Territory. Some lowland woodlands are included in Public Land in the reserves that make up Canberra Nature Park and the Murrumbidgee River Corridor. More details are contained in the ACT Woodland Strategy (ACT Government 2004).

5.3.1 (a) Management objectives (land)

The ACT woodland, grassland, and riparian strategies (ACT Government 2004, 2005, 2007a) have common goals focused on the conservation in perpetuity of grassland and woodland ecological communities and component species and the rehabilitation of degraded areas, where this is desirable and feasible. The strategies contain a range of specific objectives and actions in support of these goals. Many of the actions are underway or ongoing. Objectives for the protection of natural values are contained also in management plans for Canberra Nature Park (ACT Government 1999b) and the Murrumbidgee River Corridor (ACT Government 1998). Conservation of the remaining grassy ecosystem areas and the species they contain requires management attention to grazing pressure, fire frequency, mowing regimes, control of weeds and ground disturbance.

5.3.1 (b) Status of kangaroo populations

The grasslands and grassy understorey of woodlands provide ideal kangaroo habitat. In many areas there is a woodland–grassland matrix with kangaroos making use of remnant woodland areas for daytime shelter and protection from predation (Caughley 1964b; Viggers and Hearn 2005). Prior to the expansion of urban and other development, these grassland areas were in rural lease and mainly used for grazing. A predator trophic level acted on kangaroo populations in the form of the culling undertaken on rural leases. In reserved areas, the predator trophic level is now missing. Except for mortality from vehicle collisions, the main limitation on kangaroo population growth is food supply. Across the lowland grasslands, kangaroo populations are still increasing.

5.3.1 (c) Management issues with kangaroo populations

Due to the recent establishment of the grassland and woodland reserves and their previous rural lease status, there is limited experience with the dynamics of kangaroo populations in particular locations. However, analogies can be drawn with the population irruptions that have occurred at Googong Foreshores and Belconnen Naval Transmitting Station (Figure 3.2) and other locations in Australia (Coulson 1998).

Eastern grey kangaroos perform an important role in native grasslands; however, their density in grassland remnants is a significant management issue. Sustained heavy grazing pressure can lead to deleterious impacts on grassland communities and the animals and plants that depend on these grasslands for habitat. This impact is similar to that of overgrazing by livestock. Overgrazing is of particular concern when it affects endangered grassy ecosystems and threatened animals and plants, as any reduction in the suitability or quality of their habitat places them at higher risk of extinction. Overgrazing may also affect the regeneration of woodland tree species (Rath and Hurlstone 2006; Webb 2001).

Some form of defoliation is essential to maintaining the structure and botanical composition of most native grasslands (Eddy 2002). Historically, kangaroos have been one of the defoliation agents in grasslands. Cattle grazing is used in some ACT grassland reserves for this purpose, with the numbers being manipulated according to seasonal conditions, pasture growth and management objectives for particular areas. Defoliation by kangaroo grazing is increasing in both extent and degree, so the use of livestock has declined.

Monitoring of ground cover in native grassland areas from 1993 to 2002 shows that there was little change in this cover at sites where there has been low to moderate grazing pressure by cattle and/or kangaroos (Figure 5.3). On sites with high levels of kangaroo grazing, ground cover declined to levels associated with soil loss and reduced plant species diversity. The issue could

arise in other sites where total grazing pressure is not managed. It is of particular significance in the Majura and Jerrabomberra valleys where the grassland areas contain some of the few remaining populations of the grassland earless dragon.

With regard to kangaroo populations, the following are the main management considerations and issues for these grassland areas:

- It is appropriate to maintain a kangaroo population on the larger grassland sites that are capable of supporting that population.
- In most cases, kangaroo populations have not reached equilibrium with the pasture food supply ('ecological carrying capacity', see s. 3.9.2(c)) and are still increasing. Grasslands have been included in ACT reserves for widely varying times, from less than a year in some lowland reserves, to more than forty years at Tidbinbilla. In some areas kangaroos were barely present in the area at the time of reservation (s. 3.2, s. 5.3.2) and are now at relatively uniform high abundance e.g. Gudgenby (Fletcher 2006a). Some appear to have reached 'ecological carrying capacity' (see s. 3.9.2(c)) while others are presumed to be still increasing. In some areas irruptions (see s. 3.4.4) appear to have occurred (unpublished data, ACT Parks, Conservation and Lands).
- The attainment of 'ecological carrying capacity' where kangaroo numbers are limited by the pasture food supply is not a desirable condition of the grassland for the conservation of plant and animal species that depend on more complex structure or a higher level of cover.
- Grazing pressure is already of concern in some areas e.g. Jerrabomberra East Nature Reserve, Mulligans Flat and Goorooyarroo nature reserves.
- Impacts of overgrazing on threatened grassland specialists have been documented. There is a legislative requirement and government policy to protect these species.
- Techniques for kangaroo population control (e.g. culling), where necessary, are likely to be constrained by the proximity of reserves to residential and other urban land uses.

5.3.1 (d) Management priorities (land)

Management priorities need to be adapted to the values of particular grassy ecosystem areas, but will always involve the following:

- maintenance and improvement of the ecological condition and habitat quality of native grassland and woodland sites
- the control of threats to the natural integrity of grassland and woodland sites, including overgrazing
- the conservation of threatened species and ecological communities
- building knowledge of grassland and woodland ecology through survey, monitoring and research to assist management decision making.

5.3.1 (e) Management options (kangaroos)

Management options can be placed along a continuum from 'doing nothing' to permanently removing all kangaroos from grassland sites, and this is illustrated in Table 5.2. This shows that the most desirable option is one that maintains *grassland conservation densities* as defined in s. 5.2.

5.3.1 (f) Mulligans Flat Woodland Sanctuary

Mulligans Flat Woodland Sanctuary (the sanctuary) is situated within Mulligans Flat Nature Reserve (established 1995) in north-eastern Gungahlin. The reserve adjoins a similar area of box–gum grassy woodland in Goorooyarroo Nature Reserve (established 2004). Together the two reserves (about 1500 hectares) make up the largest and most intact contiguous area of yellow box – red gum grassy woodland in public ownership across the original range of this ecological community in south-eastern Australia. The sanctuary is within a feral animal proof fence designed, in particular, to exclude foxes, dogs and cats.

The sanctuary is part of a research project commenced in 2004, between the ACT Government and the Australian National University, designed to improve the knowledge base for understanding and managing temperate woodlands for biodiversity conservation. In particular, the sanctuary allows for assessment of the ecological impact of excluding cats and foxes and the effects of reintroducing native species. Other 'treatments' include the replacement of fallen timber, burning, and reduction of kangaroo grazing to the extent that ground vegetation recovers.

There will be the need for on-going management of the kangaroo population in the context of the objectives for the sanctuary. Kangaroos will not be able to pass through or over the sanctuary fence. The captive population enclosed by the fence will need to be managed in order to maintain the condition of the grassland and woodland, and in relation to the species introductions that will form part of the sanctuary experiment. A staged reduction to a sustainable level of grazing pressure is envisaged and as the area is mainly woodland, a lower density of kangaroos than in grassland areas is likely to be appropriate.

Given the cost of establishing the sanctuary, the research effort being invested, the opportunities it presents to re-establish a representation of pre-1750 grassy ecosystems, and the potential for the transfer to other areas of the knowledge gained; it is essential that the kangaroo population be managed so as to be integrated into the ecosystem rather than being a dominant or destructive force (see 'ecosystem engineers', s. 3.4.3).

5.3.1 (g) Lowland native grassland and grassy woodland: management policies

Lowland native grassland and grassy woodland	
All Public Land locations	· To assist management decisions, ongoing improvements will be undertaken of the ecological model for kangaroos and vegetation developed in Parks, Conservation and Lands (Figs 5.1, 5.2). · Long term monitoring of lowland grassy ecosystems will be undertaken that includes the interaction between the vegetation and principal herbivores (domestic stock, kangaroos, rabbits). · On Public Land areas containing grassy ecosystems, kangaroo populations will be managed in accordance with the management objectives for those areas. · On Public Land areas containing declared threatened species and ecological communities, kangaroo populations will be managed with the aim of achieving desirable *grassland conservation densities* (s. 5.2). · Management policy and actions for kangaroos on Public Land will be explained in information to the public, especially where interventions are required.
Mulligans Flat Woodland Sanctuary	· The captive kangaroo population in the Mulligans Flat Woodland Sanctuary will be maintained as an important component of the native grassy ecosystem. · Kangaroo density will be maintained at a level that accords with the objectives for the programs and activities being undertaken at the sanctuary.

Table 5.2 Management options for kangaroo populations in lowland grassy ecosystems and their implications

Management Option	Implication
Do nothing	· Kangaroo numbers limited only by food supply (i.e. starvation) or factors operating at particular grassland sites (vehicle collisions, fox/dog predation). · Kangaroo numbers may increase exponentially (herbivore irruption), prior to a 'crash'. · Destructive of grassland condition. As kangaroo population increases towards 'ecological carrying capacity', loss of grassland structure and cover and threat to grassland specialists including threatened species. Not in accord with second goal of this plan (s. 1.3). · Socially acceptable to some because no population control actions, such as culling, are undertaken. · Pasture availability will ultimately limit population: starving, diseased and dead kangaroos may be observed.
Maintain high densities	· May only be possible in particular environments. · Limited population control actions required. · Pasture availability will limit population: starving, diseased and dead kangaroos may be observed. · Destructive of grassland condition. Loss of grassland structure and cover, and threat to grassland specialists including threatened species. Not in accord with second goal of this plan (s. 1.3).
Maintain *grassland conservation densities*	· Maintains kangaroo populations as a component of native grassy ecosystems (first goal of this plan (s. 1.3)). · Initial and on-going population control unacceptable to some. · Population control may be difficult to achieve in some urban areas due to restrictions on use of firearms. Other methods (e.g. fertility control, darting and lethal injection) may become more practicable over time. · Advantageous to ecology of grassland sites, maintaining habitat for other grassland flora and fauna including threatened species (second goal of this plan (s. 1.3)). · Scientifically based. Requires precautionary approach and pre-emptive action (population control) based on knowledge of kangaroo biology and ecology and dynamics of grassy ecosystems. · Requires adaptation to particular sites based on an ecological model derived from ACT kangaroo populations and vegetation. A significant increase in herbage mass is associated with kangaroo densities that are in the range of approximately 0.6 to 1.5 kangaroos per hectare in grasslands (s. 5.2). For woodland areas, a lower density is likely to be optimal.
Maintain low densities	· Likely to require large initial cull and frequent maintenance culls. · Likely to disadvantage grassland sites and require other means of defoliation management e.g. cattle grazing. · Socially unacceptable to some. · May be difficult to achieve in some urban areas due to restrictions on use of firearms. Other methods (e.g.fertility control, darting and lethal injection) may become more practicable over time.
Permanently remove all kangaroos	· Occurs in other urban areas of Australia and avoids future conflicts over management of kangaroo densities. · Socially unacceptable to many and not in accord with the first goal of this management plan (s. 1.3). · Difficult to achieve, likely to require large initial cull or removal. Except in enclosed (e.g. fenced) areas, kangaroo populations will re-establish. · Likely to disadvantage grassland sites and require other means of defoliation management e.g. cattle grazing.

5.3.2 Grasslands in the western and southern ACT

Objective: grasslands in the western and southern ACT	**Kangaroo populations are maintained in Namadgi National Park, the Tidbinbilla precinct and the Lower Cotter Catchment. These will be: (a) unmanaged populations unless undesirable impacts, or specific ecological or other objectives require management intervention; and (b) managed in accordance with the objectives and policies in the management plan for each area.**

Policies related to this objective are at:

- s. 5.3.2(f) (Grasslands in the western and southern ACT)

This section refers to Namadgi National Park, the Tidbinbilla precinct (incorporating Tidbinbilla Nature Reserve, Birrigai at Tidbinbilla, Jedbinbilla (former Forestry Block 60 Paddys River), and the Lower Cotter Catchment.

Namadgi National Park (NP) comprises 46 per cent of the ACT and embraces the rugged mountain ranges and associated valleys in the western and southern parts of the Territory. The focus of this kangaroo management plan is the lower elevation grassy valleys in the southern part of the park at an altitude of 900–1200 m (s. 3.6.3). These grasslands are a mix of natural and semi-natural types as well as improved pasture (Ingwersen 2001). 'Secondary grassland' derived from clearing of tree cover in the pastoral period, prior to declaration of the park, is common in the valleys (ACT Government 2010b; Fletcher 2006a; Ingwersen 2001).

Kangaroo management has been an important issue at Tidbinbilla. The precinct borders the north-east extremity of Namadgi NP and rural land (to the east). Tidbinbilla is popular for recreation, most of which is based around the developed facilities in the valley. The 'secondary grassland' of the valley floor, cleared of its forest and woodland cover in the pastoral period, is the focus of this kangaroo management plan. Stock grazing was removed from the area in the 1960s. Burgan (*Kunzea ericoides*) has been colonising the grassland over extensive areas.

The Lower Cotter Catchment (6000 hectares) extends south and west from the Cotter Dam to the boundary of Namadgi NP. Most of the lower catchment was formerly covered with softwood plantations, which were destroyed by the 2003 bushfire. Almost 1300 hectares of pines were replanted after the fire, but it is planned to phase these out over the next 35 years.

5.3.2 (a) Management objectives (land)

Management objectives for these reserved areas are defined in management plans (ACT Government 2006, 2010a, 2010b). These objectives cover protection of water catchments, conservation of natural and cultural heritage, as well as provision for public use for recreation and education.

5.3.2 (b) Status of kangaroo populations

The four species of macropod in the ACT (Table 3.1) all occur in Namadgi, Tidbinbilla and the Lower Cotter Catchment. Eastern grey kangaroos are the dominant species in general and of the valley grasslands in particular. The other species (red-necked wallaby, wallaroo, swamp wallaby) are at low densities and tend to inhabit the fringing woodlands, rocky hill slopes or shrubby forests, rather than the grasslands.

Namadgi National Park:

Only the Gudgenby area has been intensively studied, but kangaroo populations in the southern Namadgi valleys appear to have reached equilibrium with their food supplies. At the former

Gudgenby property, where there had been pasture improvement, a heavily grazed 'macropod lawn' is the result. Grasslands in these mountain valleys are not suitable habitat for the threatened species found in lowland grasslands.

The populations of eastern grey kangaroos in the grassy valleys are free-ranging and unmanaged, in that there has been no intervention to restrict their movements or control their population sizes in recent decades. Kangaroo densities throughout the valley areas are high and relatively stable, with abundance being regulated mainly by the limits of food supply. In addition, features of kangaroo population dynamics in the southern parts of Namadgi are predation and predation sensitive foraging (s. 3.3.2). The predators are:

a) *Wedge-tailed* eagles: Scavenge on kangaroo carcasses and prey on pouch young and young-at-foot. Predation by eagles is unlikely to have any detectable effect on kangaroo density.

b) *European red fox*: Opportunistic scavenger and predator on juveniles. Presence of kangaroos in fox diets is evident from analysis of scats. Fox predation alters kangaroo group size and feeding behaviour (Banks 2001) and population growth rate (Banks et al. 2000).

c) *Dingoes*: The population of wild dogs comprises a mix of 'pure' dingoes (*Canis lupus dingo*) and so called 'hybrids' referring to the results of intraspecific breeding between *Canis lupus dingo* and the domestic dog subspecies *Canis lupus familiaris*. In spite of their white, black, brown, and brindle colourings, the DNA evidence suggests the 'hybrids' are dingoes with some dog in them, rather than the reverse. They howl rather than bark, prey on all kinds of kangaroos, and hunt both alone and in packs.

(Fletcher 2006a)

The dynamics of the large kangaroo population in the Gudgenby area have been studied by Fletcher (2006a, 2006b, 2007a). There is no quantitative record for the increase phase of this population, just anecdotal information. It is presumed that the population increased to modern levels during the 1990s following the declaration of the park (1984) and the withdrawal of stock grazing in 1989. The mean density for the former Gudgenby property, determined by nocturnal driven line transects 2001–2003, and a sweep count in August 2002 involving 105 people surrounding an area of 9.3 square kilometres, was 4.5 kangaroos per hectare (450 per km^2), which is one of the highest densities recorded in Australia.

The fecundity of the Gudgenby population is very high. The estimate of annual production of late pouch young approximates 0.89 per female. Such high fecundity shows that the per capita food shortage associated with this high density population is not affecting either adult fertility or survival of pouch young to a degree that might limit the population. Mortality of pouch young is low but mortality of sub-adults offsets some of the high fecundity (Fletcher 2006a).

Tidbinbilla Precinct:

The eastern grey kangaroo dominates the grassy valley areas of Tidbinbilla, which are ideal kangaroo habitat. The kangaroo population in these valleys has shown high increase rates to achieve correspondingly high densities. These densities have been reduced occasionally as outlined below.

Significant differences between Tidbinbilla and the southern Namadgi valleys, from a kangaroo management perspective, are the much higher level of public and tourist visits to Tidbinbilla, the presence of adjacent rural land, the lack of significant predation from dingoes/wild dogs,

and colonisation of cleared grassy areas by burgan shrub. Dingo presence at Tidbinbilla has fluctuated, but in general is less than in parts of Namadgi. Dingo scavenging has been observed and predation is likely to be occurring but not always observed. During a two-year study (2001–2003) of kangaroos in the Tidbinbilla valley, there was no evidence found of dingo scavenging or predation, nor tracks or scats (Fletcher 2006a) although dingoes were sighted several times.

The eastern grey kangaroo population at Tidbinbilla is free-ranging; but unlike Namadgi, it has been subject to management interventions over a number of years. Tidbinbilla was the first Public Land area in the ACT to experience a kangaroo irruption. Grazing was withdrawn from Tidbinbilla in the 1960s, which was earlier than for the Namadgi area, and kangaroos were reported to be scarce when the first employees were stationed there in 1963 (KAC 1996a). The kangaroo population increase over the next decade is not documented, but from 1976 to 1986, the reserve managers were shooting kangaroos to reduce their grazing effect. A density index based on spotlight counts on fixed transects from 1976 to 1992 shows a fluctuating population. It is possible that from 1963 to 1976, the increasing population ate out the food supply, causing the population to crash and the pasture-herbivore system to reverberate in the period 1976–1992 (Fletcher 2006a).

At the end of winter 1996, the death of a significant number of young kangaroos was recorded, and in May 1997 the kangaroo density was estimated to be 367 per km^2 (3.67 per ha) in the grassland and surrounding woodland and forest. A cull was undertaken with the aim of reducing the density to about 200 per km^2 (2.0 per ha) with 232 per km^2 (2.32 per ha) achieved. By 2001, the density in valley floor grasslands (not including woodland or forest) was estimated to be 510 per km^2 (5.1 per ha)—the highest recorded kangaroo density in Australia—before the population was reduced to 230 per km^2 (2.3 per ha) by the bushfire of 2003 (Fletcher 2006a). Similar to Gudgenby, the fecundity of the Tidbinbilla population is very high, and the same observation can be made of food shortage not limiting adult fertility and survival of pouch young. However, the fecundity is offset by high mortality of sub-adults. The estimate of annual production of late pouch young at Tidbinbilla approximated 0.78 per female (Fletcher 2006a).

Lower Cotter Catchment:

Kangaroo populations in the area are free-ranging. They may be affected by dingo/wild dog predation and possibly illegal shooting. The vegetation cover of the area is evolving as it recovers from the 2003 bushfire and removal of the softwood plantations. Over much of the lower elevation terrain, the establishing grassy cover and grassy understorey will provide suitable kangaroo habitat. There are no data on kangaroo populations in the area.

5.3.2 (c) Management issues with kangaroo populations

Management issues associated with the kangaroo populations in Namadgi and Tidbinbilla are outlined below. No specific issues are currently identified in the Lower Cotter Catchment.

- **'Overgrazing'**

Namadgi: The presence of high densities of kangaroos and eaten down pasture can lead to the belief that an area is overgrazed, beyond 'carrying capacity', and that the animals should be culled. The model that is being wrongly applied here is 'economic carrying capacity' that applies to a controlled herbivore–pasture system (s. 3.9.2(c)). The important question is whether the high densities are having a deleterious impact on other species, the ecosystem as a whole, or on other reserve values. There is no evidence for this at Namadgi. Unless adverse impacts are detected, it is appropriate to leave the pasture–herbivore system as a self-regulating one.

Tidbinbilla: A number of issues have been raised in relation to kangaroo grazing at Tidbinbilla (KAC 1997), namely:

- heavy grazing creating conditions suitable for expansion of rabbit populations (as they prefer short grass)
- overgrazing leading to the spread of burgan
- overgrazing increasing the potential for erosion.

In relation to these issues:

- Rabbit numbers are at relatively low levels at Tidbinbilla due to the combined effects of control action and the introduction of Rabbit Haemorrhagic Disease (RHD). While there are fluctuations in rabbit densities, these are much lower than in the early 1980s.
- The relationships between kangaroo grazing, pastures and burgan colonisation remain unknown. It is possible also that a high level of grazing pressure favours exotic weed species (e.g. St John's wort *Hypericum gramineum*, Paterson's curse *Echium plantagineum*, verbascum (mullein) *Verbascum* spp. and exotic grasses) many of which are unpalatable to kangaroos.
- Research into kangaroo–pasture dynamics by Fletcher (2006a) did not provide evidence that high kangaroo densities reduced groundcover at Tidbinbilla to the levels where erosion can accelerate.

The 'carrying capacity' question as discussed above for Namadgi is relevant also to Tidbinbilla.

- **Environmental impacts**

As noted under 'overgrazing' above, the important question for the Namadgi and Tidbinbilla grasslands is whether the high kangaroo densities are having harmful impacts. Investigations to date have not identified such impacts e.g. on a threatened species. Should such impacts be identified, then kangaroo grazing pressure would need to be reassessed in relation to that species and its habitat.

Namadgi: In terms of the grassland ecological communities that are present, the Namadgi valleys are not all the same and it may be appropriate to manage them differently. The significance of some of the natural temperate grassland areas in these valleys has gained more recognition recently. These areas warrant further research as to their ecological values and in turn an assessment as to whether there are adverse kangaroo grazing impacts. One way to research this type of issue is experimental reduction of kangaroo density in a comparison area.

Tidbinbilla: The creation of a grazed 'marsupial lawn' over much of the Tidbinbilla valley grassland reduces ground level habitat complexity. As noted in s. 5.3.1 this is a major issue in lowland grassy ecosystems but the Tidbinbilla grasslands and woodlands do not contain the threatened species found in the lowland grassy ecosystems. Neave and Tanton (1989) documented the effects of kangaroo grazing on both the grassland flora and two species of ground-nesting birds at Tidbinbilla. However, the bird species concerned (stubble quail (*Coturnix pectoralis*) and Richard's pipit (*Anthus novaeseelandia*)) are widespread, common species that breed elsewhere in the ACT. Kangaroo grazing reduced the height and percentage cover of kangaroo grass (*Themeda australis*), but not the frequency of occurrence.

- **Mortality**

Kangaroo populations at both Namadgi and Tidbinbilla exhibit high fecundity which is offset by high sub-adult mortality. Such mortality is likely to be a normal occurrence but only noticed occasionally when a coincidence of several to many carcasses comes to notice. The vast majority of sub-adult mortality goes unnoticed.

Winter conditions are more severe in Namadgi than Tidbinbilla. In the Namadgi grasslands, there

is mortality of kangaroos due to starvation in winter and early spring. In some years, pasture is particularly scarce and hundreds of young kangaroos may be found dead from starvation. Infestations of harmful parasitic nematodes contribute to this mortality (s. 3.3.7). This mortality seems heavy, but it occurs for only for a brief period, the 'die-off' is small in relation to the source population, and it affects mainly sub-adults rather than the breeding population. Annual reproductive output is such that the population can sustain occasional high losses.

During these events, the normal predators and scavengers of kangaroos are probably swamped by the sudden increase in the supply of carcasses and easy prey. The resulting visibility of kangaroo deaths may prove distressing to park staff and the public. This can lead to calls for culling to maintain kangaroo numbers at lower densities so that 'die-offs' are prevented, as well as proposals for hand-feeding of kangaroos. However, an understanding of consumer (herbivore)–resource dynamics indicates that starvation does not demonstrate that culling is necessary (Fletcher 2007a). Similar processes regulate all wildlife populations but few are as visible. Hand-feeding is very expensive, inappropriate for free-ranging animal populations, and ineffective, in that a dependent population would continue to grow and become increasingly reliant on artificial food sources (KAC 1997).

However, two management responses are appropriate: (a) the provision of interpretative material to explain natural processes and population dynamics to park visitors; and (b) the euthanasia of individual starving kangaroos by appropriately trained and equipped park staff if the animals are perceived to be causing distress to visitors.

- **Predator trophic level**

The predator trophic level has been removed wholly or partially from many kangaroo populations and no longer exerts a limitation on population growth. The presence of dingoes/wild dogs in Namadgi and (to a lesser extent) Tidbinbilla provides the opportunity to maintain this trophic level interaction. These dingo/wild dog numbers are small in relation to the kangaroo populations. Dingoes/wild dogs also predate on sheep in adjacent rural lands. This conflict is reconciled by maintaining a buffer zone near the reserve boundaries where preventative dingo/wild dog control should be maintained constantly for animals moving in either direction.

- **Tourism, wildlife viewing**

Namadgi: The Namadgi grasslands provide a wildlife spectacle of free-ranging kangaroos and opportunities for eco-tourism, which may warrant more promotion. However, Namadgi is not a zoo or wildlife enclosure. Seeing kangaroos there requires more organisation and commitment on the part of visitors, as well as preparation for the possibility of seeing the results of natural forces at work, such as dead animals.

Tidbinbilla: Recreation and tourism involving experiences with wildlife are an important component of the purpose and management of Tidbinbilla. Seeing free-ranging kangaroos at Tidbinbilla is part of those experiences. With regard to the kangaroo population at Tidbinbilla, an important aspect of visitor education is an explanation of kangaroo–pasture dynamics, the biology and ecology of eastern grey kangaroos in a temperate environment, and the management of kangaroo populations.

5.3.2 (d) Management priorities: land

Namadgi: Management priorities derive from the management objectives in the management plan (ACT Government 2010b). Policies and actions in the management plan relevant to the grassy valleys provide for conservation of native species, ecological restoration, and pest animal and fire management. The conservation of the grassy valleys is important as they are a distinctive and ecologically important landscape containing mid-level Temperate Montane Grasslands (Keith 2004) (s. 3.6.3).

Tidbinbilla: Management priorities derive from the management objectives in the management plan (ACT Government 2010a). Policies and actions in the management plan relevant to the grassy valley provide for conservation of native species, regeneration of native plant communities and pest plant and animal management. Increased attention is being given to controlling burgan and other shrub regrowth following the 2003 fire.

Lower Cotter Catchment: Catchment protection and long-term rehabilitation of the former pine plantation areas are the highest priorities for management of the Lower Cotter Catchment.

5.3.2 (e) Management options: kangaroos

Namadgi: A study of kangaroo and pasture dynamics at Gudgenby (Fletcher 2006a) has shown that the kangaroo population is at high density, but is thought to be in long-term equilibrium with its food supply. Similar circumstances are likely to prevail in other grassy valleys, some of which have a higher native component in the grassland composition, but appear to have lower self-regulating kangaroo densities. On the basis of available evidence there seems little justification for attempting to change this situation. The preferred management approach, therefore, is to maintain the kangaroos in the grassy Namadgi valleys as free-ranging, unmanaged populations. This management approach would need revision if further research indicates the need to protect particular grassy ecosystems and/or component species.

Tidbinbilla: At Tidbinbilla the kangaroo population is concentrated in the highly visited valley areas and there is an interface with rural land. There are two main management options for this population. The first is to maintain the population as a free-ranging, 'unmanaged' population ('ecological carrying capacity', s. 3.9.2(c)), unless undesirable impacts or specific ecological objectives require management intervention. The second is to have a free-ranging population that is managed, principally by population control, towards a density that accords with other objectives. The implications of these two approaches are summarised in Table 5.3.

Lower Cotter Catchment: Management options would need to be evaluated should kangaroo grazing impacts become a management issue.

Table 5.3 Tidbinbilla precinct: management options and implications

Management Options	Implications
Free-ranging, unmanaged ('ecological carrying capacity')	**Characteristics:** · Population can be expected to reach long-term equilibrium with food supply, with a balance between high fecundity and high sub-adult mortality. · Potential for very high densities with heavy grazing of pastures. · Winter 'die-off' of sub-adults will occur most years and will be greater in some years. · Given the recreational use of Tidbinbilla, requires high quality interpretation and educational materials to explain herbivore–pasture dynamics, kangaroo biology and ecology, and management of kangaroo populations. **Advantages:** · Population will self-regulate (mainly through sub-adult mortality) but density will remain high due to lack of limits other than food supply (e.g. predation). · Due to the climate of the area, a pasture biomass level can be maintained that supports relatively high kangaroo densities. · Kangaroo population represents a 'natural condition' but within a modified environment (former pastoral land, little predation, within reserve). · Reduces pasture biomass and therefore fire fuel hazard. **Disadvantages:** · Possible long-term impacts on grassland and grassland habitat. However, the grassland was formerly under pastoral use and is not recognised as having important conservation values[1]. · Depending upon seasonal conditions and kangaroo densities, reserve is likely to have an eaten down appearance. · Visitors to Tidbinbilla may be exposed to dead and starving kangaroos. This will cause distress to some visitors, notwithstanding the provision of interpretation and educational materials. · When seasonal conditions and food shortages result in starving kangaroos, euthanasia of animals may be required if they are perceived to be causing distress to visitors. · Animal welfare considerations will arise and possibly demands for management action such as supplementary feeding or culling. · Unlikely to be supported by adjacent rural land holders.

	Characteristics: · Objectives of kangaroo management need to be defined in relation to the Tidbinbilla management plan. · Population maintained at a level related to objectives and below 'ecological carrying capacity' (see s. 3.9.2(c)). · Requires regular culling. To be fully effective this would be on an annual basis. · Winter 'die-off' of sub-adults will occur most years and will be greater in some years. · Requires high quality interpretation and educational materials to explain herbivore–pasture dynamics, kangaroo biology and ecology and the need for regular culling to maintain this option.
Free-ranging, managed (carrying capacity related to particular objectives)	**Advantages:** · Higher level of pasture biomass would be retained (grassland would look 'better managed'). · Provided density was maintained at a sufficiently low level, habitat would be retained for other animals reliant on grassland. · More likely to be supported by adjacent land holders.
	Disadvantages: · Requires high initial cull(s) and annual on-going culling to be effective. Fertility control measures are not yet applicable to large free-ranging populations with open boundaries. · Difficulty of determining other than an arbitrary density target. · Tidbinbilla is a high profile location and culling would likely be targeted by protesters, especially if culls were publicised. · Culling by shooting is most cost-effective but would still be substantial regular cost. Would need careful management in relation to Tidbinbilla's tourism profile and intention to further develop this. · Retains more pasture biomass and therefore contributes to fire fuel hazard.

Note: 1 The *Tidbinbilla Precinct Draft Plan of Management* (2010) (Ch. 6) states the following:

Whilst open grasslands are largely a legacy of early farming enterprises, they serve a number of useful purposes in terms of public access, scenic quality, wildlife observation and evidence of past land-uses (cultural landscapes). They may also contribute to fire risk reduction and management access requirements.

5.3.2 (f) Grasslands in the western and southern ACT: management policies

Grasslands in the western and southern ACT	
Namadgi National Park	· Kangaroos are an integral part of the fauna of Namadgi National Park and in the grassy southern valleys, they will be maintained as free-ranging populations without direct management interventions, unless further ecological research indicates that interventions are needed to achieve specific ecological outcomes. · Research will be undertaken and supported to extend the knowledge of the mid-elevation natural temperate grasslands, their ecological relationships, and effects of herbivore grazing. · Natural population limitation factors will be allowed to operate on these populations, in particular, food limits and predation. · The predator trophic level (mainly dingoes/wild dogs) will be maintained in relation to these kangaroo populations. · Suitable visitor educational material will be provided in relation to herbivore (kangaroo)–pasture dynamics, the biology and ecology of eastern grey kangaroos, and the management of kangaroo populations. · Should seasonal conditions and food shortages result in starving kangaroos, euthanasia of animals may be undertaken especially around areas of high visitor use.
Tidbinbilla Precinct	· The kangaroo population at Tidbinbilla will be maintained as a free-ranging population without direct management interventions, unless interventions are needed to: a) achieve specific ecological outcomes; b) avoid undesirable impacts on the values of the reserve. · Suitable visitor educational material will be provided in relation to herbivore (kangaroo)–pasture dynamics, the biology and ecology of eastern grey kangaroos, and the management of kangaroo populations. · Should seasonal conditions and food shortages result in starving kangaroos, euthanasia of animals may be undertaken especially around areas of high visitor use.
Lower Cotter Catchment	· The kangaroo population in the Lower Cotter Catchment will be maintained as a free-ranging population without direct management interventions, unless interventions are needed for catchment protection.

5.4 Other ACT Government managed land

5.4.1 Roadsides

Small areas of native grassland occur along some roadsides (Appendix 2). No kangaroo management issues particular to these areas have been identified.

5.4.2 Horse paddocks

There are 17 government horse agistment complexes in the ACT, covering a total of 1038 ha. While some of these areas have remnant woodland trees, their management in relation to this kangaroo management plan is akin to rural leases and is included in Chapter 6 (s. 6.3). The Hall paddock complex includes yellow box – red gum grassy woodland. Kangaroo grazing is not considered to be an issue in relation to the overall conservation of the woodland, though kangaroos occasionally de-bark the lower trunks of individual trees.

5.5 Leased Territory Land

Remnants of native grassy ecosystems, especially woodlands, occur on rural leases in the ACT and these areas are used by kangaroos. Extensive use of open woodland remnants by kangaroos, combined with grazing by domestic stock, increases grazing pressure on these areas and adjacent paddocks (Viggers and Hearn 2005). Mitigating this potential impact is the kangaroo culling that occurs on rural leases.

Other small native grassy ecosystem remnants occur in the Canberra urban area (Other Territory Land, Appendix 2). Kangaroo grazing may become a management issue in some of these areas.

5.6 Googong Foreshores

Objective: Googong Foreshores	**The kangaroo population in the Googong Foreshores is managed so that foreshore ecosystems are conserved and water catchment conditions are maintained or improved.**

Policies related to this objective are at s. 5.6.1 (g).

5.6.1 Googong management

The Googong Dam Area (Googong Foreshores) is located in New South Wales, south of Queanbeyan. The primary purpose of Googong reservoir is the provision of high quality raw water for the supply of potable water to the Australian Capital Territory and Queanbeyan. The area is managed by the ACT Government (s. 2.2.4), and in 2008, this control was formalised in a lease between the Commonwealth of Australia and the Australian Capital Territory for a period of 150 years. The area has significant natural and cultural heritage values (ACT Government 2007b; Eddy 2009).

5.6.1 (a) Description of the area

The focus of this kangaroo management plan is on the western and southern foreshores of the reservoir. This area was formerly in pastoral land use and was extensively cleared. It now contains grassland, residual paddock trees, tree plantings and patches of tree regeneration. The vegetation contains remnants of threatened ecological communities (grassy white box woodland/yellow box – red gum grassy woodland/natural temperate grassland). Threatened plant species (e.g. hoary sunray *Leucochrysum albicans*) and uncommon plant species (e.g. yam daisy *Microseris lanceolata*) have also been recorded from the area.

5.6.1 (b) Management objectives (land)

The goals for the management of Googong Foreshores are the supply of high quality raw water for potable water supply, the conservation of natural and cultural heritage, and the provision of recreational opportunities (ACT Government 2007b). Management objectives particularly relevant to the western foreshores are protection of reservoir water quality and protection of natural heritage. With regard to kangaroos, the draft plan of management contains objectives for protection of water quality and catchment condition, and conservation of foreshore ecosystems (ACT Government 2007b).

5.6.1 (c) Status of kangaroo populations

The open grassy environment of the western foreshores, with scattered yellow box (*Eucalyptus melliodora*) and apple box (*E. bridgesiana*) trees, provides ideal kangaroo habitat.

Management of Googong Foreshores for catchment protection dates from the completion of the dam in 1977. Counts of the kangaroo population were undertaken in the early 1980s, ceased for a ten year period (1985–1995), and recommenced in 1996. The data show a classic herbivore irruption pattern with a slow increase in numbers for a few years, then a steep exponential rise from 1996 (Figure 3.2). The mean density of kangaroos in 2001 (when the population had almost reached its peak) was 4.8 kangaroos per hectare, based on nocturnal line transect estimates (Fletcher 2006a). After 2002 in developing drought conditions, the population 'crashed' and an extreme storm in March 2003 resulted in erosion of the grazed areas and temporary pollution of the reservoir. Following the January 2003 bushfires in the ACT, there was concern about water supplies and in 2004, amid concern for catchment condition, a cull of 800 kangaroos was undertaken at Googong. The aim of this was to lessen grazing pressure, such that if the drought broke, herbage mass and groundcover would be restored to a threshold level likely to prevent erosion (often defined as 70 per cent ground cover). Counts show that kangaroo density has changed little following the cull.

5.6.1 (d) Management issues with the kangaroo population

The following are the main issues:

- **Reduction of herbage:** Grazing by kangaroos at Googong Foreshores potentially performs a valuable role in fire fuel hazard reduction. The ability to manage this through changing seasonal conditions is difficult, as herbage reduction may be insufficient in good seasons and excessive in dry periods and in winter.
- **Kangaroo population growth:** Due to the management regime at Googong Foreshores (equivalent to a reserve), the kangaroo population is not subject to the rural culling and commercial harvest that occurs in surrounding New South Wales, nor is there significant predation. In these circumstances population increase to 'ecological carrying capacity' (s. 3.9.2(c)) is highly probable, and this is associated with reduced herbage mass and possible loss of soil in drought periods. It is not appropriate to allow the kangaroo population to remain indefinitely at ecological carrying capacity, given the need to protect both the water catchment and the condition of native grassy ecosystems.
- **Catchment protection:** Given the primary purpose of Googong Reservoir and its increased importance to security of the Canberra–Queanbeyan water supply, the maintenance of catchment condition is a key management task. Controlling total grazing pressure so as to maintain adequate ground cover that can resist erosion, slow overland flow and filter sediments and organic material is essential. However, there is not a simple relationship between kangaroo density and catchment stability.
- **Threatened species and ecological communities:** Overgrazing by kangaroos can have deleterious impacts on grassy ecosystems and limit woodland regeneration. Eddy (2009) notes that 'it seems probable that the current kangaroo population and grazing pressure is significantly higher than the natural level, and higher than would be desirable in the long term'.
- **Kangaroo population management:** The 2004 cull of kangaroos was targeted by animal rights protestors (Lander 2005a, 2005b; Stacker 2005) with the protest being linked also

to opposition to commercial harvesting. The Googong New Town development immediately west of Googong Foreshores will result in urban settlement replacing rural land use. From both political and practical perspectives this may make culling by shooting a more difficult task.

5.6.1 (e) Management priorities (land)

Management priorities for Googong Foreshores are to:

a) maintain catchment condition, with herbage mass and vegetation cover being central considerations

b) conserve native grassy ecosystems (maintaining or improving ecological condition, habitat quality, connectivity and conserving threatened species and ecological communities).

(ACT Government 2007b)

5.6.1 (f) Management options (kangaroos)

Examination of the pastures at Googong Foreshores, including a study of kangaroo and pasture dynamics (Fletcher 2006a), indicates the pasture is of similar food value to that in ACT lowland grassy ecosystems. Therefore, the management options for kangaroos presented in Table 5.2 are applicable also to Googong. The most desirable option in native grasslands, of maintaining *grassland conservation densities*, would also maintain suitable catchment conditions at Googong.

5.6.1 (g) Googong Foreshores: management policies

Related policies and actions are contained in the Googong Foreshores Draft Plan of Management (ACT Government 2007b):

Googong Foreshores	
Lowland grassy ecosystems	· Kangaroos will be managed as an integral part of the fauna of Googong Foreshores and the grassy ecosystems of the area. · Catchment protection and the conservation of native grassy ecosystems will be given high priority in kangaroo management at Googong Foreshores. · Googong Foreshores will be included in long term monitoring of lowland grassy ecosystems that includes the interaction between the vegetation and large/ medium herbivores (domestic stock, kangaroos and rabbits). · Management of kangaroo grazing will be undertaken in the context of total grazing pressure, considering in particular, the contribution of rabbits. · Kangaroo populations will be managed with the aim of achieving grassland conservation densities.

5.7 National Land

Objective: National Land	**Kangaroo populations are maintained in National Land areas that contain lowland native grassy ecosystems at densities that conserve the natural integrity of the grassland ecological community and result in the maintenance of habitat for other grassland plant and animal species.**

Policies related to this objective are at s. 5.7.1 (g).

5.7.1 National Land management

National Land areas (s. 2.2.2) contain some of most significant native grassy ecosystems in the Territory. Seven of the nineteen Core Conservation Sites for native grassland identified in the *ACT*

Grassland Strategy (ACT Government 2005b) are on National Land, managed by Commonwealth Government agencies for diverse purposes. There are also important areas of lowland woodland. Kangaroo grazing impacts on native grassy ecosystems have been most evident at the Defence site of Majura Training Area (MTA). Memoranda of Understanding between the Commonwealth and ACT governments were signed in 1998 with the objective of establishing a coordinated approach to the implementation of ACT Action Plans for threatened species and ecological communities (s. 2.6). The ACT Commissioner for Sustainability and Environment has recommended that the MOU with the Department of Defence be reviewed and updated (ACT Commissioner for Sustainability and Environment 2008).

5.7.1 (a) Description of areas

Native grassland sites on National Land are listed in Appendix 2. The largest areas are at Canberra International Airport and the Defence sites of Majura Training area, HMAS Harman, Bonshaw, and the decommissioned Belconnen Naval Transmitting Station (BNTS). These areas contain varying amounts and proportions of natural temperate grassland, native pasture and exotic pasture (see Botanical Significance Rating in **Glossary**). The largest grassy woodland area is at the Majura Training Area. Other sites include Campbell Park, Mt Pleasant and Stirling Ridge.

5.7.1 (b) Management objectives (land)

Primary management objectives for these areas relate to their Commonwealth use. Management objectives for the conservation of ecological communities, flora and fauna in some of the areas are set out generally in management planning documents (s. 2.6).

5.7.1 (c) Status of kangaroo populations

Grasslands and associated woodlands on the larger National Land areas provide ideal kangaroo habitat. Very high kangaroo densities have been recorded at Majura Training Area and Belconnen Naval Transmitting Station. On these two sites, the end of livestock grazing (and possibly some kangaroo shooting) occurred earlier than on other ACT lowland grasslands and grassy woodlands (but later than at Googong). Kangaroo densities at both military sites also reached damaging levels earlier than in the other lowland grasslands, and groundcover was reduced to levels associated with damaging soil loss (Figure 5.3). The security fence at BNTS, which prevents kangaroo dispersal, could have been an additional factor contributing to the increase in kangaroo density. It does not explain why grazing effects at Majura, which does not have a security fence, were worse; nor does it explain the kangaroo increase and overgrazing at Googong.

The population at Belconnen Naval Transmitting Station rose exponentially in the form of a typical herbivore irruption (Figure 3.2). Inside the security fence, there were 588 kangaroos in December 2007 (a density of 5.1 kangaroos per hectare in the 116 ha fenced site, and a rise from 2.1 kangaroos per hectare in June 2005). The ACT Commissioner for Sustainability and Environment assessed the condition and management of this site in 2008 and recommended that urgent action be taken to restore the ecological condition of the grassland, including a reduction in kangaroo density to achieve a stocking rate of 1 kangaroo per hectare or less (ACT Commissioner for Sustainability and Environment 2008). A cull was undertaken in May 2008 by which time there were 649 kangaroos (5.6 per ha), which was reduced to 135 (1.2 per ha). Subsequent culling reduced the density to approximately 0.95 per hectare.

Majura Training Area is a much larger site (~44 square kilometres) with a larger kangaroo population (~3400 in year 2004 and 11 200 in year 2009). Public attention was drawn to extreme overgrazing of the habitat of the endangered grassland earless dragon (*Tympanocryptis pinguicolla*) in the

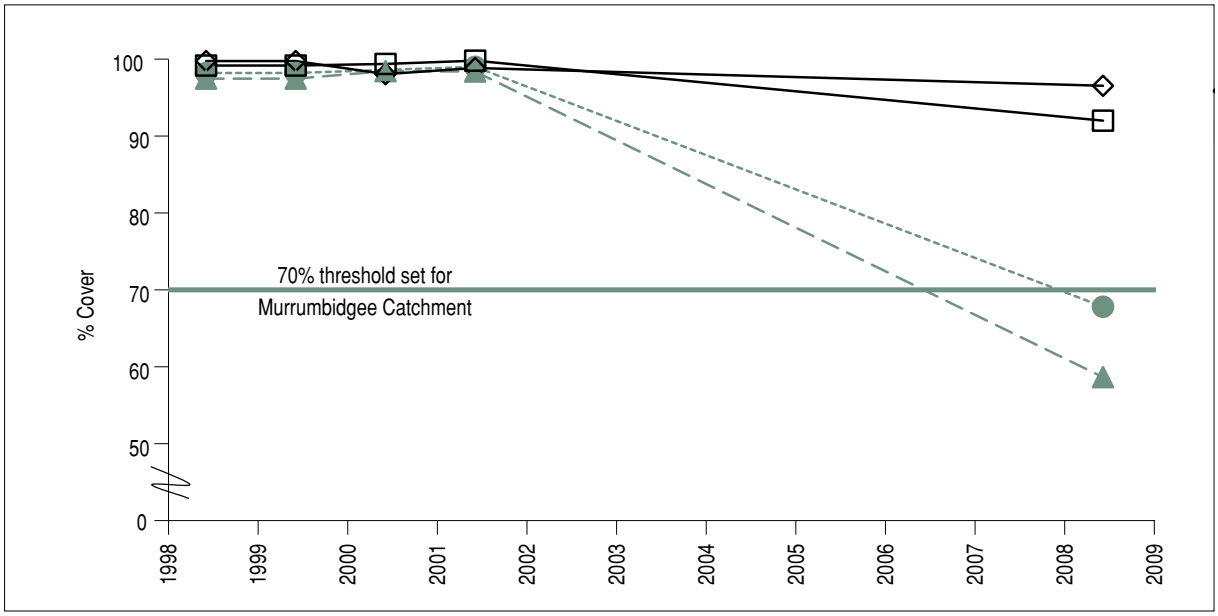
summer of 2006–07, and an associated dramatic decline in the dragon population compared to another site in the ACT that was only lightly grazed. Subsequent to the advice from grassland ecologists, the Defence Department constructed an electrified fence around a 128 ha patch of high quality natural temperate grassland as an immediate short-term solution. After initial difficulties this proved an effective barrier, so that by the spring of 2008 the grassland inside the fence was beginning to recover, compared to the unprotected area outside, which had deteriorated severely. By the end of 2008 the damage from kangaroos through the woodlands and secondary grasslands of the MTA was severe outside the fence, including in the areas of endangered yellow box – red gum woodland. Starving kangaroos were eating plant parts normally avoided, such as the base of tussocks of red-anther wallaby grass (*Joycea pallida*). A cull of 7,000 kangaroos was conducted in 2009. Frequent (e.g. annual) culling will be needed to prevent re-occurrence of this situation.

5.7.1 (d) Management issues with kangaroo populations

The threat to native grassy ecosystems by overgrazing from kangaroos has been outlined in s. 3.8.3 and s. 5.3.1.

Figure 5.3 shows the effects of kangaroo grazing pressure on ground cover. The data are from long term grassland monitoring undertaken by ACT Parks, Conservation and Lands. During drought (2002–2007) there was little change in ground cover at sites with low to moderate grazing pressure, whereas ground cover declined more rapidly on sites with heavy grazing pressure. The combination of drought plus heavy grazing caused groundcover declines three to seventeen times greater at the heavily grazed sites, a statistically significant difference.

Figure 5.3 Changes in percentage ground cover at natural temperate grassland sites in north Canberra, 1998–2008



Gungaderra Nature Reserve ◇ ; Mulanggari Nature Reserve □ ;
Majura Training Area (MTA) ● ; Belconnen Naval Transmitting Station (BNTS) ▲ .
Percentage ground cover was similar and high at four natural temperate grassland areas in north Canberra in 1998. After about 2004, kangaroo density increased to high levels at the MTA and BNTS sites. Kangaroo density was lower, and cattle were occasionally introduced to control herbage mass, at Gungaderra and Mulanggari nature reserves. Ground cover declined on all sites during a drought period up to 2008, but the decline was greater on the sites with high kangaroo densities. The pattern of change between 2001 and 2008 is unknown, and not necessarily the linear pattern indicated by lines joining the values for these years. (Based on data held by ACT Parks, Conservation and Lands)

Groundcover in the local region rarely falls below 50 per cent. In practice, the main interest locally is whether it falls below 70 per cent, a minimum acceptable threshold set by the Murrumbidgee Catchment Management Board (2003), recommended by McIvor (2002a, 2002b), and supported by studies such as that of Jefferies (1999) which showed a sharp increase in the rate of water erosion at about this level. The levels of bare ground on the heavily grazed sites (MTA and BNTS) are ones usually associated with elevated rates of soil loss, and loss of nutrients. Observations at both sites of grass tussocks on 'pedestals' (because topsoil and organic material has been removed from around them), supported the concept that groundcover below 70% is grounds for concern. Not only threatened species, but the resilience of the ecosystem is being lost in these episodes of overgrazing, whether they are caused by livestock or by kangaroos. In this case, the main grazing was by kangaroos, and there was a statistically significant linear relationship between the abundance of kangaroo pellets in 2008 (counted in the monitoring plots) and the reduction in percentage ground cover experienced since 2001. For this analysis, the pellet counts and ground cover values from all the transects on the four sites were transformed by taking natural logarithms. However it is also apparent that other factors, as well as kangaroo density, are responsible for the decline in groundcover.

5.7.1 (e) Management priorities (Land)

Commonwealth departments and agencies managing National Land have environmental responsibilities under both the *Environment Protection and Biodiversity Conservation Act 1999* and the *ACT Nature Conservation Act 1980*. Therefore, as well as the Commonwealth legal requirements, management priorities for native grassy ecosystem areas on National Land should be similar to those for ACT Public Land (s. 5.3).

5.7.1 (f) Management options (kangaroos)

Table 5.2 contains management options for kangaroos in grassy ecosystems and the implications of those options. As outlined in the table, the most desirable option is to maintain *grassland conservation densities* (s. 5.2). This option is appropriate for National Land areas.

The decommissioned Belconnen Naval Transmitting Station site requires particular consideration given its future proposed transfer to territory control and change in status from National Land to Territory Land. It is proposed that the native grassland area including the population of Ginninderra peppercress (*Lepidium ginninderrense*) be reserved as Public Land. This reserve would be surrounded by major roads and residential areas. As noted previously (s. 4.6.2), BNTS also provides an ideal location for ongoing fertility control research. To improve and maintain the condition of the grassland over the long term, as well as retain a kangaroo population that will serve an important grassland defoliation function, the following management approach is suggested for the site:

- the reserved grassland remain fenced
- public access to the site be arranged, but dogs not be permitted
- kangaroos on the site be managed as an open-space captive population
- the kangaroo population be maintained at a *grassland conservation density* (s. 5.2)
- fertility control measures be applied to the population (e.g. as occurs at Government House, Yarralumla)
- the kangaroo population be made available for fertility control research

- the site be used to provide public education on native grasslands, threatened species, kangaroo biology and ecology, and pasture–large herbivore interactions.

The context for kangaroo management would be a grassland management plan for the area (ACT Commissioner for Sustainability and Environment 2008: Rec. 9).

Most other National Land areas are likely to remain under Commonwealth control for the foreseeable future, though some areas are under negotiation to be transferred to Territory Land. Of those remaining as National Land, the extensive Majura Training Area, with a large kangaroo population, requires ongoing management of that population so that the condition of the native grasslands and grassy woodlands in the area is not further degraded.

5.7.1 (g) National Land: management policies

National Land	
Decommissioned Belconnen Naval Transmitting Station site	· After transfer to Territory Land, the policies outlined under Native Grasslands (s. 5.3.1(g)) will be applied. · The management approach suggested for the site, as outlined under Management Options (above), will be evaluated as part of the planning and management arrangements for the area.
Other National Land areas	· A review of the co-ordination arrangements between Commonwealth Government managers of National Land and ACT agencies responsible for the implementation of Action Plans for threatened species and ecological communities will be undertaken, giving attention to threatening processes, including excessive kangaroo grazing pressure · ACT Government agencies will work with Commonwealth Government managers of National Land with the aim of conserving native grassy ecosystems and their component species. This will include consideration of the management of kangaroo populations.

6 Managing Economic and Social Impacts

of Free Ranging Kangaroos

Motor vehicle collisions with kangaroos are common in the ACT and region. Education campaigns to modify driver behaviour are intended to reduce the risk.

6.1 Economic and social impacts

Economic and social considerations related to the presence of kangaroo populations in the ACT have been summarised in s. 1.4.2 and s. 1.4.3 and discussed in more detail in s. 3.9 and s. 3.10. The significant economic and social impacts of high kangaroo populations and densities are summarised in s. 3.11, namely:

Economic

1. Effects on the economic viability of rural properties and increased management costs for other lands.

2. High cost of vehicle collisions and collision avoidance in the ACT and region compared with the remainder of NSW.

Social

1. Road accident trauma.

2. Controversy in the community over kangaroo management and actions taken to reduce kangaroo population numbers in some areas.

The principles stated in s. 4.2 form a foundation for management of kangaroo populations in the ACT, in particular:

Economy and Society	**The economic and social impacts of kangaroo populations are taken into consideration in forming government policy, particularly in relation to free-ranging kangaroo populations on rural lands and along roadsides.**

The other principles related to *environment* and *managing kangaroo populations* (s. 4.2) are also relevant to managing economic and social impacts.

Inevitably, high kangaroo populations throughout the ACT, will result in economic and social impacts and some residents will be affected more than others e.g. those with rural properties and motorists that collide with kangaroos. There will always be a cost associated with maintaining large kangaroo populations, particularly in the lower elevation grassy areas. The management challenge is to manage these impacts to an acceptable level, while retaining kangaroo populations as a significant part of the fauna of the 'bush capital' (s. 1.3).

6.2 Rural Lands

Objective: Rural Lands	**Free-ranging kangaroo populations on rural lands are managed so that their densities do not seriously impact on the economic viability of rural properties.**

Policies related to this objective are at s. 6.2.3.

6.2.1 Kangaroos on ACT rural lands

Management of kangaroo populations on ACT rural lands involves an accommodation between the objectives of maintaining free-ranging kangaroo populations and ensuring the economic viability of rural leases. Under current policies, viable kangaroo populations have been retained, demonstrated by the annual cull statistics (Table 6.1). Conservation of kangaroo populations in the ACT is not reliant on rural lands, given the relatively large area in conservation reserves that provides extensive habitat for kangaroos.

Though the area of rural land has declined in the ACT over recent decades due to the growth

of Canberra and the establishment of Public Land reserves, rural land use is recognised as an important component of the landscape setting for the National Capital, to be managed on a sustained yield basis (ACTPLA 2008; NCA 2008). Most rural leases are used for grazing of sheep, cattle, and horses, with small amounts of cultivation.

6.2.1 (a) Management objectives for rural lands

Objectives for the Rural Zone (NUZ2) in the *Territory Plan* (ACTPLA 2008) that are most relevant to this kangaroo management plan cover the conservation of Canberra's rural setting, maintenance of ecological integrity, conservation of wildlife habitats, and the productive and sustainable use of the land. Lessees' objectives for their leases are expressed to some extent through their Land Management Agreements (LMAs) (s. 2.2.3) and are related to factors such as the size of holdings and land capability.

6.2.1 (b) Commercial harvesting and damage mitigation shooting

The terms 'damage mitigation shooting' or 'non-commercial shooting' are used to distinguish between shooting to reduce the impact of kangaroos on pastures and shooting for the commercial harvest. The primary difference is that the former activity is intended to reduce agricultural impacts of kangaroos, whereas commercial harvesting is intended to sustainably profit from a wildlife harvest. Commercial harvesting is discussed in s. 3.9.5 and s. 6.4. More details and a useful state of knowledge report focused to the New South Wales harvest zone are contained in Olsen and Low (2006).

Eastern grey kangaroos on rural properties are subject to commercial harvesting in specified zones within only two jurisdictions: New South Wales and Queensland. They are shot also to reduce impacts on rural production ('damage mitigation') throughout their range. For this culling, a landholder is licensed to shoot a set number of kangaroos according to a code of practice (s. 4.4.1) and is issued with numbered tags which are required to be attached to the carcasses. These kangaroos may be used directly by the landholder but may not be sold. In practice, most carcasses are left near where they were shot.

6.2.2 Managing kangaroo densities on ACT rural lands

Kangaroos, including those on rural lands, are protected species under the *Nature Conservation Act 1980* (s. 2.1.1). It is illegal to capture, keep or kill a kangaroo on those lands without a licence. Therefore rural landholders must apply for licences if they wish to legally shoot kangaroos in order to reduce their impact on rural production. Given the availability of suitable (and often ideal) kangaroo habitat in the extensive ACT reserve areas, as well as other lands, the conservation of eastern grey kangaroos in the ACT region is not reliant on the status of the kangaroo populations on rural properties. Therefore the main requirements for managing kangaroo densities on rural properties (culling by shooting) relate to animal welfare and the effectiveness of management in reducing the impact of kangaroo grazing on pastures.

6.2.2 (a) Kangaroo management on rural lands

Kangaroo populations were maintained at very low numbers in ACT rural lands until the 1960s, when, for a range of reasons, populations began to increase (s. 3.2) (KAC 1996a). By the 1990s, the density of kangaroos on rural lands was a significant issue for lessees and in recognition of the economic harm caused by high kangaroo densities, government policy was to provide rental rebates, construct electric fences at some reserve boundaries, and allow limited culling.

Management of kangaroos at the reserve–rural land interface is an important issue in some areas. The former Kangaroo Advisory Committee considered the issue of kangaroos on rural lands (KAC 1996a, 1997) and a number of their recommendations have guided kangaroo management on rural lands as well as other aspects of rural land management:

- Land Management Agreements have been established that provide for a proportion of total grazing pressure to be provided for kangaroo grazing.
- Culling of kangaroos for damage mitigation on rural leases was formalised under a licence system in 1998 and has been undertaken since that time, based on an annual application by each property owner.
- Specialised fencing has been constructed in particular locations (e.g. Tidbinbilla NR), which is successful in controlling kangaroo movements, depending upon its design, maintenance and the density of kangaroo populations.

6.2.2 (b) Status of kangaroo populations

Kangaroo densities on rural lands in the ACT have not been estimated since the mid-1990s. As noted in s. 3.2, measuring the density of an organism is a challenge and, in the ACT, attention has been given to refining methods for estimating density (Appendix 1) and to estimating densities in conservation areas rather than focussing limited resources on density estimates for rural areas. Kangaroo density estimates for ACT rural leases are likely to be several times higher than for rural land in surrounding New South Wales (s. 3.2). However, two cautions need to be made: a) NSW estimates are based on helicopter surveys which have known potential for underestimation (Clancy et al. 1997); and b) regional NSW estimates date from 2003 and 2006 (Payne 2007) while the most recent ACT estimate is from 1995 (Nelson 1996).

6.2.2 (c) Kangaroo culling

The aim of the rural kangaroo culling program that commenced in 1998 in the ACT has been to undertake a safe, humane reduction of kangaroo abundance on rural leases to a level considered reasonable by both graziers and the ACT Government. The following are the main aspects of the program:

- *Property management factors*: Rural lessees applying for a culling licence are required to provide evidence pertaining to total grazing pressure and other property management factors. This is included in Land Management Agreements.
- *Kangaroo shooting season*: The ACT is the only state or territory to issue licences for a designated shooting season (March to July). This derives from the ACT being the only jurisdiction where all the macropod species permitted to be shot are highly seasonal in their breeding. The prescribed shooting season has been shown to be effective in protecting young kangaroos of an age when they are vulnerable to being orphaned by the shooting of the mother (Fletcher 2007a) (s. 4.4.1(b)).
- *Regulation*: Kangaroo culling on rural leases is structured through a permit system which provides for a licence to shoot a specified number of kangaroos, a numbered tag system for culled kangaroos, shooter accreditation and compliance with a code of practice, approval by the Australian Federal Police for the discharge of a firearm on leased land under the *Firearms*

Act 1996, and appropriate disposal of kangaroo carcasses. The ACT is the only state or territory that requires holders of a kangaroo shooting licence (for damage mitigation) to pass an accuracy test every two years. Elsewhere the accuracy test is only required for shooters in the commercial harvesting industry.

- *Cull numbers and culling intensity*: The number of kangaroos licensed to be culled each year since the licensing arrangement was established is shown in Table 6.1.

The culling statistics (Table 6.1) show that about 23 kangaroos are shot under licence per square kilometre on ACT rural properties each year (range 16–29), with little change during the decade in either the number of properties obtaining licences or in the intensity of culling (kangaroos culled/sq km). Given that the culling system was introduced in the late 1990s, it might be argued that the absence of a decline in culling intensity over the ten year period could be symptomatic of either a failure to cull sufficiently to reduce the population on the leases, or high annual immigration of kangaroos onto the rural properties from unculled areas, or both. Neither of these would be regarded as ideal, but it is uncertain to what extent they can be overcome. If the rural kangaroo density was 50 per sq km as estimated by Freudenberger (1996) and Nelson (1996) (see Appendix 5) and increased at only 46 per cent per year, which is well within the possible range, the population could be culled at an average rate of 23 kangaroos per square kilometre per year without decreasing. Recent review of the culling arrangements has removed a previous requirement to bury all carcasses in approved pits and has enabled greater participation by landholders in the decision as to how much licensed culling is economically worthwhile. Ongoing monitoring of the cull statistics will be undertaken.

Table 6.1 Licensed kangaroo culling statistics for ACT rural lands 1998–2009

Year	No of licences issued	No. EGKs licenced to be shot	No. reported shot [a]	Tot. Property Area culled (sq km)	Culled/ sq km
1997	14	>2966	1443		
1998	35	5291	4011	224	18
1999	25	3638	2593	160	16
2000	25	3514	2961	161	18
2001	28	3316	2419	161	15
2002	36	4178	2921	182	16
2003	36	3745	2493	131	19
2004	31	3812	3218	123	26
2005	42	5170	3162	160	20
2006	34	4424	2151	181	12
2007	31	4178	3384	163	21
2008	48	7212	6193	224	28
2009	55	6967	5746	223	24

Note: a Indicative only, due to incomplete reporting for some years.

6.2.2 (d) Management issues and considerations

There are a number of factors that confound the precise evaluation of kangaroo management on rural leases including:

- the varying sizes of rural leases and the extent to which lessees rely on their lease as their main income source
- the proximity of many rural leases to other land uses where kangaroo densities may be high and from where kangaroos move onto rural leases to feed and/or replenish the numbers removed by culling
- the varying responses of rural lessees to kangaroo populations on their leases and the tendency for some lessees to allow numbers to build up before undertaking a cull.

The following issues and considerations are pertinent:

- **Welfare: shooting season and shooter licences**

As noted in s. 4.4.1(b), the RSPCA (2002) concluded that the major welfare issues with kangaroos arise from their killing outside of the commercial system. Though some shooters may consider the conditions to be onerous, the ACT designation of a kangaroo shooting season, the requirement for biennial shooter testing, and stricter licensing requirements are important policies for kangaroo welfare.

- **Kangaroos and pastures**

Measurements made in the ACT and nearby NSW of kangaroo feeding, kangaroo population levels, and the growth rate of pasture, demonstrate that when eastern grey kangaroo populations are not limited by shooting, or competition with livestock, they have the potential to increase to high levels and to consume the majority of pasture produced. The result of this is that the pasture is maintained for long periods at low biomass (Fletcher 2006a). The same effect appears in ecological models of the process (Figure 5.2). This is a contrast to the dynamics of kangaroos and pasture in the dry inland parts of Australia measured and modelled by Caughley (1987) and his co-workers (Caughley et al. 1987). In the semi-arid zone, rainfall is the main determinant of pasture biomass, and kangaroo grazing makes only a small difference; but in temperate areas, kangaroo grazing has a large effect.

The situation on ACT rural properties differs from this description of unmanaged grazing, because shooting and the activities of livestock prevent the kangaroo population from consuming much of the herbage that is produced. However, the basic ecological relationships are the same. The same rain falls on the farm, and the pasture growth equations and kangaroo feeding rates are the same. As a result of ACT research (Fletcher 2006a) and modelling, it is now more readily evident than was the case when the (former) Kangaroo Advisory Committee reports were being prepared, that without the shooting, uncontrolled kangaroo grazing would impact on the profitability of running cattle and sheep.

- **Kangaroo movement between government managed land and rural leases**

Where there is clear evidence of either a nett flow of kangaroos from government managed land (e.g. a Public Land reserve) onto a rural lease, or a daily movement between the two, actions may be taken by the government land management agency (generally ACT Parks, Conservation and Lands) as part of a 'good neighbour' approach to ameliorate the impact on the rural landholder. Important conditions for such actions to be taken are that:

  - The land holder is effectively taking part in the rural culling program to reduce kangaroo densities on the lease.
  - The proposed actions do not adversely affect the values of, or conflict with the management policies for government managed land (as set out in a management plan) or the first goal of this kangaroo management plan.

- The proposed actions (and alternative options) are properly evaluated to ensure that they will meet the objectives and are cost-effective.

The actions to be taken will need to be worked out for the particular circumstances, but are most likely to involve the following:

- Fencing, such as the fencing used at Tidbinbilla. As fencing is expensive to erect and maintain, different types of fencing, including electric fencing, may be used or trialled, drawing on experience elsewhere.
- Culling in the government managed land. This may be combined with culling for ecological objectives in some reserves. Emphasis may need to be given to the zone near the boundary fence between the two land uses.

- **Managing and maintaining densities**

As for other land use types, important issues for rural lands are how to determine an appropriate kangaroo density that results in an acceptable level of grazing impact, and once determined, how to reduce and maintain density at that level. Ideally landholders would rapidly reduce the on-farm kangaroo population to a suitable level, and then maintain it at that level, by culling every year, so that fewer kangaroos have to be killed over the longer term. This would be most effective if applied regionally, but is unlikely to be a realistic expectation for all properties. In these circumstances, the managed (reduced) kangaroo population on smaller, more isolated properties is likely to be replenished from the surplus kangaroo production on adjoining land where the populations are unmanaged. There would be considerable benefit in managing kangaroos on a catchment or district basis rather than lease by lease (KAC 1997), and this remains a desirable approach, but is not easy to achieve within legal (licensing) constraints under the Nature Conservation Act and across a large number of landholders with different land management objectives. However, better integration of the culling program across the rural lands and in relation to the rural – Public Land interface should be sought.

To hold a kangaroo population at a constant size by shooting, approximately 40 per cent have to be culled annually, if the population has a balanced age and sex structure and is not limited by food. If the shooting is male-biased, as often tends to be the case, the percentage will be greater. To reduce, rather than maintain the kangaroo population, a higher proportion must be shot.

Initially, from 1998, the number of kangaroos permitted to be shot on each ACT licence was conservative. Based on the density of 0.5 kangaroos per hectare for ACT rural land (Freudenberger 1996), and taking all rural land into account, the licensed cull was well below 40 per cent. After shooting their quota, many graziers could demonstrate that a high density of kangaroos remained. Over the years, the proportion of graziers who shot their full quota increased; a sign that the permissible numbers culled was not effective in reducing the on-farm kangaroo population to a suitable level. Surreptitious culling appeared to be increasing.

In the spirit of adaptive management, a less conservative approach to setting the quota was put on trial from 2008, one which creates an incentive to conduct regular annual culls, rather than a cycle of no culling for a few years followed by a large cull. In addition, landholders who have shot most of their quota during the regular season are being allowed to shoot an additional small number of males in spring (after the normal season). This is intended to enable the landholder to scare away mixed-sex groups of kangaroos that sometimes move back onto a farm seeking the new spring growth. Without some mechanism such as this, an inability to protect paddocks from spring grazing would be a disincentive to good farm management.

The best long-term record of the number of kangaroos licensed to be shot for impact reduction is that from Victoria; however, this is believed to typify the situation in south-eastern mainland

Australia. The pattern is one of demand to shoot increasing numbers of eastern grey kangaroos, with spikes in drought years. The record from the ACT is provided in Table 6.1.

- **Density estimates**

As noted in s. 6.2.2(a), kangaroo densities on ACT rural lands have not been estimated for over a decade. To assist in refining management policy, periodic estimates of density would be valuable. However, a precise, unbiased estimate would be expensive, so it will be necessary to develop targeted, cost-effective survey protocols. Extending the NSW south-eastern survey to cover the ACT would not provide sufficient counting effort to enable the ACT figure to be stated separately.

- **Information**

More coordinated and effective management of kangaroos on rural leases may be encouraged by the dissemination of information on kangaroo ecology and population dynamics arising from research undertaken over the last decade, particularly in relation to the moister temperate areas such as the ACT.

6.2.3 Kangaroos on rural lands: management policies

Kangaroos on Rural Lands	
Total grazing pressure	· The total grazing pressure concept will be used as the conceptual framework for determining suitable kangaroo densities on ACT rural lands, with this continuing to be incorporated into Land Management Agreements. · Licensing of rural culling will be directed towards reducing kangaroo grazing impact and achieving long-term sustainable densities.
Animal welfare	· The *Code of Practice for the Humane Destruction of Kangaroos in the ACT* will apply to culling on rural lands. · On welfare grounds, the designation of a kangaroo shooting season and strict requirements for obtaining and renewing a shooter's licence will be maintained. · Where the need can be justified, limited male only culls may be permitted in individual rural leaseholds in spring.
Density estimates	· A scientifically based estimate of kangaroo densities on rural lands will be undertaken periodically. · A targeted, cost-effective survey protocol will be sought for this purpose.
Records	· The requirement for licence holders to submit annual returns on the numbers of kangaroos culled will be continued. These records will be maintained and aggregate data made publicly available.
Adjacent lands	· Management of the rural culling program will seek to integrate the program across all rural land and the rural – Public Land interface.

6.3 Government horse paddocks

Objective: Government Horse Paddocks	**Free-ranging kangaroo populations on government horse paddocks are managed so that their densities do not seriously impact on the viability of the paddock complexes.**

Policies related to this objective are at s. 6.3.3.

Privately owned horse agistment properties are covered by the provisions of this kangaroo management plan relating to rural properties (s. 6.2). In addition to the privately owned premises, there are 17 ACT Government owned horse agistment complexes (1038 ha in total), many in close proximity to the suburbs. These are highly valued by horse owners. The government employs a contractor to manage these areas. Thus, for the purposes of this plan, the government horse paddocks are similar to other land used for rural production. All of the complexes comprise a

number of paddocks designed to allow rotational and seasonal grazing of individually fenced areas. During the last decade the number of horses in government paddocks has halved due to the effects of the 2003 fire, drought and grazing pressure from kangaroos.

6.3.1 Kangaroos on government horse paddocks

Kangaroo grazing pressure varies widely between paddock complexes, and has had a severe impact on the horse agistment function in some cases. Due to competition from eastern grey kangaroos, one horse paddock complex has closed, and the capacity of another has been reduced from 80 to about 20 horses over a 14 year period. Over this time, the capacity of a similar complex, where kangaroo grazing is not a significant issue, has increased. Capacity has been significantly reduced in another four paddocks.

6.3.2 Managing kangaroo densities

For historical reasons there has been a practice within government of considering kangaroo management in the horse paddocks to be analogous to kangaroo management in nature conservation areas. However, it is more appropriate to consider kangaroo management within government owned horse holding complexes to be analogous to that on rural properties. The agistment fees paid by horse owners provide funding for the maintenance and development of the complexes as well as providing an income to the contractor, hence any grazing competition in horse paddocks can be considered to be reducing rural business production (the same as on rural leases). As on other rural properties, where firearms safety conditions can be met, a licence can be issued to shoot a set number of kangaroos, under the same stringent conditions. In future, those tendering for the horse paddock management contract should be encouraged to take account of the cost of kangaroo management.

The main challenge is to keep kangaroos from grazing at night in paddocks that are being spelled from horse grazing at the time. Shooting is the most humane and cost-effective technique to reduce kangaroo density. On public safety grounds, this may be unsuitable for some horse paddocks, due to their proximity to suburbs. The main alternative appears to be fencing. Kangaroo-proof fencing has previously been attempted throughout the complexes, resulting in large financial outlays and continuing high maintenance requirements.

It may prove useful to investigate combinations of cheaper 'leaky' fencing (with some modifications, for example, on existing stock fences using extra wires to raise their height or diagonal fencing attached to the outside), with methods to scare the kangaroos such as use of motorbikes to occasionally herd them out of areas surrounded by leaky fences, and shooting of the occasional individual kangaroo to reinforce the scaring effect.

6.3.3 Government horse paddocks: management policies

Government Horse Paddocks	
Total grazing pressure	· The total grazing pressure concept will be used as the conceptual framework for determining suitable kangaroo densities on ACT Government horse paddock complexes.
Viability of horse paddocks	· As far as practicable, kangaroo densities in horse paddocks will be managed so as to maintain the viability of the paddocks for their horse agistment purpose.
Management contract	· The need to consider kangaroo management will be made explicit in tender information for the contract to manage the horse paddocks. · Advice will be provided to the contractor managing the horse paddocks with regard to the most suitable, cost-effective techniques for managing kangaroo densities.

6.4 Commercial kangaroo harvesting

No specific objective is specified for commercial kangaroo harvesting	**Though some people may see it as desirable to establish a commercial harvest and make use of kangaroo products derived from the current damage mitigation shooting in the ACT; economic, social and regulatory factors make such an objective unlikely to be achieved in the ACT at the present time or in the foreseeable future.**

Policies related to commercial kangaroo harvesting are at s. 6.4.2.

The question of commercial kangaroo harvesting in the ACT has been investigated previously (KAC 1997), but it was considered unlikely that such an operation would be feasible because:

- shooting with high-powered rifles would not be permitted in many areas where kangaroos were abundant
- costs associated with establishing, administering and monitoring such an operation were likely to be significant
- market demand was being met by existing operations in other states.

At the time, the ACT would have been an isolated operation separated from the NSW commercial zone further west. The most significant development in the subsequent period has been the trial and subsequent commencement of commercial harvesting in Livestock Health and Pest Authority areas surrounding the ACT (NSW DEC 2006) (s. 3.9.5(b)). There has also been a shift in the basis of the commercial industry to treat kangaroos as a resource ('sustainable harvesting') rather than as a pest ('damage mitigation') (Olsen and Low 2006).

In 2009, the South-East NSW Commercial Zone annual quota was 62 291 eastern grey kangaroos, which is 15 per cent of an estimated population of 415 271 (Payne 2008b). The number of kangaroos culled annually on ACT rural leases is small by comparison (approximately 2000–3500) (Table 6.1). There have also been well-publicised culls on National Land in 2008–2009 with some suggestion that these would be more acceptable if the bodies were utilised.

6.4.1 Issues and considerations

Any commercial industry established in the ACT would be based, most likely, on rural land (Territory leasehold), Government managed land (but not Public Land), and possibly National Land. The following issues and considerations are pertinent and indicate that a commercial kangaroo harvesting industry remains unlikely in the ACT in the foreseeable future:

- While an ACT industry would need to be integrated with the NSW South-East Zone for economic and logistical reasons; the ACT would still need to prepare and regularly update a management plan for Commonwealth approval under the *Environment Protection and Biodiversity Conservation Act 1999*. It is unrealistic to expect that the ACT could establish its own industry solely for the domestic market.
- A commercial harvest quota of 15–20 per cent on rural land (the maximum normally allowed) would be only half to one-third of the number allowed to be shot from 1998 to 2009 on ACT land for damage mitigation. A small off-take for sustainable commercial harvesting would probably be too small to achieve desirable reductions in grazing pressure for economic purposes on rural lands and for ecological purposes in other areas, necessitating damage mitigation shooting as well.

- The costs of establishing, administering and monitoring a commercial operation are likely to be significant and include population estimates, preparation of a harvest management plan, compliance and reporting. Given the relatively small harvest that would be involved, the operation is unlikely to be cost-effective for the ACT Government.
- Rural lessees would be unlikely to gain a direct economic benefit from commercial harvesting (e.g. a payment for kangaroos taken), though they would save the cost of undertaking an equivalent damage mitigation cull. In New South Wales, graziers are not significant participants in the industry (Olsen and Low 2006). There would be a benefit in increased farm production, but as noted above, supplementary damage mitigation shooting would probably be necessary on many properties.
- Commercial kangaroo harvesting is a strong focus of animal rights organisations opposed to any killing of kangaroos. A commercial operation in the ACT would be likely to draw publicity out of all proportion to the numbers involved, as the National Capital provides a symbolic location to project the opposition to the industry.
- In contrast to the above, a survey of ACT residents in 2008 found a moderately high level of support for the use of the kangaroos that are shot annually, rather than the bodies being left where they are shot or buried (Micromex 2008). (Survey results indicated 53% were supportive/very supportive; 26% were not very supportive/not at all supportive; while 22% were unsure.)

6.4.2 Commercial kangaroo harvesting: policies

Commercial Kangaroo Harvesting	
Commercial harvest not pursued	· The establishment of a commercial kangaroo harvesting operation will not be pursued in the ACT in the foreseeable future. · Any decision to introduce commercial kangaroo harvesting in the ACT would need to be based on a rigorous analysis of costs and benefits, independently reviewed.

6.5 Vehicle collisions and collision avoidance

Objective: Vehicle–kangaroo collisions	**The incidence of vehicle–kangaroo collisions in the ACT is reduced.**

Policies related to this objective are at s. 6.5.4.

Collisions between vehicles and kangaroos and accidents due to collision avoidance are the most significant negative interactions between ACT residents and kangaroos. The accident rate is unknown, but in some years, there are more than 1000 callouts to the Urban Wildlife Program (s. 4.4.2(a)) to attend to dead or injured kangaroos. These collisions have economic and social impacts as well as raising animal welfare concerns. As noted in s. 3.9.4, there is a very high incidence of such collisions in the ACT region, reflecting high kangaroo densities and high traffic flows on high speed roads. The three broad factors that contribute to the potential for collisions are briefly outlined in s. 3.9.4 and a summary assessment of the practicality of a range of techniques is contained in Table 3.4. Road-kill mitigation measures that have been integrated into the planning, design and maintenance of major roads are outlined in Magnus (2006), with particular reference to Tasmania.

6.5.1 Modifying attributes of the road

Road-kill mitigation measures that form part of road and verge design are discussed in s. 3.9.4(a) and a summary assessment is contained in Table 3.4. Of these, fencing combined in some instances with underpasses, presents the main technique that has potential application on major urban arterial roads in the ACT with adjacent high density kangaroo populations. Other design features, such as overpasses, escape routes from road cuttings and table drain management, have been used elsewhere (Magnus et al. 2004; Magnus 2006), but these have little application on major ACT roads.

The construction of new urban arterial roads and upgrades of others, the rise in kangaroo densities in lowland areas, and the increase in vehicle numbers and traffic flows have resulted in an increase in the incidence of vehicle–kangaroo collisions. Given that the problem has become worse, it is appropriate to re-evaluate the use of fencing on such roads, and where fencing is used, to evaluate the results. Where kangaroo movement corridors are involved and the terrain and road design are compatible, underpasses should also be considered. Because fences and underpasses are expensive, their placement needs to be rigorously evaluated. A first step is to record the locations of kangaroos attended following vehicle collisions and of carcasses collected from the roadside. This would assist in identifying areas of likely kangaroo movement such as where roads separate bushland shelter from grazing areas. Together with other information, this would enable a predictive model for zones of high collision risk to be developed. Thus the location of fencing and underpasses could be well targeted, especially at the design stage for future roads.

As noted in s. 3.9.4(a), the use of fences and underpasses has become more common on highways in recent years for both biodiversity conservation and road-kill mitigation purposes. One application of fencing and underpasses in the ACT has been on sections of the Gungahlin Drive Extension. Kangaroos are thought to be using some of these underpasses and this would be a suitable location to study the effectiveness of such structures. The design of new arterial roads such as the Majura Parkway could be used as an opportunity to quantify the benefit of fencing one or both sides and providing wildlife underpasses. Fences could be added progressively, or removed, and underpasses opened and blocked to ascertain effectiveness and which designs are most cost effective.

6.5.2 Modifying animal behaviour

As discussed in s. 3.9.4(b), this method is aimed at deterring animals from venturing onto the road when a vehicle is approaching. The two main types of device are roadside reflectors and vehicle mounted sound emitters. Electronic animal warning systems are briefly discussed in s. 3.9.4. These are not considered to have any current application to kangaroos. Reflectors were originally developed in Europe to prevent collisions with deer, but despite three decades of use, the results remain equivocal. Following a rigorous study with captive kangaroos and wallabies, Ramp and Croft (2006) were unable to support their use in Australia. In a review of road-kill mitigation measures, Magnus (2006) does not recommend their use. As well as their doubtful effectiveness, the high costs of placement and maintenance, and the need for solid mounting posts, are significant issues.

A range of ‘ultrasonic’ devices are marketed that claim to evoke a vigilance response in kangaroos, such that the animals do not approach the roadway. These products generally do not match manufacturers’ claims; there is no evidence for statements about animal behaviour; and there is no statistically significant difference in animal–vehicle collisions whether or not the devices are fitted/activated (Bender 2001).

The policies in s. 6.5.4 should be reviewed should devices become available that are scientifically demonstrated to be effective in modifying kangaroo behaviour such that there is a significant reduction in vehicle–kangaroo collisions.

6.5.3 Modifying driver behaviour

Education campaigns aimed at modifying driver behaviour are probably the most practical intervention action to manage conflict between kangaroos and vehicles (s. 3.9.4(c); Table 3.4). Publicity campaigns were conducted in the ACT between 2000 and 2004 and gained high community recognition, but it is difficult to assess their effectiveness in terms of actual collision reduction. Road warning signs have also been used; however, their efficacy in terms of collision reduction is also uncertain.

Canberra is unique compared with other major Australia urban areas in having large populations of free-ranging kangaroos within and on the margins of the urban area. Therefore, despite the uncertainties about effectiveness, it is appropriate that driver awareness programs be undertaken occasionally aimed at encouraging slower speeds and extra alertness in 'black-spot' areas. An occasional higher profile campaign is likely to be most effective. In the past these campaigns have been run in association with the NRMA and this model should be considered for any future programs.

6.5.4 Vehicle collisions and collision avoidance: policies

Vehicle Collisions and Collision Avoidance	
Modifying attributes of the road	· Inclusion of road attributes that may reduce the incidence of vehicle–kangaroo collisions will be considered in the design of new or upgraded major urban arterial roads in the ACT and will be subject to cost-benefit analysis. The main attributes to be considered are fencing and underpasses. · Studies will be encouraged that: a) improve understanding of kangaroo behaviour in relation to roads and collision mitigation measures; b) assess the effectiveness of road design features aimed at reducing the incidence of vehicle–kangaroo collisions.
Modifying animal behaviour	· Given the lack of scientifically based evidence to date as to the effectiveness of currently available devices: (a) 'Wildlife reflectors' will not be installed on ACT roads for the purpose of deterring kangaroos from entering the roadway (b) 'Ultrasonic' deterrents will not be endorsed for fitting to vehicles.
Modifying driver behaviour	· Driver awareness programs will be periodically undertaken aimed at encouraging slower speeds and extra alertness in 'black-spot' areas for vehicle–kangaroo collisions. Partnerships will sought with other interested organisations for such campaigns.

6.6 Controversy over kangaroo management

Social considerations in relation to kangaroo management in the ACT have been discussed in s. 1.4.3 and s. 3.10. It was noted in s. 1.4.3 that there are entrenched conflicts over kangaroo management in Australia, especially with regard to commercial harvesting. There is a belief, promoted by a range of allied 'animal rights' organisations, that kangaroos (i.e. the harvested species) are on the brink of extinction (see, for example, Sutterby 2008). Such concerns, about the extinction of the harvested species, can be traced back for more than forty years. However, considerable research effort has been directed to understanding the biology, ecology, and population dynamics of these species, and methods of estimating their densities and population sizes. The latest edition of *The*

Mammals of Australia (Van Dyck and Strahan 2008), with contributions by over 240 mammalogists, shows all the harvested species are assessed as being common or abundant, while conservation concerns are raised about many of the lesser known species.

This kangaroo management plan shows that ACT populations of eastern grey kangaroos are probably greater than at any time during the twentieth century. For example, parts of Namadgi National Park and Tidbinbilla Nature Reserve carry high numbers and densities (among the highest naturally occurring densities of eastern grey kangaroos recorded in Australia). In the lowland grassy reserve areas that interlace and border the ACT urban area and on National Land, densities are high and in some areas still increasing. This is not a picture of an animal under threat. The plan stresses that management approaches need to be tailored to the management objectives of the land in question, and the range of values that need to be protected and managed. A one-dimensional focus on kangaroos in some areas would result in a dereliction of management responsibility to conserve habitats for other species.

Although there is no commercial harvesting of kangaroos in the ACT, it is inevitable that kangaroo management in the nation's capital will be affected by 'animal rights' campaigns against any management actions that involve the killing of kangaroos. As a result, residents will be drawn into these conflicts of values. These philosophical differences cannot be resolved by this kangaroo management plan. However, the plan has set out to be comprehensive and is the only plan of its type in Australia for kangaroos. It covers the different categories of land in the ACT, the issues that surround kangaroo management, and the scientific underpinnings for both kangaroo and grassy ecosystem management. In this way it should provide a sound basis for the concerned individual to assess the various claims made about kangaroos and their management, in the ACT and surrounding area.

Appendices and References

The ACT Government conducts kangaroo research, some as partnerships with universities. Tracking collars, as seen here, provide data to answer questions about kangaroo movements.

APPENDIX 1
Methods Used to Estimate Kangaroo Densities

In controversies over management of wildlife populations, it is not unusual for density estimates of the wildlife species to be challenged, and sometimes the methods of obtaining the estimates. This appendix is intended to improve awareness of the methods used by scientists to estimate the abundance of wildlife populations. First, a common misunderstanding must be dispelled. Whereas a dairy farmer can literally count the cows coming to the dairy to be milked, and he or she will usually know if one is missing, or if an intruder has joined the herd, when the same word 'count' is used in relation to estimating the abundance of wildlife, misunderstanding is sometimes created. In reality the exact number of most wildlife populations is unknowable.

Ecologists estimate the density (number per square kilometre, see **Glossary**) of a population within statistical limits of precision (also called 'error') such as ± 10% Standard Error. Appendixes 5 and 6 include examples. Sometimes the number of the whole population is stated instead, but density is more commonly used. One reason for preferring density is that the estimation of the population often requires an additional parameter to be estimated, the spatial extent of the population, thereby introducing further sources of uncertainty.

However there are exceptions. Entire kangaroo populations in some small reserves in Canberra are literally counted individually: see *Direct Observation Counts* and *Sweep Counts* below. Even in these cases, there is still a small uncertainty (error). Results of such counts are preferably stated as the mean of three or more counts.

The fact that the exact abundance of large populations of wildlife cannot be ascertained is not the barrier to management it may be assumed to be. All measurements and measuring equipment have some limit of precision. Part of the science of applied ecology is to respond appropriately in the context of inexact estimates, and to judge when the level of precision is acceptable.

Spotlight Count refers to a common practice of recording the numbers of animals seen in the beam of a spotlight from a vehicle moving along defined transects, usually along vehicle trails or roads. They produce a 'density index', as opposed to an estimate of absolute density. The advantages of density indexes are simplicity and low cost. A good index is proportional to true density, meaning the index will double if the true population doubles. However, the number of animals recorded is arbitrary, and only the change relative to previous and future counts (e.g. doubling) is obtained.

Direct Observation Counts are the simplest method of estimating absolute abundance (kangaroos per hectare), and the least costly, but are suited only to small open sites where one to three people can see all the kangaroos. The results are only acceptable if three independent counts over a few days produce close results. Applicable sites include Crace and Mulanggari Grasslands Nature Reserves, Jerrabomberra East Nature Reserves and some fenced enclosures.

Sweep Counts, also known as *Drive Counts* involve a group of people walking in an organised way through the kangaroos so that all animals are recorded once and only once. Belconnen Naval Transmitting Station was frequently counted before the cull in May 2008, by averaging a set of three sweep counts, each using nine people. The largest sweep count conducted in the ACT employed 105 people to surround 9.4 sq km at the former 'Gudgenby' property in Namadgi National Park. More than 5700 kangaroo movements into and out of the area were recorded, by more than 4000 individual kangaroos. This and another sweep count confirmed the accuracy of the nocturnal line transect counts (which were much faster and cheaper). Repeats are advisable to test the results of sweep counts.

Distance Sampling refers to a group of methods, of which only the linear subset (or *Line Transect Method*) is applied to kangaroos. Line transect is probably the most widely used method in the world for estimating abundance of wildlife. For kangaroos, the observer travels along a transect line in a helicopter, off-road vehicle, or on foot, and records the distance from the point of observation to each group of kangaroos with a laser rangefinder, and their angular displacement from the line with a compass or compass rose, enabling their perpendicular *distance* (displacement) from the transect to be estimated. The key step in Distance Sampling is to fit a *detection function* to the observed displacements, and use the fitted detection function to estimate the proportion of objects missed by the survey. Thus, the absolute abundance of the population (animals seen plus unseen) can be estimated. The method is well explained at < www.ruwpa.st-and.ac.uk >.

Estimates of kangaroo density are made by *helicopter line transect* every three years in the rural areas within the NSW South-East Kangaroo Management Zone (Cairns 2004; Payne 2007; Pople et al. 2003). This method is also used in the Queensland kangaroo harvest zone. The helicopter line transect method is suited to large scale applications (such as the NSW survey) but is unsuited to high density populations on small sites, such as those in Namadgi National Park. *Walked line transect* surveys have had extensive use in the ACT, carried out through the daylight hours (e.g. Freudenberger 1996). In a variation of the walked method, Fletcher (2006a) counted from first light until a criterion was met referring to the number of kangaroos seen lying down, in order to overcome the different detectability of kangaroos standing and lying, which varies through the day. That study also found that the accuracy and precision of the daylight counts could be obtained three times faster using a white spotlight on moonless nights from an off-road vehicle driven cross country. A red spotlight method was also trialled with less success.

Line transect counts of kangaroo populations at moderate density or higher are effective in open woodland but appear to be unreliable in woodland or forest, because many kangaroos move off before they are detected by the counter, thereby violating one of the important assumptions required for Distance Sampling methods.

Faecal Pellet Counts have a number of variations. The method most used in the ACT follows that of Perry and Braysher (1986) in comparing pellet density on the unknown site with pellet density in a similar site where kangaroo density is known. More recent work (Howland (2008); Howland and Fletcher (2009), unpublished data, ACT Parks, Conservation and Lands) compared direct visual counts with population estimates from pellet counts, and showed that remarkably accurate results can be obtained if the reference site has similar pasture quality and food availability. Stratification by pasture type using Krebs (1999) 'optimal sampling design' was also an important innovation compared to previous applications of the method. The requirement to clear plots of pellets a few weeks before counting makes this method tedious and, therefore, unpopular with many researchers. However, the results show that it can be one of the most efficient and effective methods, rivalling the line transect method, if a high standard of precision is required.

Strip Counts from fixed wing light aircraft have been the mainstay of kangaroo population estimates in semi-arid Australia for almost half a century and many papers have been published about the method (e.g. Caughley 1974; Caughley et al. 1976; Gilroy 1999; Grigg and Pople 1999; Pople 1999; Pople et al. 1998). It is necessary to have a correction multiplier to convert the count to density because the majority of kangaroos on the strip are missed (depending on vegetation type and kangaroo species). The correction factor is obtained from simultaneous estimates of true density by one of the other methods, usually helicopter line transect. Strip counts are not applicable in the ACT due to its small area and localised high density kangaroo populations.

APPENDIX 2
Lowland Native Grassland Sites in the ACT

The table below lists all the lowland native grassland sites in the ACT, their size, botanical significance, conservation category, and threatened species they contain. For location of sites, see maps in *ACT Lowland Native Grassland Conservation Strategy* (ACT Government 2005).

Native Grassland in the ACT: List of sites grouped by land use or managing agency

Name of site	Site No.	Land use	Area (ha)	Grassland type	Area (ha)	BSR	Threat. Spp	Cons. Cat.
TERRITORY LAND: Public Land (Nature Reserve and Special Purpose Reserve)								
Crace Nature Reserve	GU03	Nature Reserve	136.0	NTG NP EP	61.5 41.1 33.3	3(5)	BW SLL PG	C1
Gungaderra Nature Reserve	GU02	Nature Reserve	187.3	NTG NP EP	41.9 115.2 30.2	5(2,4)	SLL PG	C1
Mulanggari Nature Reserve	GU01	Nature Reserve	68.5	NTG NP EP	58.6 9.4 0.5	2(3)	GSM PG SLL	C1
Dunlop Nature Reserve	BE02	Nature Reserve	81.9	NTG	81.9	3(2)	GSM	C1
Jerrabomberra West Reserve	JE03	Nature Reserve	116.9	NTG NP	115.2 1.7	3	PTWL GED GSM PG	C1
'Callum Brae' *	JE02	Nature Reserve, Rural lease	162.7	NP	162.7	5	GED GSM	C1
Jerrabomberra East	JE05	Proposed Nature Reserve	72.0	NTG NP EP	62.2 7.8 2.0	4(3)	GED GSM PG	C1
'Mugga Mugga' Homestead	JE01	Special Purpose Reserve	15.0	NTG	15.1	4(3)		C2
NATIONAL LAND (with some Rural Lease at Harman–Bonshaw)								
Air Services Beacon	MA02	Airport Services Australia	10.7	NTG	10.7	2(4)	GED GSM PG SLL	C1
Canberra International Airport	MA03	Canberra International Airport	203.6	NTG NP EP	73.6 62.9 67.1	3(1,2,5)	GED GSM PG	C1
Majura Training Area	MA01	Dept. Defence	126.6	NTG NP EP	113.7 5.8 7.1	2(1)	BW GED GSM PG SLL	C1

Name of site	Site No.	Land use	Area (ha)	Grassland type	Area (ha)	BSR	Threat. Spp	Cons. Cat.
Campbell Park	MA05	Dept. Defence	11.7	NTG EP	10.9 0.8	3(2)	BW GED GSM PG SLL	C1
Harman Bonshaw North	JE07	Dept. Defence, Rural lease	114.6	NTG NP	46.3 68.3	5(4)	GED SLL	C1
Harman Bonshaw South *	JE06	Dept. Defence, Rural lease	105.7	NP	105.7	5	BW SLL PG	C1
Belconnen Naval Transmitting Station	BE08	Dept. Defence (proposed reserve)	120.3	NTG	120.4	2(3,4)	GSM GP PG SLL	C1
'Malcolm Vale' *	MA04	Dept. Defence	155.4	NP	155.4	5	GED	C2
Yarramundi Reach	CC06	National Capital Authority	21.2	NTG	21.2	4(3)	GSM SLL	C2
York Park, Barton	CC05	Dept of Finance and Deregulation	0.4	NTG	0.4	4	GSM	C2
Ginninderra Experimental Station	BE01	CSIRO	19.4	NTG EP	18.9 0.5	4		C2
TERRITORY LAND: Roadside								
Lady Denman Drive, Yarralumla	CC07	Roadside	0.4	NTG	0.4	3	GSM	C2
Woods Lane	JE04	Roadside	10.3	NTG	10.3	3	BW	C2
Wells Station Road	GU07	Roadside	0.2	NTG	0.2	4		C3
TERRITORY LAND: Rural								
Kama South	BE12	Rural (agisted) (proposed reserve)	38.5	NTG	38.5	2		C1
Tennant St, Fyshwick	JE10	Rural (agisted)	0.3	NTG	0.3	3	BW	C2
'Jarramlee'	BE03	Rural (agisted)	52.0	NTG	52.0	4(3)		C2
Kaleen east paddocks	BE09	Rural (agisted)	28.2	NTG NP	4.0 24.2	5(3)		C3
Lawson Territory	BE07	Rural (agisted)	59.2	NTG NP EP	3.3 46.9 9.1	5(3)		C3
Majura West *	MA06	Rural lease & agistment (proposed reserve)	133.3	NP	133.3	5	SLL	C1
Caswell Drive	BE10	Rural lease	4.8	NTG	4.8	2		C1
'Cookanalla' *	JE08	Rural lease	81.5	NP	81.5	5	GED	C2
Canberra Riding Club	GU06	Rural lease	0.3	NTG	0.3	4		C3

Name of site	Site No.	Land use	Area (ha)	Grassland type	Area (ha)	BSR	Threat. Spp	Cons. Cat.
TERRITORY LAND: Public Land (Urban Open Space)								
Glenloch interchange	BE11	UOS	2.2	NTG	2.2	2		C1
Isabella Pond, Monash	TU01	UOS	1.2	NTG	1.2	2		C1
North Mitchell	GU04	UOS	15.9	NTG EP	15.8 1.2	3(4)	SLL	C2
Black St, Yarralumla	CC11	UOS	3.6	NTG	3.6	3	GSM	C2
Constitution Ave, Reid	CC02	UOS (Designated Area)	0.7	NTG	0.7	3	GSM	C2
Dudley St, Yarralumla	CC08	UOS	2.2	NTG EP	1.5 0.7	3	GSM	C2
Umbagong Park South, Florey	BE04a	UOS	2.8	NTG	2.8	3		C2
Lake Ginninderra	BE06	UOS	1.9	NTG	1.8	3		C2
Umbagong Park North, Florey	BE04b	UOS	12.7	NTG NP EP	7.2 1.8 4.7	4(5)		C3
Evatt Powerlines	BE05	UOS	1.1	NTG	1.1	3		C3
Nicholls	GU08	UOS	0.3	NTG	0.3	4		C3
Novar St, Yarralumla	CC10	UOS	0.2	NTG	0.2	4		C3
Other TERRITORY LAND								
ACC&C, Barton	CC04	Urban Lease (Designated Area)	1.9	NTG	1.9	1	BW GSM	C1
St Johns Church, Reid	CC03	Urban Lease (Designated Area)	0.9	NTG	0.9	4	GSM	C2
Amtech	JE09	Vacant	18.0	NTG	18.0	4	GED	C2
Kintore St, Yarralumla	CC09	Vacant (Designated Area)	0.8	NTG	0.8	3	BW	C2
Mitchell	GU05	Vacant	1.6	NTG	1.6	3	GSM	C3
CSIRO HQ, Campbell	CC01	Urban Lease	3.0	NTG	3.0	3	GSM	C2
Total			2212	NTG NP EP	1031 1024 134			
GUNGAHLIN Total native grassland area: 410.1 ha. Area of natural temperate grassland: 179.2 ha								
MAJURA VALLEY Total native grassland area: 641.3 ha. Area of natural temperate grassland: 208.9 ha.								
JERRABOMBERRA VALLEY Total native grassland area: 697.1 ha. Area of natural temperate grassland: 267.4 h								
BELCONNEN Total native grassland area: 426 ha. Area of natural temperate grassland: 338.6 ha.								
CANBERRA CENTRAL and **TUGGERANONG** Total native grassland area: 36.5 ha. Area of natural temperate grassland: 35.8 ha.								

Notes:

1) **Site No**: Refers to site numbers of areas of native grassland and native pasture in the ACT Grassland Strategy (ACT Government 2005). Letters indicate location e.g. GU = Gungahlin.
2) **Land use (UOS):** Urban Open Space (Public Land category).
3) **NTG** (Natural Temperate Grassland, BSR 1–4); **NP** (Native Pasture, BSR 5); **EP** (Exotic Pasture, no BSR rating).
4) **BSR:** Botanical Significance Rating (see Glossary).
5) **Threatened Species**: **PTWL** (pink-tailed worm-lizard); **GED** (grassland earless dragon); **GSM** (golden sun moth); **PG** (Perunga grasshopper); **SLL** (striped legless lizard; **BW** (button wrinklewort); **GP** (Ginninderra peppercress).
6) **Cons. Cat. (Conservation Category):** All native grassland sites in the ACT have been assessed and placed in one of three categories of conservation value. The key criteria are Botanical Significance Rating, threatened species habitat, and size. Category 1 (Core Conservation Sites) are the highest value sites.
7) * – Denotes native grassland sites that do not contain natural temperate grassland (BSR 5).
8) **Designated Area**: Planning is the responsibility of the National Capital Authority, not the ACT Government.

APPENDIX 3
Lowland Woodland and Threatened Species

Note: Areas in **Complex** and **Units** columns (e.g. 4435/1920 ha) indicate the estimated total area of woodland of all types in the complex (4435 ha) and the area of yellow box – red gum grassy woodland (1920 ha). The latter is the ecological community declared threatened under ACT and Commonwealth legislation (s. 2.4) and contains an understorey in varying states of modification (ACT Government 2004). The **Threatened Species** list is indicative only. For locations of sites, see maps in the *ACT Lowland Woodland Conservation Strategy* (ACT Government 2004).

Complex	Units	Significant Woodland Areas	Threatened Species (relevant to Kangaroo MP)
Gungahlin 4435/1920 ha	**a) North Gungahlin** 2219/649 ha	· Hall–Kinlyside · Mulligans Flat NR (west of Gundaroo Rd) · Remnants of Snow Gum woodland	· Tarengo Leek Orchid · Hooded Robin · White-winged Triller · Superb Parrot · Golden Sun Moth
	b) Gooroo–Mulligans Flat 1623/1146 ha	· Throughout area	· Austral Toadflax · Hooded Robin · White-winged Triller · Brown Treecreeper · Superb Parrot · Golden Sun Moth
	c) Central Gungahlin 579/68 ha	· Remnants of Snow Gum woodland	· Striped Legless Lizard
Majura–Kowen 4900/1560 ha	**a) Mt Ainslie-Mt Majura** 1041/697 ha	· Throughout; lower slopes of Mt Ainslie near Fairbairn Ave; near Campbell Park · Remnants of Snow Gum woodland	· Hooded Robin · White-winged Triller · Brown Treecreeper · Canberra Spider Orchid
	b) East Majura 3448/832 ha	· Majura Training Area and Newline Quarry	· Hooded Robin · White-winged Triller · Brown Treecreeper
	c) Kowen 409/44 ha	· Small remnant of Snow Gum woodland	· None identified
Callum Brae–Jerrabomberra 2325/1040 ha	**a) Red Hill** 346/261 ha	· Throughout area	· Button Wrinklewort
	b) Mugga Lane West 577/292 ha	· Throughout area	· Perunga Grasshopper · Pink-tailed Worm-lizard
	c) Mugga Lane East 872/395 ha	· Very high quality woodland in northern third of area	· Pink-tailed Worm-lizard · White-winged Triller · Brown Treecreeper
	d) Wanniassa Hills 369/113 ha	· Upper slopes of Wanniassa Hills	· None identified
	e) Farrer Ridge 174/53 ha	· Throughout area	· Pink-tailed Worm-lizard · Small Purple Pea

Complex	Units	Significant Woodland Areas	Threatened Species (relevant to Kangaroo MP)
Tuggeranong–Naas 18 800/5405 ha	**a) Tidbinbilla–Booroomba** 6432/1806 ha	· Castle Hill · Throughout area	· Hooded Robin · White-winged Triller · Brown Treecreeper
	b) Rob Roy Range 4094/1012 ha	· Throughout slopes of Rob Roy Range	· Hooded Robin · Pink-tailed Worm-lizard
	c) Naas 7306/2769 ha	· Slopes of Mt Tennant and Billy Range	· Hooded Robin · White-winged Triller · Brown Treecreeper · Pink-tailed Worm-lizard
North Murrumbidgee–Lower Molonglo 6545/940 ha	**a) Bulgar Creek** 3997/361 ha	· Only small patches in good condition	· Small Purple Pea · Austral Toadflax · Hooded Robin · Pink-tailed Worm-lizard · White-winged Triller
	b) Uriarra 904/15 ha	· None identified, note small area of Yellow Box – Red Gum Grassy Woodland	· Brown Treecreeper · Pink-tailed Worm-lizard
	c) Belconnen 1587/536 ha	· South-west lower/mid slopes of Black Mtn, 'Kama' property. · Remnant Snow Gum woodland	· White-winged Triller · Brown Treecreeper · Small Purple Pea

APPENDIX 4
Uncommon Grassland Flora and Fauna Species

As well as declared threatened species (Table 2.1), some species in lowland woodland and native grassland areas of the ACT are naturally rare or have become uncommon due to clearance, fragmentation and degradation of their grassy ecosystem habitat. Species that have shown the most substantial decline and are threatened with extinction may be declared threatened under legislation (s. 2.4). Under the *Nature Conservation Act 1980* (ACT), native plants and animals may be declared also as 'protected' (s. 34 of the Act) or as having 'special protection status' (s. 33 of the Act). An important role of habitat management is the conservation of species that are uncommon so that they do not decline to the level of being threatened. Many of these species are adversely affected by overgrazing of grassland and loss of grassland structure.

Assessment of species as uncommon depends upon surveys and monitoring over time. For reasons such as the inconspicuous habit of some species, seasonal variation, and lack of historical knowledge of abundance and distribution, considerable uncertainty may surround these assessments. Examples of uncommon flora and fauna species found in lowland grassland and/or grassy woodland are given below. More detail is contained in the ACT Woodland Strategy (ACT Government 2004) and the ACT Grassland Strategy (ACT Government 2005).

Flora

Amphibromus nervosus	G
Milkmaids (*Burchardia umbellata*)	G
Yam Daisy (*Microseris lanceolata*)	G
Adder's Tongue (*Ophioglossum lusitanicum*)	G
Spoon Cudweed (*Stuartina muelleri*)	G, GW
Silky Swainson-pea (*Swainsona sericea*)	G, GW
Zornia (*Zornia dyctiocarpa*)	G, GW
Australian Anchor Plant (*Discaria pubescens*)	GW
Emu-foot (*Cullen tenax*)	GW
Silky Swainson-pea (*Swainsona sericea*)	G, GW
Notched Swainson-pea (*Swainsona monticola*)	G, GW
Wedge Diuris (*Diuris dendrobioides*)	G
Scaly Buttons (*Leptorhynchos squamatus*)	G, GW

Fauna

Key's Matchstick Grasshopper (*Keyacris scurra*)	G, GW
Canberra Raspy Cricket (*Cooraboorama canberrae*)	G
Lewis's Laxabilla (*Laxabilla smaragdina*)	G
Black-headed Snake (*Suta spectabilis dwyeri*)	GW
Shingleback Lizard (*Trachydosaurus rugosus*)	G, GW
Brown Toadlet (*Pseudophryne bibronii*)	G
Lace Monitor (Goanna) (*Varanus varius*)	GW
Stubble Quail (*Coturnix pectoralis*)	G
Brown Quail (*Coturnix ypsilophora*)	G
Singing Bushlark (*Mirafra javanica*)	G
Brown Songlark (*Cincloramphus cruralis*)	G

G = lowland grassland; **GW** = lowland grassy woodland

APPENDIX 5
Kangaroo Density Estimates (KAC 1997)

Estimated densities of eastern grey kangaroos in open woodlands in the ACT during November 1995 (Freudenberger in KAC 1996a), April/May 1996 (Nelson, 1996), November/December 1996, and April/May 1997 (Environment ACT, unpublished data) (Calculated by DISTANCE software).

Land use	Year	EGK/km²	EGK/ha	Coefficient of variation	95% confidence interval
Reserves*	1995 (Nov)	233	2.33	9.8	193–282
Reserves*	1996 (Apr/May)	236	2.36	16.9	170–327
Reserves*	1996 (Nov)	246	2.46	17.5	175–345
Reserves*	1997 (Apr/May)	237	2.37	21.4	157–359
TNR	1995 (Nov)	357	3.57	14.4	268–475
TNR (pre-cull)	1997 (Mar/Apr)	367	3.67	19.2	250–539
TNR (post-cull)	1997 (July)	232	2.32	12.9	180–301
NNP	1996 (Mar/Apr)	193	1.93	20.5	128–290
NNP	1996 (Nov)	275	2.75	23.6	174–433
NNP	1997 (Mar/Apr)	270	2.70	29.6	151–483
Rural	1995 (Nov)	50	0.50	19.7	34–74
Rural	1996 (Apr/May)	59	0.59	16.9	43–83
Rural	1996 (Nov)	48	0.48	30.5	27–85
Rural	1997 (Apr/May)	39	0.39	21.8	26–59

Note: EGK = eastern grey kangaroos
TNR = Tidbinbilla Nature Reserve
NNP = Namadgi National Park
* Data for TNR and NNP are included in these estimates.
No figures are provided for NNP in 1995 or TNR in 1996, due to insufficient data, or assumptions for the application of statistical analysis software not being met.

APPENDIX 6
Kangaroo Density Estimates since 1997

Methods used to estimate kangaroo densitie are explained in Appendix 1.

Location and date	Method used	Kangaroo density (No./ha)	Standard Error	Population estimate	Who estimated
BNTS[a] – 2004	Direct Count	1.72		200	HLA for Defence
BNTS – 2005	Direct Count	2.16		250	HLA for Defence
BNTS – 2006	Sweep Count-mean of 3	3.53		410	PCL 2008
BNTS – Mar 2007	Sweep Count-mean of 3	4.35		505	PCL 2008
BNTS – Dec 2007	Sweep Count-mean of 3	5.07		588	PCL 2008
BNTS – 2008 before cull	Direct Count	5.59		649	PCL 2008
BNTS – 2008 after cull	Direct Count- mean of 2	1.12		130	PCL 2008
Callum Brae NR[b] – Spring 2008	Direct Count – only 1	≥ 1.3		≥ 180	PCL 2008
Callum Brae NR – Spring 2009	Pellet Counts	2.05	0.35	289	PCL 2009
Crace NR – Spring 2008	Direct Count – mean of 3	0.75	0.01	123	PCL 2008
Crace NR – Spring 2009	Direct Count	1.4		224	PCL 2009
Dunlop NR – Spring 2008	Direct Count – mean of 3	0.60	0.07	63	PCL 2008
Dunlop NR – Spring 2009	Direct Count	0.60		65	PCL 2009
Googong Foreshores W June 1996	Line Transect	2.00	0.54	900	Muranyi 2000
Googong Foreshores W August 1999	Line Transect	3.60	0.96	1600	Muranyi 2000
Googong Foreshores NW 800ha 2001-02[c]	Line Transect	4.97	1.33	4000	Fletcher 2006a
Googong Foreshores NW 800ha August 2001	Sweep Count	3.80	NA	1710	Fletcher 2006a
Googong Foreshores NW 800ha 2002-03[c]	Line Transect	4.26	1.11	3400	Fletcher 2006a
Googong Foreshores NW 800ha – Spring 2009	Pellet Counts	2.15	0.08	1420	PCL 2009
Goorooyarroo NR grazing exclosure – Spring 08	Pellet Counts	0.85	0.07	33	Howland 2008
Goorooyarroo NR – Spring 08	Pellet Counts	1.85	1.72	1330	Howland 2008
Goorooyarroo NR – Spring 09	Pellet Counts	2.17	0.23	1260	PCL 2009
Gudgenby Grassland in NNP 2001-02[c]	Line Transect	4.38	1.21	6600	Fletcher 2006a
Gudgenby Grassland in NNP April 2002[c]	Sweep Count	4.69	NA	7000	Fletcher 2006a
Gudgenby Grassland in NNP 2002-03[c]	Line Transect	5.01	1.47	7500	Fletcher 2006a
Jerrabomberra West NR – Spring 2008	Direct Count – mean of 4	0.52	0.01	139	PCL 2008
Jerrabomberra West NR – Spring 2009	Pellet Counts	1.19	0.16	318	PCL 2009
Kama NR	Sweep Count-mean of 3	1.5		227	PCL 2009
Mulanggari NR – Spring 2008	Pellet Counts	0.71	0.02	107	PCL 2008
Mulanggari NR – Spring 2008	Direct Count – mean of 3	0.73	0.16	102	PCL 2008
Mulanggari NR – Spring 2008	Line Transect survey	0.63	0.12	88	PCL 2008
Mulanggari NR – Spring 2009	Direct Count – mean of 3	1.05		148	PCL 2009
Mulligans Flat NR –Winter 08[d]	Pellet Counts	1.42		1060	Howland 2008
Mulligans Flat NR –Winter 09	Pellet Counts	1.64	0.26	592	PCL 2009
Tidbinbilla NR Grassland 2002-03[c]	Line Transect	5.01	1.31	2800	Fletcher 2006a
Wanniassa Hills	Pellet Counts	1.27	0.14	309	PCL 2009

[a] Belconnen Naval Transmitting Station
[b] NR = Nature Reserve
[c] Mean of six bimonthly surveys
[d] Many had moved onto adjoining rural property. Includes Mulligans North.

GLOSSARY

1. Abbreviations

BP = before present

DI = Disallowable Instrument (under ACT legislation)

EGK = eastern grey kangaroo

GL = gigalitre (1 000 000 000 litres or 1000 megalitres (ML))

ML = megalitre (1 000 000 litres)

ha = hectare

2. General

Abundance

Abundance of organisms means how many there are. Abundance may refer either to the total number in a population, e.g. 'there are 55 cows on this farm' or to their average density (defined below) e.g. 'there are 9.0 trees per hectare in this plantation, on average'. Abundance may be quantitative, as in the previous examples, or relative, e.g. 'rare', 'common', 'abundant'. Statements of abundance depend on a common understanding of where they apply.

Abundance is typically uncertain for wild populations. The exact number of cows that come to be milked on a farm on a particular day can be counted, but it is not possible to know *exactly* how many wild kangaroos live within even a relatively small nature reserve such as Tidbinbilla. Because of the unavoidable uncertainty, measurements of abundance are often referred to as 'estimates' although enormous effort and skill may have been used to obtain them. A rigorously determined 'estimate' is not a guess but a recognition that the statement of abundance is not precise. Abundance measurements/estimates of wild organisms should preferably be accompanied by estimates of uncertainty, such as the Standard Error of the mean.

The four population parameters that change abundance are:

- *Natality*: the reproductive output of a population
- *Mortality*: the death of organisms in a population
- *Immigration*: the number of organisms moving into the area occupied by the population
- *Emigration*: the number of organisms moving out of the area occupied by the population.

(Krebs 2001: p. 116)

See also the definition of **density**.

Adaptive management

Adaptive management is defined as management research involving the development of prior hypotheses about a dynamic natural resource, experimental application of a management treatment, collection of data sufficient to evaluate the effect of the intervention, and analysis (adapted from Walters 1986). Under this approach, management intervention is conducted in a

rigorous experimental framework where the intervention is implemented as a scientific experiment (Georges, Hone and Norris 2008).

The term 'adaptive management' often has a different meaning to the one intended here because it has been devalued in popular usage to mean 'learning by doing' or simply that the manager will do what seems best at the time. However, 'there is a long history of sad experience with the false premise that it is possible to "learn by doing" through sequential application of different policies to whole systems'. In these cases 'there is little prospect of resolving the uncertainties through continued monitoring and modest policy change' (Walters and Holling 1990).

Biota

Biota is a term for all the animal and plant life of a region or area.

Blastocyst

This is an early stage in the development of an embryo, when it consists of a hollow ball of cells with no differentiation of organs (Van Dyck and Strahan 2008).

Botanical Significance Rating (BSR)

As used in the ACT, botanical significance ratings are based on a qualitative assessment of the naturalness of the vegetation community in grassland sites. The ratings reflect the diversity of native and exotic plant species and the occurrence of species that are indicative of disturbance levels. Diversity is a measure of species richness measured over a specified area, such as species per hectare. In the *ACT Lowland Native Grassland Conservation Strategy* (ACT Government 2005), native grassland sites were given BSR ratings of 1 to 5 as shown in the table below.

Botanical Significance Rating (BSR)	Descriptive Category	Characteristics
NATURAL TEMPERATE GRASSLAND		
BSR 1 (Very High)	Partially modified **Natural Temperate Grassland**	Very high diversity and cover of native plant species, especially native forbs, including uncommon species and several to many disturbance sensitive species, and a low cover of exotic species.
BSR 2 (High)	Partially modified **Natural Temperate Grassland**	High to very high diversity of native plants. Fewer species indicative of minimal disturbance than areas categorised as BSR1. Contain uncommon species and several disturbance sensitive species.
BSR 3 (Moderate)	Moderately modified **Natural Temperate Grassland**	Moderate to high native species diversity, but contain only species tolerant of disturbance. Sites have been moderately altered and have low to moderate exotic species cover.
BSR 4 (Low)	Highly modified **Natural Temperate Grassland**	Very low diversity of native species, particularly native forbs. High cover of native grasses. May have high diversity but low to moderate cover of exotic perennial plants.
NATIVE PASTURE		
BSR 5 (Very Low)	Substantially modified **Native Grassland (Native Pasture)**	High cover of native grasses but native forb cover and diversity is very low to zero. Contain only disturbance tolerant native species.
EXOTIC		
BSR E (Exotic)	Exotic pasture	Dominated by perennial exotic species. May contain some disturbance tolerant native species, mainly grasses.

Capture myopathy

This is caused by the stress of capture, resulting from excessive chasing of animals prior to

capture and/or their struggle to escape from traps, nets or capture bags. It is characterised by the degeneration and necrosis of skeletal and cardiac muscles. Treatment is rarely successful. Prevention involves the use of quick captures in the cooler part of the day and for large species, such as kangaroos, darting and sedative drugs (Jackson 2003).

Cline

This refers to a continuously graded variation in the characteristics of a species over distance. It is contrasted with the division of a species into sub-species (when variation is notably discontinuous) (Van Dyck and Strahan 2008).

Damage mitigation

Wildlife agencies in several Australian states issue 'damage mitigation' licences to kill native species where such killing is justified on economic or social grounds. The term is used to distinguish this process from commercial harvesting, which has different goals and ecological requirements. In this plan, 'damage mitigation' means the measures legally adopted to relieve undesired economic or social effects of kangaroos. In reference to grazing management, damage mitigation is most often achieved by shooting, but other measures such as fencing are also used.

Density

Density of organisms is their abundance (defined above) when expressed in the form of a number or amount per area e.g. 4 kangaroos per hectare or 100 kg per hectare. Density is often the form of abundance preferred by ecologists (rather than the total population size) because the average density can be directly measured for a defined area. In contrast, the total population size often depends on both the measurement of average density and on a definition of the extent of the population, which is typically variable, uncertain, and because of animal movements, dependent on what time scale is relevant.

See also the definition of **abundance**.

DSE (Dry Sheep Equivalent)

Dry Sheep Equivalent (DSE) refers to annual pasture consumption by one non-lactating sheep. It is a way of converting pasture consumption by different herbivores to a common unit. A DSE of 0.7 would mean that an animal consumes 70 per cent per annum of what a sheep consumes or that an area capable of supporting 70 sheep could support 100 of the alternative herbivore.

Fire regime

Fires occur as discrete events but their effects on the environment, ecological communities, and component species depend upon the history of these events, the seasons in which the fires occurred, and their properties (e.g. intensity). Together, these elements comprise a fire regime (Gill et al. 2002).

Fecundity

In population ecology, fecundity refers to the rate of production of offspring, and may be expressed as the proportion of adult females producing young. As a conservative approximation which could be estimated without catching or killing a large number of eastern grey kangaroos, Fletcher (2006a) defined fecundity as the proportion of females delivering a young kangaroo permanently from the pouch.

Fitness

Fitness is a measure of the contribution of an individual to future generations. Individuals have

higher fitness if they leave more descendants. Fitness is a relative term applying to individual organisms within the same species (Krebs 2001).

Forb

A forb is a herbaceous (non-woody) plant that is not a grass (Scarlett et al. 1992).

Functional response

The functional response of the herbivore is its eating rate as a function of vegetation availability.

Mitochondrial DNA

Mitochondria are structures within cells that convert the energy from food into a form that cells can use. Although most DNA is packaged in chromosomes within the nucleus, mitochondria also have a small amount of their own DNA. This genetic material is known as mitochondrial DNA or mtDNA. In most multicellular organisms, mtDNA is inherited from the mother (maternally inherited).

Natural integrity

The degree to which a place or ecosystem retains its natural *biodiversity* and *geodiversity* and other natural processes and characteristics (Australian Heritage Commission 2002).

Biodiversity (biological diversity) is the variety of all life forms (plants, animals, micro-organisms, their genes) and the ecosystems of which they form a part (Commonwealth of Australia 1996).

Geodiversity means the natural range (diversity) of geological (bedrock), geomorphological (landform) and soil features, assemblages, systems and processes (Australian Heritage Commission 2002).

Numerical response

The numerical response of the herbivore is its population growth rate as a function of vegetation availability.

Population

A *population* may be defined as a group of organisms of the same species occupying a particular space at a particular time (Krebs 2001: p. 116). The population is a basic unit of study in ecology and genetics. Ecologists have a particular interest in population *density* (see above).

Quadrat

A *quadrat* is a defined unit of measurement such as a frame enclosing 1 square metre. Such measurements are often made along a line called a transect.

Range

Range refers to the spatial distribution of a species. The terms *restricted* (or localised) and *widespread* describe extremes of spatial distribution (Lindenmayer and Burgman 2005: p.57; based on Brown 1984 and Rabinowitz et al. 1986).

Regeneration, Restoration and Reinstatement

These terms are defined in the *Australian Natural Heritage Charter* (Australian Heritage Commission

2002).

Regeneration means the natural recovery of natural integrity* following disturbance or degradation.

Restoration means returning existing habitats to a known past state or to an approximation of the natural condition by repairing degradation, by removing introduced species or by reinstatement.

Reinstatement means to introduce to a place one or more species or elements of habitat or geodiversity* that are known to have existed there naturally at a previous time, but that can no longer be found at that place.

(* see definitions above)

Ungulate

An *ungulate* is a hoofed mammal (e.g. deer).

3. Pasture and biomass

Pasture

Pasture is ground layer vegetation potentially or actually subject to grazing.

Pasture biomass

Pasture biomass is used here to refer to the total (dried) weight of the living pasture vegetation i.e. including roots, but not the dead component, or *necromass*. However, *pasture biomass* is often used as a synonym for *total herbage mass*.

Biomass

Biomass is the dried weight of living material. It is commonly used with a qualifying term to refer to components, as in 'plant biomass' or 'herbivore biomass'. It usually, but not always, refers to density (e.g. kg/ha) rather than populations.

Herbage mass

Herbage mass is synonymous with what agronomists call *yield*, and is defined as the grazable (or to the researcher, clippable) above-ground component of the pasture, including both dead and living plant parts. It can be subdivided into dead and living components, and the Dry Weight Rank method is routinely used to subdivide it by species.

Green herbage mass/green grass herbage mass

Green herbage mass is the living portion of clippable above ground pasture (see herbage mass), which is what herbivores seek. In temperate grazing studies it is generally considered necessary to use *green herbage mass* in preference to *total herbage mass* to detect or predict the relations between weather and pasture and between pasture and herbivores. Eastern grey kangaroos eat mainly green grass and few forbs, so *green grass herbage mass* may be the most relevant quantum in this case. *Green herbage mass* plus *necromass* equals *total herbage mass*.

Necromass

Necromass is the dead portion of clippable above ground pasture (see *herbage mass*). *Green herbage mass* plus *necromass* equals *total herbage mass*.

Units for vegetation biomass

Biomass, *necromass*, and *herbage mass* are always expressed as densities, in the form of dried mass per unit area, and in agronomic or ecological studies the units are generally kilograms (dried weight) per hectare. However, in most studies the animal density is represented as numbers, rather than mass, per unit area, with the exception of the GMM (Growth Metabolism Mortality) school of thought, a so-called 'metaphysiological' approach which represents both the plant and animal populations as mass per unit area.

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