Australian Capital Territory

Nature Conservation (Eastern Grey Kangaroo—Draft Controlled Native Species Management Plan) Public Consultation Notice 2017

Notifiable instrument NI2017–51

made under the

Nature Conservation Act 2014, s 162 (Draft controlled native species management plan—public consultation)

1 Name of instrument

This instrument is the *Nature Conservation (Eastern Grey Kangaroo—Draft Controlled Native Species Management Plan) Public Consultation Notice 2017*.

2 Commencement

This instrument commences on the day after its notification day.

3 Draft controlled native species management plan

I have prepared the Eastern Grey Kangaroo: Draft Controlled Native Species Management Plan (the ***draft controlled native species management plan***) at schedule 1 to this instrument.

4 Details of public consultation

(1) I invite written submissions from anyone about the draft controlled native species management plan. Submissions may be sent to:

Conservator of Flora and Fauna
c/o Manager, Conservation Research
Environment, Planning and Sustainable Development Directorate
GPO Box 158
CANBERRA ACT 2601
Email: environment@act.gov.au

(2) Submissions may be given on the draft controlled native species management plan only during the period starting on the notification day of this public consultation notice and ending on 24 March 2017.

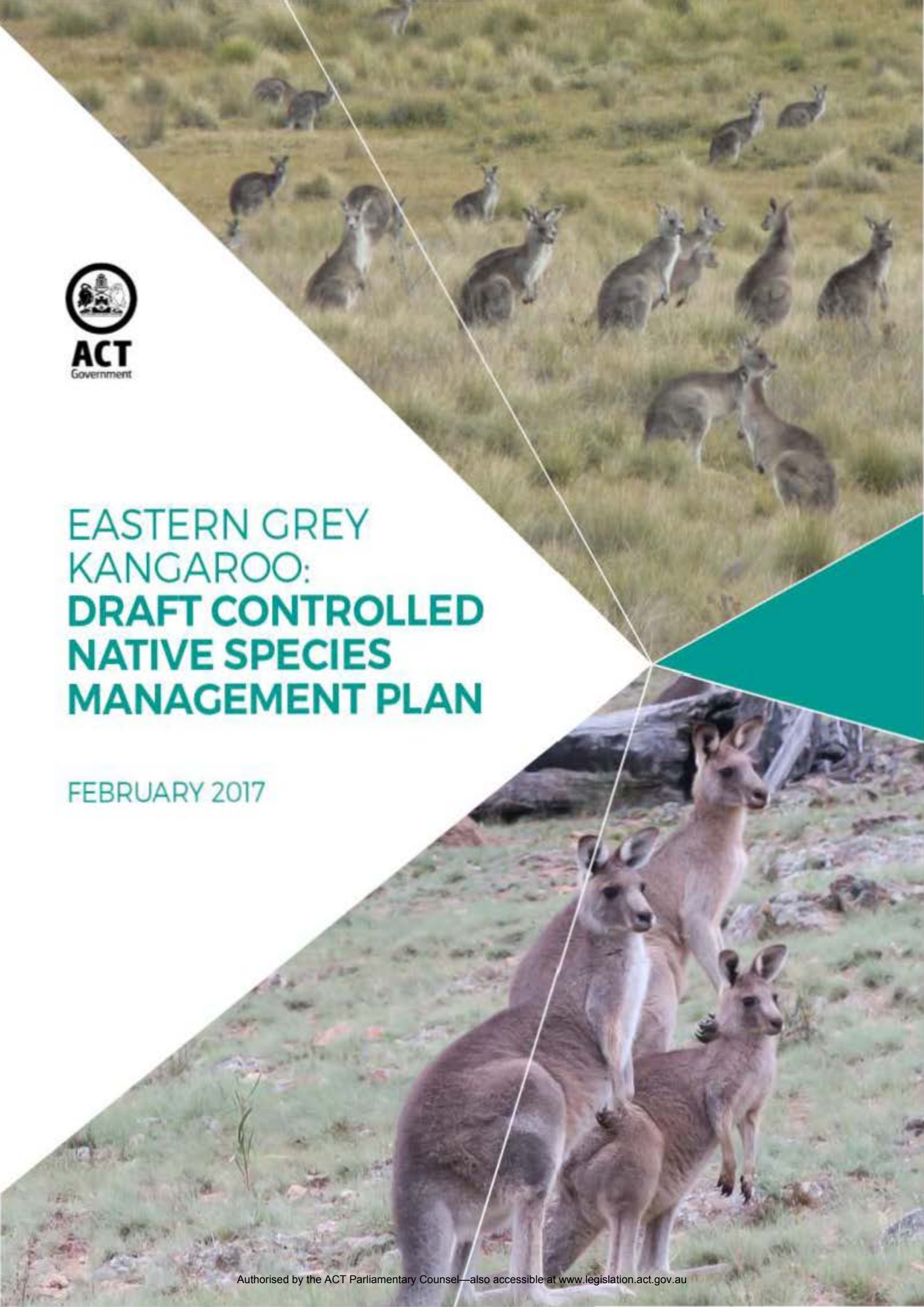
(3) The draft controlled native species management plan is also available for inspection during business hours at Ground Floor South, Dame Pattie Menzies House, 16 Challis Street, Dickson, and is available at www.environment.act.gov.au.

Annie Lane
Conservator of Flora and Fauna

7 February 2017

Schedule 1 Eastern Grey Kangaroo: Draft Controlled Native Species Management Plan

(see s 3)



ACT Government

EASTERN GREY KANGAROO: **DRAFT CONTROLLED NATIVE SPECIES MANAGEMENT PLAN**

FEBRUARY 2017

Have your say

The ACT Government welcomes comments on this draft plan. To make comments:

Visit: www.environment.act.gov.au

Email: environment@act.gov.au

Post: Controlled native species management

Environment Division

PO Box 521

Canberra ACT 2601

Comments can be made until 24 March 2017

All comments will be taken into consideration during preparation of the final plan. The final plan will be considered by the ACT Government in 2017.

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1 INTRODUCTION

The ACT Kangaroo Management Plan 2010 (ACT Government 2010) was prepared in the legal, policy, scientific and social context prevailing at that time. Since then there have been developments in many of these areas, specifically:

- **Legal** – Changes to the *Nature Conservation Act* in 2014 provided for the declaration of controlled native species where it is considered that a species is having an unacceptable impact on an environmental, social or economic asset (s. 157 of the *Nature Conservation Act 2014* [NC Act]). Once a species is declared as a controlled native species, the Conservator for Fauna and Flora may prepare a 'controlled native species management plan'. The objective of the plan is to detail the appropriate management of the species on the land specified in the plan. In another legal development, appeals against conservation culling licences were lodged in the ACT Civil and Administrative Tribunal in 2009, 2012, 2013 and 2014 but were unsuccessful.
- **Scientific** – The extensive peer reviewed research that underpinned the 2010 plan has been supplemented by further research that is relevant to the management of Eastern Grey Kangaroos in the ACT region. This is described in Chapter 3.
- **Policy and administrative procedures** – In 2013 the ACT adopted the National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes (NRMMC 2008b). This national code replaced the Code of Practice for the Humane Destruction of Kangaroos in the ACT that was previously applied.
- **Social** – Surveys conducted in 2008, 2011 and 2015 indicated there is growing support for the ACT Government's approach to managing kangaroo populations. The 2015 survey indicated that 86% of ACT residents agreed that culling kangaroos is appropriate under certain circumstances, 76% supported kangaroo culling for conservation of other native species while 7% are against culling under any circumstances. The support for culling has grown from 59% in 2008.
- **Land use planning** – There has been a continued growth in the area of protected lands in the ACT with a focus on the establishment of reserves to conserve remnant grassy and woodland ecosystems as the urban area of Canberra grows for example, extensions to Mulanggari and Gungaderra Nature Reserves in northern Canberra.
- **Review** - In April 2014, Kurahaupo Consulting (Parkes and Forsyth 2014) independently reviewed the kangaroo population count methods, the count results and the method of determining the number of kangaroos to cull set out in 'Calculation of the Number to Cull' (ACT Government 2016a) and the science behind the relevant parts of the 2010 Kangaroo Management Plan. The review endorsed the ACT Government's counting methods and culling advice. The Kurahaupo report, the ACT Government's response and other recent reports can be viewed at ACT Government Environment website Kangaroos page.

This controlled native species management plan for Eastern Grey Kangaroos responds to those changes.

This plan does not unilaterally replace the 2010 ACT Kangaroo Management Plan (ACT Government 2010). The 2010 plan applied to all kangaroo species within the ACT: Eastern Grey Kangaroo (*Macropus giganteus*), Common Wallaroo (*M. robustus*), Red-necked Wallaby (*M. rufogriseus*) and Swamp Wallaby (*Wallabia bicolor*). This plan applies only to Eastern Grey Kangaroos. Hence, the 2010 plan should still be considered the source document for the background and justification leading to policy statements generally about kangaroo management in the ACT. In regard to macropod species other than Eastern Grey Kangaroos and for all kangaroos at Googong Foreshores, the 2010 plan continues to be the sole ACT policy document for kangaroo management. Its explanations include over 400 references including approximately 125 articles in peer-reviewed science journals and 115 books or book chapters, most of which have been peer reviewed.

The 2010 plan was independently reviewed by eminent ecologist Professor Dr Graeme Coulson from the University of Melbourne (Coulson G, undated) who recommended it *"serve as a model for the management of kangaroos and other wildlife in Australia".*

The principles, objectives and policies of the 2010 Kangaroo Management Plan are adopted for this plan unless indicated; changes have resulted due to new scientific information or from fine tuning to focus solely on Eastern Grey Kangaroos.

Primary changes since 2010 included in this plan are:

- the ACT has adopted the National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes (NRMMC 2008b)
- the Conservator or land custodian are required under the NC Act to implement this plan and can authorise others under this plan to undertake certain management activities that previously required a licence under the NC Act. Note: the plan itself does not require or permit a leaseholder to undertake kangaroo culling on their land. A separate authorization issued by the Conservator will be required.
- the section on managing captive populations has been updated to include definitions of the different types of enclosed kangaroo populations in the ACT and which of these are subject to the captive management policies
- the decision of the ACT Civil and Administrative Tribunal in 2011[1] to approve the licence to Wildcare Queanbeyan to export 35 dependent animals from the ACT
- the addition of policies relating to management of kangaroos at greenfield development sites and on agisted and unleased land.

This plan incorporates the research conducted since 2010 that is relevant to Eastern Grey Kangaroos. It also meets the legislative requirement to provide detail on how control programs will be conducted following the declaration of Eastern Grey Kangaroos as a controlled native species.

While the 2010 Kangaroo Management Plan was prepared to cover all macropod species in the ACT, it used the term 'kangaroo' to refer specifically to Eastern Grey Kangaroos. As indicated above, this new plan focuses solely on Eastern Grey Kangaroos and continues to use the term 'kangaroo' to refer specifically to this species. Where necessary other species are referred to by their widely accepted common names.

[1] *Wildcare Queanbeyan NSW Inc & Conservator of Flora and Fauna* (Administrative Review) [2011] ACAT 68

2 PURPOSE OF THIS MANAGEMENT PLAN

2.1 Background

Kangaroos are an integral and important 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 in 1996–97, which made many recommendations, including that an overall kangaroo management plan be prepared for the entire ACT (Kangaroo Advisory Committee 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. From January 2010 this role was fulfilled by the ACT Kangaroo Management Plan (ACT Government 2010), which had been released as a public consultation draft in March 2009.

This plan is a draft controlled native species management plan prepared by the Conservator of Flora and Fauna under section 160 of the NC Act. After consultation and any necessary revision it is intended that it will become a controlled native species management plan under section 165 of that Act.

2.2 Purpose of the management plan

Purpose

The purpose of the controlled native species 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 primary 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 and primary production.

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/wild dog and Aboriginal predation of native herbivores, the fire regime and small-scale soil disturbance by animals such as bandicoots and bettongs. Ongoing management will always be required to substitute for the elements and processes that are now missing from the system (Braid et al. 2008). Some 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 threatened plants and animals in native grassy ecosystems are rare (though they may be locally common). They are often cryptic and inconspicuous, possess unusual life cycles that result in them being rarely observed, and are little known outside of scientific and conservation circles. While there are animal rights campaigns regarding kangaroos, there are no equivalent campaigns for the protection of these small grassland plants and animals, some of which are critically endangered and the subject of specific conservation management programs.

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.

This controlled native species management plan does not contain the detailed operational procedures necessary to undertake all aspects of wildlife management. 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.

Unlike the 2010 ACT Kangaroo Management Plan, this Plan does not apply to Googong Foreshores as this area lies within NSW and remains land acquired by the Commonwealth and leased to the ACT for water supply purposes.

2.3 Implementation of the management plan

This plan will be implemented on public land, unleased land and rural lands, whether National Land or Territory Land, by applying each policy or objective stated in the relevant 'Policies' box or boxes that occurs in each of the paragraphs set out below, subject to the qualifications set out in parts 4, 5 and 6 of this plan.

Paragraph No.	**Name of policy**
4.3.1(d)	Humane treatment of wild kangaroos
4.3.1(e)	Keeping of kangaroos by wildlife carers
4.3.1(f)	Translocation of kangaroos
4.3.2	Interactions between humans and kangaroos
4.3.3(a)	Kangaroo culling
4.3.3(b)	Fertility control
4.3.3(c)	Environmental modification
4.3.4	Humane treatment of captive kangaroos
5.4.1	Lowland native grassland and grassy woodland
	Grasslands in the western and southern ACT
5.4.2	National Land
5.4.3	Greenfield development sites
5.4.4	Agisted or unleased sites
6.1.1	Kangaroos on rural lands

6.2	Government horse paddocks
6.3	Commercial kangaroo harvesting and utilisation of carcasses
6.4.3	Road safety

The expressions 'National Land' and 'Territory Land' refer to National Land and Territory Land as provided for in sections 27 and 28 of the *Australian Capital Territory (Planning and Land Management) Act 1988 (Cth)*.

As required by section 167 of the NC Act the plan is required to be implemented by the Conservator or, if the land is unleased land or public land, the custodian of the land. The plan itself does not require or permit a leaseholder to undertake kangaroo culling on their land. A separate authorization issued by the Conservator will be required. The conservator or custodian may authorise another person to take action to implement the Plan. A reference in this plan to an 'authority' is a reference to an authorisation under section 167.

If such action includes culling, in determining the number of kangaroos recommended to be culled in each case, the Conservator or the custodian must have regard to the Nature Conservation (Eastern Grey Kangaroo) Conservation Culling Calculator, as in force from time to time, in relation to public, unleased and National land, or the Nature Conservation (Eastern Grey Kangaroo) Rural Culling Calculator, as in force from time to time, in relation to rural lands.

Note The Nature Conservation (Eastern Grey Kangaroo) Conservation Culling Calculator and the Nature Conservation (Eastern Grey Kangaroo) Rural Culling Calculator are notifiable instruments (see the Legislation Act 2001, s 47). The text of the instruments is published in the ACT Legislation Register.

3 KANGAROOS IN THE ACT

3.1 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). Collectively known as macropods, they 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).

3.2 Species description

Eastern Grey Kangaroos (*Macropus giganteus*) are marsupials, with much of the development of the young taking place outside the body cavity in a pouch. They have the large, powerful hind legs (much larger than their forelimbs) typical of macropods, and 'hop' as their principal method of locomotion. Their long muscular tails assist with balance when hopping and act as a fifth limb when they are slowly 'punting'. They are distinguished from other kangaroos except the Western Grey Kangaroo by the light fur on their rhinarium (end of the muzzle, bare and black in some other species) and from the Western Grey Kangaroo by their pale face with dark eye rings, paler greyer colour overall, and ears that are well furred on the back surface, smaller, more rounded and lower on the head. In most individuals the short fur is pale brown with areas of pale grey for example, on the neck. The distal quarter of the tail is usually black. Body length for males is to 1.3 metres and tail to 1 metre; while females' body length is to 1 metre and tail to 0.84 metres (Menkhorst and Knight 2004). In the local region adult females weigh 18-40 kilograms (kg) and adult most males weigh 45–75 kg with some individuals exceeding 80 kg.

3.3 Species distribution

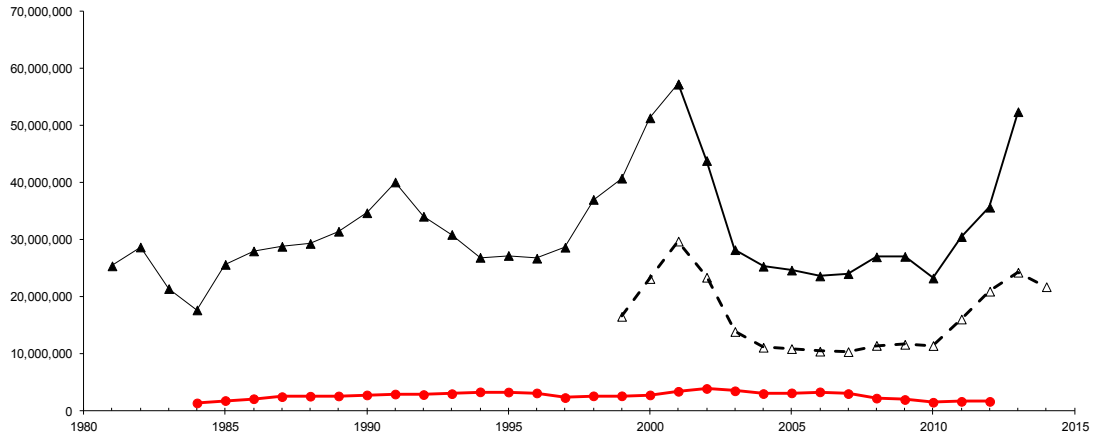
The national distribution of the Eastern Grey Kangaroo is from Cape York to eastern Tasmania—including central and south-western Queensland, all of NSW and all of Victoria except the north-west—and westward into eastern and south-eastern South Australia. The species occurs in the highest rainfall bioregions, where mammal persistence is generally higher and also extends into more arid areas. The ACT is a relatively small area within the broader distribution of the Eastern Grey Kangaroo.

The Eastern Grey Kangaroo 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.

3.4 Conservation status

Under assessments conducted by the International Union for Conservation of Nature (IUCN), Eastern Grey Kangaroos are listed as being of 'least concern'. The species is considered abundant locally (Coulson 2008) and is not listed as threatened in any jurisdiction within Australia. Like the other kangaroo species, the national population of Eastern Grey Kangaroos fluctuates by millions due to changes in weather and food supply. Monitoring of population numbers of the commercially harvested species over almost 30 years shows a significant capacity for population recovery after drought.

Figure 1 Kangaroo population in the Australian commercial harvest zones
Dashed line and hollow triangles = EGK, solid line and solid triangles = all commercial kangaroo species. EGKs and Western Grey kangaroos were not counted separately until 1999 but the full time series for the combined species illustrates the natural variation due to seasonal conditions and also shows that natural variation is greater than the numbers shot (red circles).



Only the population in the area of the commercial harvest is counted and this excludes much of the range of this species—Victoria, the ACT and coastal parts of NSW and Queensland—so the actual population is much greater than indicated in Figure 1.

In marked contrast to the picture of kangaroo population dynamics in the arid and semi-arid zone (Caughley et al. 1987a and b), 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 may be simply the much higher herbage mass than in the rangelands, combined with successful survival mechanisms that allow the kangaroos to bridge many of the troughs in food availability in this temperate environment (Fletcher 2006a).

3.5 Biology and ecology - summary

The following table (Table 1) identifies some of the key features of the biology and ecology of the Eastern Grey Kangaroo (based on ACT Government 2010).

Table 1 Key features of biology and ecology

Feature	Description/detail
Home range	ACT data show high fidelity to remarkably small home ranges for such a large, mobile animal. Female home range approximately 0.5 square kilometre, male home range approximately 1.0 square kilometre. Weak genetic structure for populations and dispersal inferred up to 230 kilometres from genetic evidence.
Sexual maturity	Males approximately 4 years old. Females 2 years old.
Reproductive cycle	Seasonal breeding in the ACT: most young born in summer with pulse of young permanently leaving the pouch in spring.

Feature	Description/detail
	Oestrous cycle 46 days (45.6 ± 9.8 SD[2]). Gestation 36 days (36.4 ± 1.6 SD). Birth, neonate climbs to pouch (referred to as a 'pouch young'). First pouch exit at 283 days (283 ± 24 SD) or 9.3 months (still 'pouch young'). Permanent pouch exit at 319 days (319 ± 18 SD) or 10.6 months (referred to as a 'young-at-foot' or 'YAF'). Weaning typically 540 days or 18 months (referred to as a 'sub-adult').
Fecundity (production of offspring)	ACT data show high levels of fecundity even at high population density and low *per capita* food availability. This is probably typical of temperate populations.
Mortality	High mortality of young prior to breeding age, especially for males. Few males more than 10 years old in wild.

3.6 Habitat

Nationally, there are extensive areas of habitat for the Eastern Grey Kangaroo comprising forest, woodland and heath in reserves, pastoral land and areas unsuitable for agriculture. 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 (for example, remnant areas of natural temperate grassland) to those containing only introduced species (for example, the greens of golf courses).

The ACT has a number of characteristics conducive to the establishment, maintenance and growth of kangaroo populations. Suitable kangaroo habitat, combining open grassland and adjacent woodland and/or forest cover, extends throughout the ACT 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 large proportion (over 70%) of the territory is reserved Public Land (including wilderness areas, national park and nature reserves) or other largely undeveloped, open space land managed by the ACT Government. There are also extensive areas of relatively undeveloped National Land managed by Commonwealth Government agencies. A significant area of the ACT is held under rural lease and, together with other leased land such as golf courses provides suitable, often ideal, kangaroo habitat.

3.7 Impacts of Eastern Grey Kangaroos

Eastern Grey Kangaroos can reach densities where they have unacceptable impacts on environmental, social or economic assets. These impacts are summarised in Table 2 and detailed in further sections. Measures may be required to reduce these impacts including density reduction (culling, fertility control) and indirect measures such as fencing and collision avoidance technology in motor vehicles.

[2] SD refers to the standard deviation

Table 2 Summary of impacts from Eastern Grey Kangaroos (from ACT 2010)

Impact type	Summary of unacceptable impacts
Environmental impacts	• Excessive grazing pressure on native grassy ecosystems resulting in degradation of the natural integrity of those ecosystems. • Excessive grazing pressure resulting in loss and degradation of habitat critical to threatened species of grassy ecosystems.
Economic impacts	• Effects on the economic viability of rural businesses and increased management costs for other lands. • Cost of vehicle collisions and collision avoidance measures and toll of human injuries.
Social impacts	• Road accident trauma. • Concernin the community over kangaroo management and actions taken to reduce kangaroo densities in some areas.

3.8 Environmental impacts

Resident populations of kangaroos are now present throughout the ACT, being largely absent only from mountain forests. They are our largest indigenous mammals, both individually (up to 100 kg) and in terms of their biomass (up to 25 tons/hectare) and are one of the most prominent and well recognised native animals.

Kangaroos are responsible for almost all of the herbivory in natural grassy communities of the lowland ACT, including two endangered communities, Lowland Natural Temperate Grassland and Yellow Box-Red Gum Grassy Woodland. Kangaroos occupy a central place in the food web of the relevant ecosystems, being integral in the flow of energy and nutrients between plants and predators, plants and scavengers, and plants and decomposers (Fletcher 2006a). These are the main flows within a terrestrial ecosystem. They are preyed upon by Dingoes (*Canis familiaris*), Wedge-tailed Eagles (*Aquila audax*) and introduced Red Foxes (*Vulpes vulpes*) (Robertshaw and Harden 1989) and their carcasses provide food for a diversity of scavengers (Barton et al. 2011, 2013a, 2013b). The kangaroo is a true 'keystone species' whose presence appears vital to a number of other species that may disappear in its absence (although many are retained if an artificial substitute for kangaroo grazing is introduced such as livestock grazing).

Equally important, kangaroos are an 'ecosystem engineer' as defined by Jones et al. (1997) and Wilby et al. (2001) because they alter habitat structure in ways that are to the advantage or disadvantage of many other species, including weeds, pest animals and species of conservation concern. They graze selectively and their browsing of *Eucalyptus* and *Acacia* seedlings (Webb 2001) appears to help maintain secondary grasslands against invasion of forest and woodland. They modify the habitats of, and alter the local population of grassland birds, invertebrates and reptiles (Neave and Tanton 1989; Neave 1991; Barton et al. 2011; Howland et al. 2014; Howland et al. 2016a).

The 2010 plan provides an explanation and references to support the contention that a native species can deleteriously impact on other native species. An example of this in the Canberra region is the elevated predation of small native birds by the native Pied Currawong as a result of the city providing a favourable environment year round for currawongs, which are naturally migratory.

Thus the conservation and management of kangaroo populations is important for the conservation of endangered ecological communities, other ecological communities and a wide range of invertebrates, small animals and plants. The control of the effects of grazing by kangaroos in temperate Australia is being increasingly recognised as an important part of the management of grassy ecosystems for conservation. This aims to achieve broad effects at the ecosystem level rather than saving individual threatened species.

3.8.1 Extinction processes

A number of factors 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 at high 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 among Australian mammals (Caughley and Gunn 1996, Frank et al. 2014).

The threat to species in Australia currently considered to be at risk of extinction arises from multiple causes. Extinction processes in lowland grasslands and grassy woodlands are outlined in Table 3.

In general, widespread factors such as habitat loss and fragmentation reduce the remaining fragmented population to low levels and divide it into sub-populations. Specific factors may then result in the death of the last animal on each site. These factors may differ between sites and can only rarely be specifically identified.

In ecological communities that are reduced to small and fragmented remnants, such as Natural Temperate Grassland or Yellow Box – Red Gum Grassy Woodland, a large number of species potentially face the threat of extinction.

The remaining fragments of Natural Temperate Grassland and Yellow Box – Red Gum Grassy Woodland require conservation management. In general, management should be conservative. Extremes of fire frequency, mowing, and grazing pressure should be avoided, and management changes undertaken cautiously.

Table 3 Extinction processes in lowland grasslands and grassy woodlands (from ACT Government 2010, Section 3.8.1)

Alienation of habitat	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 grasslands. Of the estimated original ACT lowland grassland, 95% has been alienated and about 5% remains.
Fragmentation	Fragmentation of remaining native grassland and woodland 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. 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. They 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. Variation in the quality of habitat fragments is also likely and this will affect survival and breeding rates.
Degradation	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.
Lack of recolonisation following disturbance	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 (alienation) 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.

3.8.2 Conservation of grassy ecological communities and species

In the ACT, and throughout their former south-eastern Australian distribution, 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 (for example, the Australian Bustard, Brolga, bettong species, bandicoot species and the Eastern Quoll). Others survive, in mainly small populations, in isolated patches of habitat (for example, the Golden Sun Moth and Small Purple Pea).

In some instances, species may be reasonably common in habitat where they occur, but there may only be one or a few areas of habitat (for example, the Ginninderra Peppercress and 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.

In the ACT, Natural Temperate Grasslands and Yellow Box–Red Gum Grassy Woodlands have been declared as Threatened Ecological Communities. Both are also listed under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). A number of component species are also listed as threatened under both legislations. The management of these ecological communities is identified in recovery and action plans and has also been progressed through the establishment of conservation reserves such as the grassland and woodland reserves in the Gungahlin and Jerrabomberra districts of the ACT.

Since the early 1990s, attention has been given to understanding the management requirements for long-term conservation of grassland and woodland remnants in the ACT. This is a big challenge because ecosystems are characteristically complex, dynamic, interactive and liable to be responding to lag effects from former conditions. In addition, all grassland areas have been subject to degrading disturbances (for example, weed invasion) and have lost the type of natural disturbances that maintained them in the past (for example, bandicoot diggings).

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).

Since the 2010 plan was published, eight studies on the effects of kangaroo grazing on biodiversity, based on work carried out in the ACT, have been published. These are summarised in Table 4 and discussed further in Sections 3.8.3, 3.8.4 and 3.8.5. Collectively the eight studies provide strong evidence that high densities of kangaroos can negatively impact a range of taxa in the ACT. Several studies were conducted in a way that enabled particular kangaroo densities to be recommended. (The advised densities are between 0.4 and 1.2 kangaroos/hectare).

Table 4 Summary of research on the effects of kangaroo grazing on biodiversity, based on field work in the ACT and published since the publication of the 2010 plan. These studies are discussed in Sections 3.8.3, 3.8.4 and 3.8.5.

Title of study	Year	Primary author	Studied taxon	Negative effect of high density of kangaroos?	Recommended kangaroo density (EGK/ha)
Biomass and floristic patterns in the ground layer vegetation of box-gum grassy eucalypt woodland in Goorooyarroo and Mulligans Flat Woodland Sanctuary, Australian Capital Territory	2010	Sue McIntyre	Ground-layer plants	Yes	-
Experimental reduction of native vertebrate grazing and addition of logs benefit beetle diversity at multiple scales	2011	Philip Barton	Beetles	Yes	0.4
Back to the brink – population decline of the endangered grassland earless dragon (*Tympanocryptis pinguicolla*) following its rediscovery	2012	Wendy Dimond	The Grassland Earless Dragon	Yes	-
Bringing forward the benefits of coarse woody debris in ecosystem recovery under different levels of grazing and vegetation density	2013	Adrian Manning	Reptiles	Yes	0.4
Eaten Out of House and Home: Impacts of Grazing on Ground-Dwelling Reptiles in Australian Grasslands and Grassy Woodlands	2014	Brett Howland	Grass and Reptiles	Yes	< 0.5
Restoration of eucalypt grassy woodland: effects of experimental interventions on ground-layer vegetation	2015	Sue McIntyre	Ground-layer plants	Yes	
Habitat preferences of the threatened striped legless lizard: implications for the management of grazing in grasslands.	2016	Brett Howland	Striped legless lizards	Yes	< 1.2
Birds of a feather flock together: using trait- groups to understand the effect of macropod grazing on bird communities in grassy habitats	2016	Brett Howland	Birds	Some yes Some no	varied

The eight studies collectively support the policy recorded in the 2010 plan. However some areas for potential improvement or adjustment have been identified in some studies.

3.8.3 Impacts of high density populations of Eastern Grey Kangaroos on fauna species

Competition, predation and parasitism

Grazing by high density populations of Eastern Grey Kangaroos can have effects on whether other species persist on a site (Neave and Tanton 1989). The relationships that cause these impacts are fundamental and well known in ecology; they involve competition, predation and parasitism.

Over the past 200 years, many Australian ecosystems have been altered, reduced and fragmented to the extent they no longer retain all the ecological processes 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. The threat of extinction is much greater when habitat is fragmented and some species exist only in small and separated populations.

ACT grassy ecosystems evolved under the influence of grazing herbivores, macropods in particular. Without intervention, 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 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. Excessive kangaroo grazing pressure impacts the specialised habitat of threatened species resulting in habitat loss and degradation which may lead to the death of significant parts of a population through starvation or predation (for example, by raptors or feral cats).

Impacts on bird species

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 (Neave and Tanton 1989). 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).

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 Woodland Sanctuary). Here kangaroo densities had increased, grassy understorey and adjacent grassland had been heavily grazed, and seeding of grasses suppressed. Diamond Firetails had been recorded in small numbers in neighbouring Goorooyarroo Nature Reserve in and around a paddock enclosed by a kangaroo exclusion fence (Canberra Ornithologists Group 2009).

In one study (Howland et al. 2016b), the effect of kangaroo grazing on birds was investigated at 18 grassland and grassy eucalyptus woodland properties across the ACT, NSW and Victoria. With over 300 species of birds recorded in the ACT alone, it is not feasible to investigate the effects of grazing on all individual species. Instead the study used a trait-based approach, grouping birds based on shared life-history traits likely to be affected by grazing.

These groups were: large ground-foraging; small ground-foraging; aerial insectivorous; and ground-nesting/concealment species. Howland et al. (2015b) evaluated effects of kangaroo grazing on these four trait groups by studying the birds in 18 sites that provided a gradient in kangaroo density.

Howland et al. (2016b) found that birds that utilised the grassy layer for food and relied on early detection of predators were more common under high grazing intensity, whereas birds that nested on the ground and relied on grass for concealment from predation, and birds that fed on invertebrates above the grass layer (i.e. aerial insectivores) were both more common under low grazing intensities. Large bodied (> 250 gram) ground-foraging birds (for example, galah, Sulphur-crested Cockatoo, White-winged Chough) were most common at very high grazing intensities and appeared to benefit from a very open grass layer. Small ground-foraging species (for example, Crested Pigeon, Magpie-lark, Red-rumped Parrot, Superb Fairy- wren) were most common at moderate to high grazing intensity and declined at very high and low grazing intensities. The authors concluded that a mix of low and high grazing intensities would be important in promoting a diverse bird assemblage. They suggested the duration of very high grazing events should be limited to prevent simplification of habitat and loss of food items.

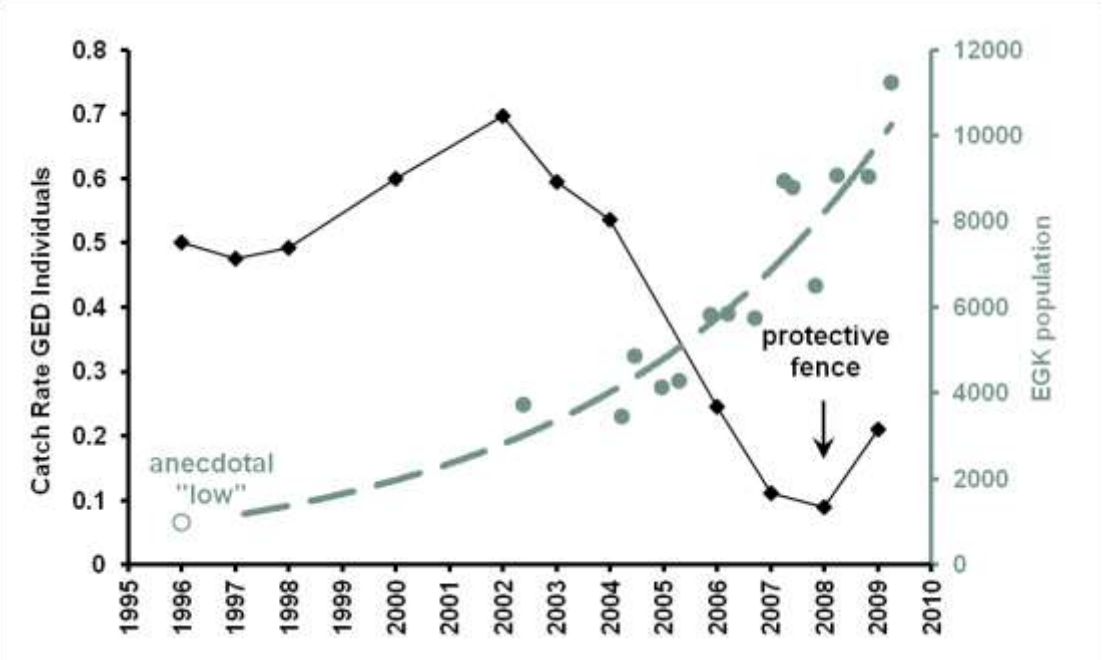
Impacts on reptiles

Grassland Earless Dragon

Dimond et al. (2012) studied the Grassland Earless Dragon *(Tympanocryptis pinguicolla)* and found the species is in danger of becoming the first recorded extinction of an Australian reptile. The Grassland Earless Dragon only occurs in Natural Temperate Grassland, an endangered ecological community. The remaining patches of this habitat are so small and isolated there is no prospect for the species to naturally recolonise areas where it has died out. Other than habitat destruction and fragmentation, the key threats to the species are drought and overgrazing resulting in a failure of recruitment of young into the adult population.

A particular case study is the Majura Training Area, where heavy grazing in drought conditions severely changed the habitat of the Grassland Earless Dragon and the density of the dragons plummeted (see Figure 2). Dragon numbers remained high on a less heavily grazed site in a nearby valley.

Figure 2 Abundance of Grassland Earless Dragons (GED, left axis) and kangaroos (EGK, right axis) at Majura Training Area



Note: Kangaroo counts (solid circles) by Defence contractors 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 and Conservation Service. The catch rate in Figure 2 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 proof fence.

Most likely the dragons need the longer grass to shelter from predators and to provide habitat for the insects on which they feed. When kangaroos were fenced out, the population of Grassland Earless Dragons began to recover (unpublished data, ACT Parks, Conservation and Lands).

Striped legless lizard

A study of the habitat preferences of the Striped Legless Lizard, *(Delma impar)*, was conducted over two years at six ACT grassland reserves (Howland et al. 2016a). Study sites were selected to cover a range of kangaroo densities (1.2 kangaroo/ha – 5 kangaroo per/hectare), a range of grassland sizes (10 – 200 hectare) and to contain a mix of native and introduced grasses. The study was initiated in 2012 by the ACT Government as part of a long-term investigation of kangaroo grazing impacts on biodiversity. The Striped Legless Lizard is a good indicator species for the effects of grazing as the species relies on grass structure for shelter from predators, for food and to regulate its body temperature. High levels of grazing are known to negatively affect this species as high grazing removes grass structure. However, some level of grazing is considered important as it promotes the formation of a mix of short and tall grass which this species is thought to prefer.

This study found that the Striped Legless Lizard can occupy even small and degraded grasslands provided there is sufficient grass and high kangaroo numbers are avoided. The authors recommended that to ensure the ongoing conservation of this threatened reptile, kangaroo numbers should be limited to less than 1.2 kangaroos/hectare, but with some level of grazing maintained to promote the mix of short and tall grass that the Striped Legless Lizard prefers. Although the study was conducted in grasslands grazed by kangaroos in the ACT, the results have implications for management of grazing outside the ACT and for both native and domestic herbivores. The recommendations made in this study for the conservation of the Striped Legless Lizard are likely to benefit a range of grassland species such as the endangered Grassland Earless Dragon.

Other reptile species

A further study (Howland et al. 2014) investigated the effect of kangaroo grazing on reptiles at 18 grassland and grassy woodland sites in the ACT, NSW and Victoria. Ground-dwelling reptiles were chosen to test the effects of grazing as reptiles are known to be sensitive to changes in grass structure. The sites were grazed primarily by kangaroos, covered a range of kangaroo densities (from 0.3 kangaroo/hectare to over 3.0 kangaroo/hectare) and had relatively intact vegetation.

The study found that sites with higher kangaroo densities had less grass than sites with lower kangaroo density. There was a greater abundance of reptiles and a greater number of reptile species in areas with high grass structure and low kangaroo numbers. No species of reptile was more common in areas with low grass structure and high kangaroo numbers. However, not all species favoured the same amount of grass. Legless Lizards were more common in areas with moderate grass, whereas the Eastern Three-toed Skink was more common in areas with high grass. The authors concluded that the best outcome for the conservation of reptiles would be to maintain a mix of moderate and high grass structure within reserves and prevent the formation of low grass structure found under high kangaroo numbers. The results of this study tentatively suggest that kangaroo densities less than 0.5 animals/hectare could benefit a range of reptiles.

Research into reptile abundance (Manning et al. 2013) was undertaken in two endangered Yellow Box – Red Gum grassy woodland sites (Mulligans Flat and Goorooyarroo) over a four year period. This study evaluated the biodiversity effects of adding large tree trunks (at 0, 20 and 40 tonnes/hectare) and reducing kangaroo density from 2.1 to 0.4 kangaroos/hectare. The effect of kangaroo grazing pressure on skinks was found to be dependent on the shrub density. The greatest negative effect of high grazing pressure was on small skinks in high shrub density. The addition of large logs was estimated to be able to fast-track ecosystem restoration processes between 100 and 200 years. Aside from this benefit, the study found all areas treated with timber debris, in presence of high kangaroo grazing pressure, resulted in a small decrease in small skink abundance. Once kangaroos were excluded from the denser woodlands this proved beneficial for skinks.

Impacts on diversity of beetles

A 16 month study (Barton et al. 2011), undertaken in the local Goorooyarroo Nature Reserve, manipulated kangaroo grazing levels to examine the response on beetle populations. Beetles were chosen to test responses to kangaroo grazing due to their potential for rapid response to habitat change. The experiment evaluated the biodiversity effects of adding large tree trunks (at 0, 20 and 40 tonnes/hectare) and reducing kangaroo density from 2.1 to 0.4 kangaroos /hectare.

The main message from the results of this study was that ‘management of appropriate levels of grazing is the key objective for management of plant and insect communities’. In summary, this study found heavy grazing from a high density of kangaroos poses a significant barrier to sites undergoing ecological restoration due to the reduction of herbage mass. In addition the study found that hardwood logs placed in clumps at a certain ratio had a positive effect on beetle diversity. The reduction in grazing was found to have a significant positive effect on both beetle abundance and diversity. The addition of logs somewhat offset the negative impact of grazing by providing refuge for beetles from the impacts of grazing. Rapid response of beetles suggests potential for a positive flow-on effect for other organisms.

This study provided quantitative guidelines for kangaroo densities for the conservation of a native taxon (i.e. beetles), with beetles more abundant and of higher diversity when there were 0.4 kangaroo/ha compared to areas with 2.1 kangaroo/ha.

Impacts on fauna species—summary

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 Government 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 limited stock grazing in particular locations for fire fuel reduction or other specific management objectives, grazing is mainly by kangaroos and rabbits. However, measurements of herbivore offtake by the two species showed that, in the times and places measured, the amount of herbage being removed by rabbits was less than measurement error, and insignificant compared to kangaroos (Fletcher and Wimpenny unpublished data).

The relationships between the habitat requirements of ACT threatened fauna species and kangaroo grazing are summarised in Table 5.

Table 5 Habitat requirements for threatened fauna species in ACT native grassy ecosystems and significance of kangaroo impacts

Habitat requirements for threatened fauna species in ACT native grassy ecosystems and significance of kangaroo impacts		
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 Wallaby Grass and Spear Grass species. 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.
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 Wallaby Grass in the ACT), but has been found to utilise the introduced Chilean Needle Grass when native grasses have been significantly depleted (Braby and Dunford 2006). Wallaby Grass 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.

Species	Habitat requirements	Significance of kangaroo grazing impacts
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 understory. 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 understory 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 understory habitat is a threat and in some important ACT woodlands (e.g. Mulligans Flat) this grazing is mainly by kangaroos. Rabbits are also impacting in some areas.
Brown Treecreeper *(Climacteris picumnus)* (ACT Woodland Strategy, pp. 43–54)	Critical habitat is relatively undisturbed grassy woodland with native understory, especially grasses.	Intensive grazing which reduces the complexity of understory habitat is a threat and in some important ACT woodlands (e.g. Mulligans Flat) this grazing is mainly by kangaroos. Rabbits are also impacting 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 understory and fallen timber that support insects and other invertebrates on which the species feeds.	Intensive grazing which reduces the complexity of understory habitat is a threat and in some important ACT woodlands (e.g. Mulligans Flat) this grazing is mainly by kangaroos. Rabbits are impacting in some areas.
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.

Source ACT Kangaroo Management Plan (ACT Government 2010**)**

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 2007).

3.8.4 Impacts of high density populations of kangaroos on flora species

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 2002).

Uncommon plants living in the grass sward 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 (for example, Kangaroo Grass). 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 (for example, Wallaby Grass, Windmill Grass, Red-leg Grass) are grazing-tolerant and short growing, even when ungrazed (Braid et al. 2008; McIvor 2002).

The relationships between the habitat requirements of ACT threatened flora species and kangaroo grazing are summarised in Table 6.

Table 6 Habitat requirements for threatened flora species in ACT native grassy ecosystems and significance of kangaroo impacts

Habitat requirements for threatened flora species in ACT native grassy ecosystems and significance of kangaroo impacts		
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 (for example, 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, p. 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.
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 two sites 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. One site is protected by a fence.

Species	Habitat requirements	Significance of kangaroo grazing Impacts
Golden Moths (*Diuris pedunculata*) (ACT Grassland Strategy, p.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.

Source ACT Kangaroo Management Plan (ACT Government 2010**)**

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 2007).

3.8.5 Impacts of high density populations of kangaroos on ecosystem function

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.

A grassland flora study undertaken in Mulligans Flat and Goorooyarroo nature reserves established methods and reported baseline conditions for the long term grassy woodland restoration study commenced in 2007. McIntyre et al. (2010) cite the extremely high kangaroo densities in ACT reserves as the highest reported densities of any wild kangaroo populations (higher densities were later reported from Victoria).

The study indicated that herbage mass was consistent with high grazing pressure from the high density of kangaroos. The study concluded that ACT reserves are under extremely high grazing pressure sufficient to affect soil processes and habitat. Continued high levels of grazing may inhibit soil, water and nutrient processes essential for healthy functioning of grassy woodlands (McIntyre et al. 2010).

The study recorded change in the characteristics of ground-layer plants (i.e. herbage mass, plant species diversity, ground-cover attributes and life-form) from 2007 to 2011 in relation to the following experimental interventions: (1) reduced kangaroo density; (2) addition of coarse woody debris; and (3) fire (a single burn) (McIntyre et al. 2015).

McIntyre et al. (2015) found that reducing kangaroo density doubled total herbage mass in one reserve, but had no effect on exotic plant herbage mass, species counts or ground cover attributes. In one of the reserves, coarse woody debris also promoted herbage mass, particularly exotic annual forbs, as well as plant diversity. The single burn reduced herbage mass, but changed little else. The greatest driver of change regardless of treatment was the end of drought conditions in 2009 and several years of good rainfall. This increase in rainfall appears to have resulted in herbage mass increasing by 67% (mostly owing to the growth of perennial native grasses), overall native species counts increasing by 18%, and exotic species declining by 20% over this four year period. They suggest that strategic management of grazing pressure, use of fire where herbage mass has accumulated and placement of coarse woody debris in areas of persistent erosion will contribute to improvements in soil and vegetation condition and gains in biodiversity in the future.

This longer-term study has shown the overriding role of climate in driving plant production in these temperate reserves but, importantly, has shown that management of grazing

pressure, addition of woody debris and fire can all be used to increase recovery rates. These are regarded as key components in ecological restoration.

It is sometimes suggested that grazing in conservation reserves should be undertaken using native herbivores (for example, 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, a key difference between grazing with stock and with kangaroos, from a management perspective, is that stock grazing can be readily controlled to achieve desired ecological outcomes, whereas this cannot be done easily with kangaroos (Lunt 2005).

However the nature of kangaroo grazing has important advantages over domestic grazing as their diet is almost entirely grass (Kirkpatrick 1965, Taylor 1983; Jarman and Phillips 1989), unlike the diets of sheep and cattle. This likely reduces the kangaroos' potential effect on the broad leaved plants which comprise most of the plant biodiversity.

3.9 Economic impacts

The presence of kangaroo populations in the ACT can have both positive and negative economic impacts, which 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. Whilst this Management Plan acknowledges the significant conflict that occurs between kangaroos and vehicles, this is considered primarily a road safety issue and is managed by roads authorities rather than this plan.

3.9.1 Impacts of kangaroos on rural and other lands

There are 150 rural leases in the ACT, covering 39,500 hectares or 17% 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 Non Urban Zones covering landscape setting, ecological integrity, biodiversity conservation, rural productivity and sustainability, land parcel sizes and lease periods. The management of high density populations of kangaroos is essential to retain ecological integrity, rural productivity and sustainable land management.

Key considerations of managing high density populations of kangaroos on rural lands are to reduce competition with domestic stock, manage total grazing pressure and ensure land is managed sustainably. Conservation of kangaroo populations in the ACT is not reliant on rural land, given the relatively large area in conservation reserves that provides extensive habitat for kangaroos.

Kangaroos, including those on rural lands, are protected species under the NC Act. It is illegal to capture, keep or kill a kangaroo on those lands without an authorisation. Therefore rural landholders must apply for an authorisation if they wish to legally shoot kangaroos in order to reduce their impact on rural production.

Competition for domestic stock

Assumed competition for pasture between domestic stock and kangaroos, and the associated response of culling for damage mitigation, has been a constant in rural land management in Australia. Most studies of the issue have been conducted in the arid and semi-arid rangelands (for example Dawson et al. 2004; Witte 2002). In these areas, rainfall, which is unpredictable, is the main factor in pasture condition; 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).

Although 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.

It has been assumed that kangaroos have 70% of the food requirements of sheep (a dry sheep equivalent (DSE) of 0.7; see Glossary) (Olsen and Low 2006). Grigg (2002) suggested that a DSE of 0.15–0.25 would be more realistic. Fletcher (2006a) noted that no single DSE value can well represent 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.

Resilience of kangaroo populations

During the 25 years that kangaroos have been commercially harvested and monitored in eastern Australia, populations, particularly in the rangelands, have undergone huge fluctuations and shown a corresponding capacity for recovery (DEWHA 2013). See Figure 1.

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. This may be explained by the much higher herbage mass in the ACT 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).

Kangaroo population growth rates of up to 40% per annum have been recorded in the ACT (ACT Government 2016a). To hold a kangaroo population with this annual growth at a constant size, approximately 30% have to be culled annually (Hone 2007). If the culling 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 culled.

3.9.2 Impacts of 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 kangaroos, one horse paddock complex in the ACT 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 complexes.

3.9.3 Impacts of collisions between vehicles and kangaroos

The presence of free-ranging kangaroos along roadsides can have an adverse economic impact due to collisions between kangaroos and motor-vehicles (including motorcycles) and accidents derived from collision avoidance. The ACT Government does not cull to address vehicle-kangaroo collisions. It is considered a road safety matter and the Territory has employed methods such as fencing to deter kangaroos from grazing roadsides and crossing roads. Substantial fence structures have been erected along the Majura Parkway and Tuggeranong Parkway and are being considered for other high kangaroo collision 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; good quality roadside herbage (ungrazed by stock and/or green pick after mowing); high speed roads with frequent traffic; the funnelling effect of some roads with central concrete and vegetation barriers; and climatic conditions (for example, drought) that result in kangaroos moving at night into suburban areas to feed.

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 2015, 8 per cent of drivers of ACT-registered cars reported they had collided with a kangaroo in the last three years (Micromex 2015). One third of those drivers reported more than one accident with a kangaroo over that period. Some 27% of residents reported at least one collision in their lifetime (Micromex 2015). The survey indicated that one third of respondents involved in a collision with a kangaroo did not report the accident to any authority (Micromex 2015).

Based on records of ranger attendance at accident sites from 2003 to 2007, collision hotspots within the ACT have been identified. Hotspots were Limestone Ave, Sulwood Drive, William Hovell Drive, Antill St, the former Caswell Drive (now part of Gungahlin Drive Extension), Woodcock Drive, Monaro Highway, 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.

Information and data obtained from NRMA Insurance and AAMI confirm that a high proportion of ACT/NSW 'hit animal' claims relate to the Canberra area. Of 19,000 animal collision reported nationally by AAMI in 2014 (AAMI 2015) some 700 animal related crashes occurred in the ACT region. In recent years, the NRMA has recorded around 600 kangaroo accident claims annually, which is almost 90 per cent of their animal collision claims in the ACT (NRMA 2015). 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).

Collisions often result in costly damage to the vehicle (an average of $4,000 per collision (RACV 2014[3]) and may involve death, trauma and/or injury to the occupants of the vehicle, motorcycle riders and cyclists. 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 (Rowden et al. 2008).

Further detail on the impacts of motor vehicle collisions with kangaroos can be found in the 2010 plan.

[3] In 2014, the RACV in Victoria had 3593 kangaroo-related claims, accounting for $15 million of claims in Victoria averaging $4174 per claim.

3.10 Social impacts

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 beautiful animal to be protected, 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.

The main negative social impacts of high kangaroo densities predominantly relate to road trauma, occasional reported kangaroo 'attacks' and concern 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. It is difficult to estimate the social costs of vehicle collisions with kangaroos.

4 GOALS, PRINCIPLES AND POLICIES

4.1 Introduction

The goals, principles and policies for the management of kangaroos in the ACT are presented below. Except where discussed below they are unchanged from those included in the 2010 plan, which should be referred to for the extensive background information and discussion leading to the expression of these policies.

The primary 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 and primary production.

4.2 Principles

The following principles apply to 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 authorising management actions, 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 conservation 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 are based on scientific knowledge supported by ongoing research, appropriate regulation and monitoring, and codes of practice.

4.2.1 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, the ACT Government has prioritised research which complements work being done interstate and addresses local research needs including kangaroo movements behavior, dart delivery of fertility control, population dynamics and ecological effects of kangaroos on endangered ecological communities. Such research is intended to provide a solid scientific foundation for future management policy.

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.

4.3 Policies

The general policies relating to the management of kangaroos in the ACT are grouped within four categories:

- Kangaroo welfare
- Managing interactions between humans and kangaroos
- Managing kangaroo densities
- Managing captive populations

Area specific management policies are provided in Chapters 5 and 6.

4.3.1 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.

4.3.1 (a) 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' (Visit the ACT Government Environment website Kangaroos page)

4.3.1 (b) Legislation and codes of practice in the ACT

Kangaroo management in the ACT must be undertaken in accordance with the provisions of the *Animal Welfare Act 1992*. 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.

The *Animal Welfare Act 1992* (Part 3) provides for animal welfare standards through ministerial approval of codes of practice for various types of animal use or for different animal species. Codes of practice are generally regarded as the minimum standard that is acceptable for dealing with, or interacting with, an animal. There is one code that applies to kangaroos in the ACT:

- National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes (NRMMC 2008b) – permanently adopted in the ACT from 19 March 2014 (See the legislation register for the Code of Practice)

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 2013). This is notified under the Animal Welfare Act (DI2014–195).

4.3.1 (c) National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes (NRMMC 2008b)

This national code covers circumstances under which kangaroos may be killed for non commercial purposes (for example, conservation culling or euthanasia following injury), and includes specific consideration for euthanasia of pouch young and young at foot.

The ACT has stringent requirements for licensing of non-commercial kangaroo shooting. Kangaroo culling requires a special shooter's permit. Accredited kangaroo shooters are required to pass a marksmanship accuracy test every two years as well as tests on the code of practice and a macropod identification test. Compliance with the code is a requirement for any person authorised to kill kangaroos in the ACT.

The ACT is the only Australian jurisdiction that restricts culling of female kangaroos to a defined season (March–July), timed to minimise the rate shooters will encounter female kangaroos with young in the age of animal welfare concern i.e. between 8 to 12 months of age with high milk demand but sufficiently mobile to escape when the mother is shot. Where young are present, the code of practice states that pouch young and young-at-foot should be humanely killed immediately. Acceptable euthanasia methods are described for three categories: 'small furless pouch young', 'all furred pouch young' and 'young at foot'.

On the basis of research conducted on Tammar Wallabies by Diesch et al. (2010) and on Red Kangaroos by Russell (1973), McLeod and Sharp (2014) conclude that the approximate onset of brain activity in the main harvested species including Eastern Grey Kangaroos occurs when they first start to develop fur which they state to be at approximately 27 weeks of age.

The timing of the culling season may be revised in the future, depending on collection of additional non-selective samples of pouch young. Limited male-only culls may occur on rural leases in spring.

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.

4.3.1 (d) Illegal killing

In the ACT, native animals (including kangaroos) are protected under the NC Act (s. 130). Unless authorised under this plan, a licence 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). It is illegal to kill an animal without an authorisation under this Plan, a Nature Conservation licence or other exception under Chapter 6 of the NC Act.

POLICIES: Humane treatment of wild kangaroos	
Welfare	• Animal welfare, including legislative requirements, is a primary factor in all decisions and actions regarding kangaroo management in the ACT. • Information for the public on kangaroo welfare in the ACT will continue to be provided and made accessible, e.g. at ACT Government shopfronts and on websites.
Shooter's licence	• The special requirements for a kangaroo shooter's licence in the ACT will be maintained.
Culling season	• A kangaroo culling 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 authorisations may be issued outside this season, e.g. small supplementary male-only quotas on rural lands in spring.
Urban wildlife program	• A program that provides advice to the public on 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.
Euthanasia	• Euthanasia of injured kangaroos will be carried out according to the National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes (2014), established guidelines for the management of urban wildlife, and relevant Standard Operating Procedures for staff and contractors of ACT Government.

4.3.1 (e) Keeping of kangaroos by 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 (for example, 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, amounting to many thousands per year, hand rearing of orphaned young has no impact on 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 ACT Wildlife 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 NC Act to keep any kangaroo, including young, for more than 48 hours without a licence.

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 (1982) 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.

In 2011 the ACT Civil and Administrative Tribunal upheld an appeal against an earlier decision not to issue a licence to a group of carers in NSW for the export from the ACT of orphaned kangaroos to be hand reared and released in NSW. The licence for the export of 35 'dependent animals' has been renewed annually since that time. While the Tribunal acknowledged the licence was contrary to the policy applying to rearing and releasing in the ACT it approved the application on the basis inter alia that the kangaroos would be reared and released in NSW. The reasons the application was opposed in the first instance are still current and relate to animal welfare issues and human safety.

POLICY: Keeping of kangaroos by wildlife carers	
Hand-rearing	Licences will not be issued for the hand-rearing of young kangaroos or their release in the ACT. This is: • due to animal welfare concerns and the need for consistent management as kangaroo populations are managed mainly to reduce impacts and there is no need to supplement the population • to reduce the risk of injuries to humans from large male kangaroos that were originally hand-reared.

4.3.1 (f) Translocation

Translocation is the deliberate movement of multiple wild animals for free release away from their original home range. It is mainly used in the management of rare or threatened species and referred to as introduction, re-introduction and supplementation. Translocation has also been advocated by community groups as an alternative to culling, for dealing with excess numbers, particularly when it is frequently suggested that large-scale, successful translocations are being carried out elsewhere.

The ACT Civil and Administrative Tribunal took evidence from several expert witnesses on the matter of translocation of kangaroos in hearing the challenge to the proposed cull in 2014. The Tribunal concluded that "the technical development of translocation or fertility control has not progressed sufficiently at this stage as to allow it to be considered a practical alternative to culling by firearms."

Translocation of kangaroos will not be permitted as a management solution. The primary reasons for not undertaking or licensing large scale translocations of kangaroos in the ACT:

- **Eastern Grey Kangaroos are not a threatened species.** There is no conservation reason for translocating kangaroos because the conservation status of the species is secure. They are abundant across their range in eastern Australia (refer to Section 3.4). Translocation is a technically demanding, labour intensive, expensive activity and, for these reasons, is generally only applied to threatened species programs. Kangaroos are a relatively nervous and excitable species, lightly built for speedy escape from predators, and require expert care to minimise deaths and injuries.

- **Translocation is ineffective for population control.** Translocation is not an effective management technique for reducing populations of kangaroos at a rate faster than their capacity to increase. Large numbers of kangaroos (hundreds or perhaps thousands, depending on the specific site) would need to be translocated annually. At the level of care needed for the species, and the numbers which need to be handled at once for effectiveness, cost and time are prohibitive.

- **Animal welfare.** Translocation has inherent animal welfare concerns. Kangaroos are fast, lightly built animals, prone to bone fractures in legs, feet, nasal bones, tails and necks, dislocated hips and other injuries. They are known to be nervous and excitable in captivity and prone to a range of debilitating or fatal conditions. Substantial suffering is likely without the appropriate expertise, or without substantial funding. Well-meaning attempts in other states to translocate kangaroos have killed a high proportion, even within the first 24 hours.

- **Lack of suitable release sites.** Ecological factors such as the availability of food supply, predators and habitat quality will limit the number of kangaroos that can survive on an area of land. These factors are often hard to identify but are the reason that most proposed sites turn out to be unsuitable when evaluated by qualified ecologists. With much effort being put into annual culling programs to reduce kangaroo populations in the south-east of Australia, rural communities and government agencies alike rarely favour proposals to move excess populations of kangaroos to their land.

POLICY: Translocation of kangaroos	
Translocation of kangaroos	• Based on animal welfare concerns, lack of known conservation benefits, ineffectiveness in reducing large source populations, and the expense and logistical requirements involved, translocation of kangaroos is not considered to be an appropriate management technique for reducing kangaroo numbers. Translocation will not be permitted for such purposes.

4.3.1 (g) Pouch young and 'ghost' populations

The kangaroos counted, included in culling authorisations or shot in the ACT are 'independently mobile kangaroos' comprising young at foot, sub adults and adults. The conviction that a 'ghost population' comprising suckling young at foot kangaroos is orphaned during culling arises because of the mistaken belief that all kangaroos that are shot are adults. Pouch young are not independently mobile and are not counted or shot. The term 'pouch young' refers to a range of stages from tiny furless young that are impossible to detect in kangaroo counts up to large furred young. Kangaroo culling in the ACT is timed for when there are few large pouch young and small young at foot, thereby avoiding creating 'orphans' in the vulnerable 8–12 month age bracket when they are dependent on suckling. Pouch young must be euthanised in accordance with the National Code of Practice (see 4.3.1 (c)).

4.3.2 Managing interactions between humans and kangaroos

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

While there are no reliable data on kangaroo–human confrontations in the ACT, a few incidents have been reported. These are mainly cases related to dog harassment and intervention by the dog owner. Management programs will continue to concentrate on the provision of advice to the community.

POLICY: Interactions between humans and kangaroos	
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.

4.3.3 Managing kangaroo densities

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

Management of kangaroo densities should be based on clear management objectives for the integrity of the ecosystem, kangaroo population data for particular areas and kangaroo welfare concerns. Without these, resources may be expended unnecessarily and other problems created. Two key questions need to be answered before undertaking population management, especially culling, namely:

- Is the density of kangaroos causing environmental, economic or social problems?
- Will intervention, especially by culling, cause other problems? (Kangaroo Advisory Committee 1997)

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.

4.3.3 (a) Methods of Culling

Culling involves the removal of a proportion of an existing animal population and may involve certain parameters (for example, 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.

Shooting

Shooting is recognised by the Australian Government and all state and territory governments as target specific and the most humane way of culling and commercially harvesting kangaroos when 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.

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.

Capture darting and lethal injection

For small populations such as those in fenced enclosures less than 100 hectares in size, capture darting followed by lethal injection is an acceptable and practical culling method when shooting is inappropriate, for example in areas close to residential areas. The kangaroos are rendered unconscious by the dart delivered capture drug and then hand injected with a lethal overdose of anesthetic 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 (Vogelnest & Woods 2008).

Orally ingested poisons

Theoretically, the best way to reduce kangaroo abundance would be to feed a humane toxin to a proportion of the population. However at this stage no known toxin and delivery system meets requirements for safety, animal welfare, and target specificity. Of these three requirements it appears likely the safety and target specificity requirements are the easier to achieve. 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. At this stage the conclusion of the Kangaroo Advisory Committee (1997) remains valid that 'poisons (i.e. able to be delivered by baits) are not a desirable method of reducing kangaroo numbers when more humane, safe and environmentally benign techniques are available'. Future research may identify poisons that satisfy welfare, safety, effectiveness and environmental impact criteria.

Frequency of culls

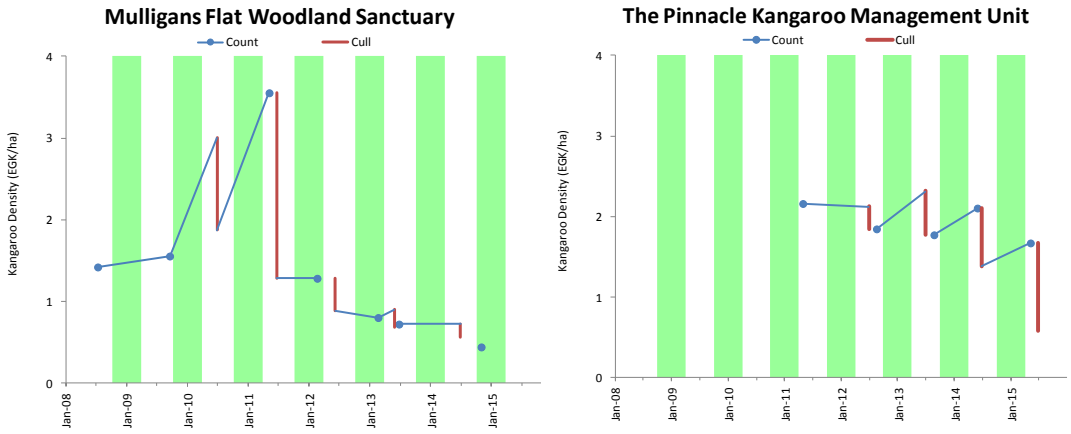
When culling is not carried out annually, the result is that more animals will need to be killed per year on average. This is because populations grow exponentially, meaning the number of new animals added to the population is greater in the subsequent year than the previous year. Thus, to cull less often is worse for animal welfare and impact reduction, and usually costs more.

Size of culled population

If a proposed population reduction (cull) is reduced in number it does not mean that fewer animals will be killed in the long term. Subsequently, a greater number must be killed annually to maintain a population at a larger size, which can quickly outweigh the effect of a smaller initial cull.

This is demonstrated by the experience at two sites in Canberra Nature Park. Figure 3 illustrates a desirable pattern at Mulligans Flat Woodland Sanctuary (on left) which involved a higher initial cull followed by smaller maintenance culls. Culls at the Pinnacle (on right) ended prematurely due to bad weather each year for a few years and little real progress was made, resulting in the killing of more animals overall.

Figure 3 EGK densities and culls on two sites



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

4.3.3 (b) Fertility control

This information on fertility control has been reviewed and updated since appearing in the 2010 plan.

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 large scale control of wild kangaroo populations (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 by reducing the growth rate of the kangaroo populations and reducing the frequency and amount of culling required.

Fertility of 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 remotely, such as in a dart or in food. Population modelling suggests it is also desirable to find methods with an effective life of several years.

The general aim of fertility control is to reduce the population growth rate. This means that lethal interventions would be needed less often. 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 7 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 support for research into kangaroo fertility control methods since 1998, a record unmatched by any other state or territory government. This research has been conducted under cooperative arrangements between ACT Government, the University of Newcastle, CSIRO and the Invasive Animals Cooperative Research Centre (IACRC).

The ACT Government's research investment has focused on immunocontraceptive vaccines, because this method has the potential to be delivered remotely. In trials undertaken in partnership with the University of Newcastle, Eastern Grey Kangaroos were made infertile for at least one year when injected with two doses of a vaccine based on Zona Pellucida (ZP, egg coat) proteins (Kitchener et al. 2009). Despite these promising early results, trials of administering a single dose only failed to cause infertility in a high proportion of treated kangaroos. ACT Government's involvement in ZP vaccine research ended in 2011.

In 2008, the ACT Government partnered with staff from CSIRO (funded by the Invasive Animals CRC) to trial GonaCon Immunocontraceptive Vaccine, a Gonadotrophin Releasing Hormone (GnRH) vaccine that disrupts the hormonal control of reproduction in the brain. A single injection of GonaCon has caused infertility for at least eight years in a high proportion of females treated before they reached sexual maturity (Environment and Planning Directorate 2015, CSIRO and ACT Government unpublished data).

The ACT Government is continuing the collaboration with CSIRO to research the use of GonaCon for kangaroos. The current research is expanding the trial of hand injected GonaCon, this time treating adult females as well as sub-adults, and investigating and trialling a dart delivery method for the vaccine.

Table 7 Summary of macropod fertility control alternatives

SURGERY: Summary Readily available but expensive, invasive, and requires capture and anaesthesia of animals. If vasectomy/castration of males only, then immigration of non sterilised males must be closely monitored and tightly controlled.		
Method	**Estimated effective life**	**Notes**
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 kangaroos.
Tubal ligation of Females	Permanent	Equivalent to vasectomy but requires endoscopic surgery or abdominal incision. Has had limited use.
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), Wilson et al. (2013) and Wilson & Coulson (2016).		
Non-steroidal agents - Deslorelin®/ Suplorelin®	1- 3 years	Non-steroidal contraceptive registered as an off-the-shelf veterinary product. Research at University of New South Wales and University of Melbourne. Retreatment 1-2 years.
Steroidal agents - Levonorgestrel®	3-5 years	Most common form of steroidal contraception used in zoos because of efficiency and low cost. Research at University of Melbourne. Retreatment 3–5 years.
IMMUNOCONTRACEPTIVES (VACCINES): Summary Immunosterilisation or immunocontraception has potential for dart or oral delivery, which makes this approach attractive. A single treatment (injected delivery) with GnRH vaccine, GonaCon, is likely to reduce fertility for several years, dart delivery research is underway.		
ZP (zona pellucida) vaccine	At least 1 year (when 2 doses given)	Potential for future delivery in food. Potential for species specificity. Likely to require second booster shot to be effective. Research by Marsupial Research Laboratory, University of Newcastle.
GnRH vaccine – e.g. GonaCon Immunocontraceptive Vaccine	8 + years (?)	Potential for future delivery in dart or food. Research by Invasive Animals Cooperative Research Centre, CSIRO and ACT Government. Efficacy of dart delivery of GonaCon currently being evaluated by ACT Government and CSIRO.
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.

POLICIES: Fertility control	
Development of fertility control methods	Cooperation between ACT Government and research institutions in the development of fertility control methods for controlling kangaroo populations, especially immunocontraception (vaccines), will be continued. This support may include: • administrative and regulatory arrangements • funding • staff resources • 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.

4.3.3 (c) Environmental modification

The options for controlling kangaroo abundance by modifying environmental conditions (vegetation, availability of water, reintroduction of predators) are very limited in the ACT. The opportunities to reduce available grazing habitat by reintroducing native tree cover are restricted in productive rural lands and inappropriate in protected areas being managed for their grassland values, as in grassland reserves in the ACT. While limiting access to water has been claimed to have the potential to reduce kangaroo abundance, the availability of food rather than water appears to be more significant for kangaroo distribution (Pople and Page 2001 in Olsen and Low 2006) particularly in the ACT and other temperate areas where accessible surface water is rarely more than a kilometre away from most kangaroo populations.

Similarly, it is not practical that predators such as dingoes/wild dogs are reintroduced into reserves bordering the Canberra urban area.

POLICIES: Environmental modification	
Vegetation manipulation	• Vegetation manipulation to influence kangaroo densities will only be considered in areas where this would support the management objectives for the land, particularly 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.

4.3.4 Managing captive populations

Kangaroo populations enclosed behind security fences or specialized animal fences are protected from important mortality factors such as predation and vehicle collisions. In the absence of population controls, their numbers may increase exponentially (herbivore irruption) as has occurred previously at Government House, Royal Canberra Golf Club and Belconnen Naval Transmitting Station. It is important that managers of enclosed populations take responsibility from an early stage for the welfare of the kangaroos and control of their abundance.

However there is a wide variety of enclosed situations. Accepted standards for captive management such as the Australian Animal Welfare Standards and Guidelines for Exhibited Animals are clearly not appropriate to all of them. Beyond a certain size an enclosure has more in common with the wild than with e.g. an urban zoo. The following policy reflects the diversity of situations by distinguishing between enclosures where the managers are responsible for the welfare of the animals in both the short term and long term (e.g. they may provide artificial water or food or control breeding) and larger areas where the kangaroos are more appropriately regarded as falling under the policies applying to wild kangaroos.

Several of the enclosed populations are on National Land or managed by Commonwealth authorities, or both. The NC Act (ACT) binds the Crown in respect to both Commonwealth and ACT governments, i.e. these captive populations are fully included within this policy.

Enclosed kangaroo populations in the ACT include:

(a) small areas in zoos and research facilities (usually less than 20 ha in area) where artificial food or water are likely to be supplied including the Tidbinbilla Nature Reserve enclosures and the National Zoo and Aquarium;

(b) moderately larger fenced areas where there is a more relaxed level of captive kangaroo management (e.g. artificial food is not routinely provided) including enclosed golf courses, Government House (~50 ha), HMAS Harman (~50ha), the Australian National Botanic Gardens (~30 ha), and the telecommunication facility at Bellenden Street, Crace (~20 ha); and

(c) large fenced areas (substantially larger than the home range of a wild kangaroo) where the kangaroos are almost the same as wild populations, including the Belconnen Naval Transmitting Station (116 ha) and the Mulligans Flat Woodland Sanctuary (currently 485 ha and about to be increased).

Some of these enclosures are not complete all the time due to gates which may be left open during the day to admit visitors. However the kangaroos are deemed to be effectively captive. In some cases kangaroos were deliberately enclosed; in others the enclosed kangaroo population arose as a byproduct of fencing for other purposes. The origin of the captive kangaroo population is considered immaterial for the purpose of kangaroo management policy.

Enclosures in categories (a) and (b) above, are deemed to be holding kangaroos captive, and will be subject to the policies in this section. Populations in category (c) will be deemed to be wild populations subject to the policies relating to kangaroos generally.

Developers, lessees or government agencies have a responsibility to manage populations they enclose. Proposals to erect new fences that enclose kangaroo populations should be dealt with at the same time as the statutory planning and development assessment processes to facilitate suitable solutions.

Where captive populations exist, a licence to keep the kangaroos will be required including the condition to prepare and maintain a management plan. There will also be a requirement to maintain abundance mainly by controlling breeding, rather than by culling.

POLICIES: Humane treatment of captive kangaroos	
Licence and management plan	• Maintaining a captive kangaroo population requires: (a) a licence under the *Nature Conservation Act 2014*; and (b) a management plan for the captive population prepared by the licensee and approved by the Conservator of Flora and Fauna.
Management of abundance	• Abundance of category (a) and (b) populations (see text) must be managed mainly by breeding control rather than intermittent culling.
Removal of a captive population	• Removal of a captive population requires: • a licence from the Conservator of Flora and Fauna under the *Nature Conservation Act 2014* • actions to be in accordance with the relevant codes of practice and standards and guidelines. • actions to be in accordance with relevant legislation including the Animal Welfare Act 1992.
Protection of natural and cultural heritage values	• Enclosed populations of kangaroos will be managed 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.

5 MANAGING ENVIRONMENTAL IMPACTS OF KANGAROOS IN GRASSY ECOSYSTEMS

5.1 The conservation culling program in the ACT

From 2009, kangaroo populations in some reserves or future reserves of Canberra Nature Park (CNP) have been reduced by culling for conservation reasons. Culling for grassland conservation was also conducted by the Australian Government in grasslands it manages within the ACT under a licence issued by the ACT Government.

The ACT Government program increased gradually from an initial five reserves and 500 kangaroos (Table 8). As of 2016, 14 of the 39 conservation reserves in Canberra have been included in the culling program at least once. Culling has been maintained (carried out more than once) in 11 of areas.

Most areas included in the conservation culling program contain patches of an endangered ecological community, either Yellow Box-Red Gum Woodland (ACT Government 2004) or Lowland Natural Temperate Grassland (ACT Government 2005), or both. Only one species of kangaroo or wallaby (the Eastern Grey Kangaroo) has been subject to culling licences in the ACT, a circumstance unique among the states and territories. For example, culling licences are issued in surrounding NSW for all the other macropod species still extant in the ACT, Common Wallaroos, Red-necked Wallabies and Swamp Wallabies.

At the commencement of culling, most reserves had a much higher kangaroo population than was ecologically sustainable. Hence the initial population reduction in most of the eleven reserves was expected to be large compared to the later 'annual maintenance' culling. Mulanggari Nature Reserve is an exception that exemplifies the more desirable situation where the kangaroo population was monitored as it increased to a sustainable level after which time it was added to the culling program to maintain this level. After the high kangaroo populations were reduced in an initial set of conservation areas, more conservation areas were progressively added to the conservation culling program without a proportional increase in the number of kangaroos culled (Table 8).

Table 8 Numbers of kangaroos culled for conservation reasons in CNP

Site	2009	2010	2011	2012	2013	2014		2015		2016	
	Independent* males and females culled	Independent* males and females culled	Independent* males and females culled	Independent* males and females culled	Independent* males and females culled	Independent* males and females culled	Pouch young# culled	Independent* males and females culled	Pouch young# culled	Independent* males and females culled	Pouch young# culled
Mt Ainslie/Mt Majura Nature Reserves (added 2016)										461	154
Callum Brae Nature Reserve	140	200	252	100	94	126	45	284	103	0	0
Crace Nature Reserve	42	26	0	0	0	0	0	90	37	0	0
Goorooyaroo Nature Reserve & adjacent unleased land		Combined w MFWS in 2010	843	629	725	663	231	93	36	19	9
Goorooyaroo Nature Reserve AND Mulligans Flat Woodland Sanctuary (added 2010)		1208	Goorooyarroo and MFWS were managed separately after 2010								
Gungaderra Nature Reserve (added to program in 2014)						0	0	486	208	108	48
Jerrabomberra East Nature Reserve	164	removed from program after 2009									
Jerrabomberra West Nature Reserve	73	127	296	0	0	0	0	0	0	0	0
Kama Nature Reserve	75	57	0	0	27	0	0	0	0	0	0
Mt Painter Nature Reserve (added to program in 2010)		221	106	18	0	135	44	110	51	58	19
Mt Mugga Mugga/Isaacs Ridge Nature Reserves (added to program in 2016)										818	403
Mulanggari Nature Reserve					25	82	33	25	8	31	12
Mulligans Flat Woodland Sanctuary (MFWS) (added to program in 2010)		Combined w Goorooyarroo in 2010	942	191	78	249	90	0	0	442	136
The Pinnacle Nature Reserve & adjacent unleased land (added to program in 2012)				104	200	266	117	399	160	52	19
Wanniassa Hills Nature Reserve (added to program 2012)				112	0	0	0	202	98	removed from program	
TOTAL	494	1839	2439	1154	1149	1521	560	1689	701	1989	800

* The kangaroos counted, licenced or shot are 'independently mobile kangaroos' comprising young-at-foot, sub-adults and adults. The myth of a 'ghost population' arises because they are mistakenly considered to all be adults.

Pouch young are not independently mobile. 'Pouch young' refers to tiny furless animals that are impossible to detect in kangaroo counts, as well as large furred young carried in the pouch. Reporting of number of culled pouch young commenced in 2014.

5.2 The purpose of the conservation culling program

The purpose of conservation culling in protected areas in the ACT is to maintain densities of kangaroos at levels that maintain grassland conservation values. In particular the aim is to achieve a grazing regime favourable for the conservation of plants and small animals that frequent the ground-layer vegetation. The phrase 'animals that frequent' is used deliberately to include species, such as some birds, that depend on ground layer vegetation without necessarily being regarded as living in it. It is an important principle that the aim of the culling program is focused primarily on endangered ecosystems rather than individually threatened species.

It is necessary to recognise the aim is to moderate, not minimise, kangaroo grazing effects. The influence of kangaroo grazing is both positive and negative for conservation depending on circumstances. The heterogeneous pasture structure desired for biodiversity conservation does not develop at either extreme of high or low grazing. Although it would be easier and cheaper in the long term for the reserve managers to reduce kangaroo populations to much lower levels (for example, the levels typical on rural properties) or to refrain altogether from culling, these strategies would result in a level of grazing outside the range considered optimal for conservation.

5.3 Grassland target densities

The available research at the inception of the conservation culling program indicated there was a significant increase in herbage mass associated with kangaroo densities below 1.5 per hectare in grassland areas (Fletcher 2006a). The research conducted since 2009 (detailed in section 3.9) will enable further fine tuning for the requirements of each site. Current knowledge indicates that a density of approximately one kangaroo per hectare in grassland is likely to provide the desired conservation environment in average pasture growth conditions for small animals, with the corresponding figures for other vegetation types being inversely proportional to the percentage canopy cover, that is:

- Open woodland – 90% of grassland (0.9 kangaroos per hectare)
- Woodland – 50% of grassland (0.5 kangaroos per hectare)
- Forest/open forest – 10% of grassland (0.1 kangaroos per hectare)

Determination of grassland target densities requires answers from formulas as well as professional judgment. For example, a degraded grassland would recover faster if grazing pressure was kept lower for a few years, whereas a grassland which had grown tall for several years may benefit from more severe grazing pressure for a short time. In a similar way, adjustment for pasture type would be appropriate, providing it is kangaroo specific, as kangaroos have different feeding preferences to livestock. For this reason the target is not the same for all seasons at all sites.

Future improvements are likely to involve the application of different formulas in different sites to allow for differences in environmental variables (for example, rainfall, pasture type) or to manage habitat for specific species. For example, monitoring suggests that in some wet years the above formula can result in too much grass for Golden Sun Moths so, if more kangaroos are desirable in reserves prioritised for Golden Sun Moths, refinements will be needed.

5.3.1 Allowing for other forms of herbage mass removal

At times, parts of reserves or whole reserves will be burnt in prescribed burns or wild fires, or livestock will be used to achieve certain conservation effects or to reduce fire. Some areas may be slashed for similar reasons. Kangaroo management and other methods of managing herbage mass must be integrated. For example, the temporary addition of livestock may require prior consideration of a temporary reduction in kangaroo abundance to avoid excessive grazing pressure. Communication between the relevant land managers is essential to achieve this.

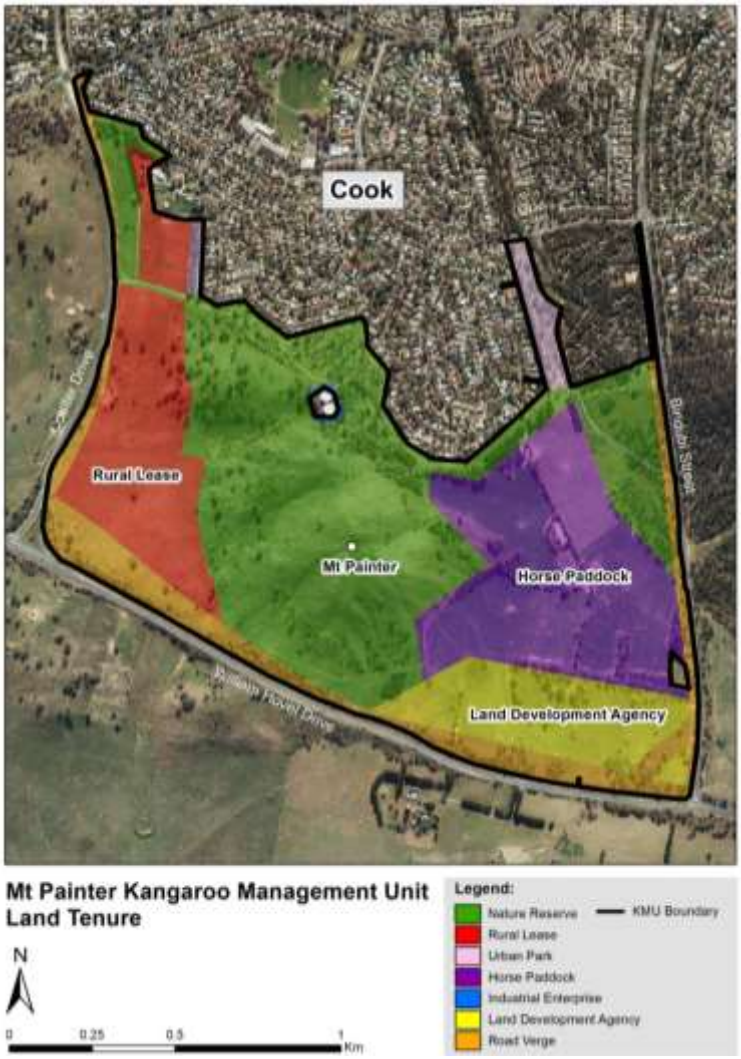
5.3.2 Kangaroo Management Units

While land management boundaries such as nature reserves or rural leases can usually be readily defined on the ground, the land areas called Kangaroo Management Units (KMU) are used for the calculation of kangaroo populations in the ACT. This recognises that while kangaroos occupy surprisingly small home ranges for species of their size and mobility—typically 1 square kilometre for males and half to three quarters of this for females (Fletcher and Wimpenny unpublished data)—even these small home ranges are so large that a significant proportion will straddle the boundary between the reserve and adjoining open space areas such as rural properties, horse agistment paddocks or golf courses. During counting or culling activities, much of the kangaroo population can appear to move between the nature reserve and the adjoining areas to avoid the people doing the counting/culling. Another effect is that a count of the kangaroo population on only one of the component land areas used by the population will vary between days and hence is relatively unreliable compared to an estimate of abundance over a larger area bounded by features which discourage kangaroo movement. In such cases it is usually more appropriate, as well as more efficient, to define a biologically meaningful area in which to measure kangaroo abundance, rather than providing a measurement for the nature reserve only.

In these cases the population in a defined KMU is counted, preferably in an area bounded by high speed roads and the suburban edge or other features known to inhibit kangaroo movement (Fletcher and Wimpenny unpublished data). Whereas kangaroos may move readily between the component areas of the KMU, they move much less readily to adjoining KMUs. As described in 'Calculation of the Number of Kangaroos to Cull' (ACT Government 2016a), each KMU includes at least one nature reserve and some contiguous open space land, such as the example in Figure 4.Figure 4

A KMU is a 'nil tenure' approach to management in which there should be cooperative decision making and shared action by the group of landholders who manage each KMU. However for legal reasons, culling authorisations can be issued only for the individual components. Therefore it is necessary to artificially subdivide the counted KMU kangaroo population (and the culling allocation) between the component land tenures. However the areas used in calculations of population density and number to cull includes areas to which the kangaroo population has ready access without crossing roads, including road verges and other urban open space.

Figure 4 Example of a Kangaroo Management Unit, showing multiple land tenures.
The Mt Painter Kangaroo Management Unit (KMU) is bounded by suburbs and three high speed roads (≥ 80kph). It comprises a number of land tenures separated by stock fences, all of which are inhabited by the one kangaroo population.



5.4 Area specific management policies

Unlike other Australian jurisdictions, the ACT has no freehold land and the ACT Government retains a strong interest in all land management, be it extensive national parks (for example Namadgi National Park which, at 106,095 hectares, represents 46% of the ACT), rural land (39,500 hectares or 17% of the ACT) or small areas of unleased land in the urban area.

Australian Government authorities in the ACT are in a position that is exceptional nationally, in that while they are bound by the *ACT Nature Conservation Act* (2014), they are not bound by all ACT laws. Thus culls on National Land by Commonwealth agencies, such as in the Majura Training Area, a 44 square kilometre military area used for live fire training, have been subject to licences issued by ACT Government and would be subject to authorisation under this plan in the future.

Since the mid 1990s, the ACT Government has given specific attention 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. Most contain populations of threatened species,

which are grassland specialists (for example, Grassland Earless Dragon, Striped Legless Lizard). The grassland nature reserves are all categorised as Conservation Significance Category 1 sites due to their high ecological condition or presence of key threatened species habitat (ACT Government 2016b).

5.4.1 Public Land

Public Land 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)*. Areas of Public Land include:

- the network of reserves that make up Canberra Nature Park, 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 2010 plan describes the differences in ecosystem function between lowland grasslands in Canberra Nature Park and those grasslands at higher altitudes in the west and south of the ACT (Namadgi National Park, Tidbinbilla Nature Reserve and the Lower Cotter Catchment). These differences manifest in the different approaches to kangaroo management presented in the following tables.

Lowland native grassy ecosystems

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: Lowland native grassland and grassy woodland	
All Public Land locations	• To assist management decisions, ongoing improvements will be made to the ecological model for the interaction between kangaroos and vegetation. • Long-term monitoring of lowland grassy ecosystems will be undertaken, including 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 target densities. • 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 kangaroo population in the fenced 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.

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: Grasslands in the western and southern ACT	
Namadgi National Park	• Kangaroos are an integral part of the fauna of Namadgi National Park. 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 kangaroos, and the management of kangaroo populations. • Should seasonal conditions and food shortages result in starving kangaroos, euthanasia of animals may be undertaken, particularly 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 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.

5.4.2 National Land

Objective: National	• 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.

National Land areas contain some of the most significant native grassy ecosystems in the Territory. These areas are managed by Commonwealth Government agencies for diverse purposes and include grasslands categorized as Conservation Significance Category 1 sites (ACT Government 2016b) and important areas of lowland woodland. Kangaroo grazing impacts on native grassy ecosystems have been most evident at the Department of Defence site at Majura Training Area (MTA). Memoranda of Understanding (MOU) 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 the Environment has recommended that the MOU with the Department of Defence be reviewed and updated (ACT Commissioner for Sustainability and the Environment 2008).

Primary management objectives for these areas relate to their Commonwealth use. Commonwealth departments and agencies managing National Land have environmental responsibilities under both the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) and the NC Act (ACT). 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 i.e. to maintain grassland target densities.

POLICIES: National Land	
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.

5.4.3 Greenfield development sites

Individual kangaroo populations in Canberra usually exhibit strong fidelity to their home range (Fletcher and Wimpenny unpublished data). There have been instances of urban development (for example, the suburb of Lawson in Belconnen) where the grazing area available to the long-term resident kangaroo population has been greatly reduced. This can impact on both kangaroo welfare and grassland conservation values. Managing kangaroo welfare should be a component of the development plan for future sites including consideration of culling where it is preferable to having kangaroos subject to trauma such as road collisions, dog attacks and starvation.

POLICIES: Greenfield development sites	
Greenfield sites adjoining high conservation grasslands	• Managing kangaroo welfare will be included in initial planning for development sites. • Kangaroo populations will be managed to achieve grassland target densities.
Other greenfield development sites	• Kangaroo populations will be managed to achieve the best welfare outcome for the kangaroos.

5.4.4 Other land

There are areas of land in the ACT other than those that have already been addressed that sustain kangaroo populations. They include unleased unreserved areas, areas slated for development but not currently grazed by domestic stock, areas available for agistment licences (91 blocks totaling 9758 hectares) and roadsides (discussed further at 5.4). Where appropriate these areas will be included in kangaroo management units (KMU – see 4.3.3(b)). Otherwise management of kangaroos in these areas will be consistent with the management objectives for the area.

POLICIES: Agisted or unleased sites	
Unreserved sites containing high conservation grasslands or within KMUs	• Kangaroo populations will be managed to achieve grassland target densities.
Other unreserved sites with low conservation value e.g. agisted land or roadsides	• Kangaroo populations will be managed to achieve the management objectives for the site and to achieve the best welfare outcome for the kangaroos.

6 MANAGING ECONOMIC AND SOCIAL IMPACTS OF FREE RANGING KANGAROOS

6.1 Kangaroo management on 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.

The background to management of kangaroos on rural lands in the ACT is provided in the 2010 plan (ACT Government 2010).

The key elements underpinning the policies below are:

- Land Management Agreements (LMAs) have been established that apply the 'total grazing pressure' concept as the basis for managing grazing on rural lands. This allows for the grazing pressure of all vertebrate herbivores, including livestock, kangaroos and feral animals, to be considered when making decisions about grazing management.
- 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 (for example, Tidbinbilla). Such fencing is successful in controlling kangaroo movements, depending upon its design, maintenance and the density of kangaroo populations.
- Property management factors: Rural lessees applying for a culling authorisation are required to provide evidence pertaining to total grazing pressure and other property management factors. This is included in each LMA.
- Kangaroo culling season: The ACT is the only state or territory to designate a culling 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 culling 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 2007).
- Regulation: Kangaroo culling on rural leases has been structured through a licensing system that provides for an authorisation to shoot a specified number of kangaroos on an identified property, a numbered tag system for kangaroo carcasses, 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 kangaroo shooters undertaking non-commercial culling to obtain a kangaroo culling permit and to pass a shooter accreditation test every two years. Elsewhere the accuracy test is only required for shooters in the commercial harvesting industry.
- Cull numbers and culling intensity: The concept of 'total grazing pressure' has been used as the conceptual framework for determining suitable kangaroo densities on ACT rural lands. The number of kangaroos licensed to be culled each year since the licensing arrangement was established is shown in Table 9.

Table 9 Licensed kangaroo culling statistics for ACT rural lands 1997–2015

Year	Number of properties licensed	Number of kangaroos licensed to be shot	Number of kangaroos reported culled
1997	14	2966	1443
1998	35	5291	4011
1999	25	3638	2593
2000	25	3514	2961
2001	28	3316	2419
2002	36	4178	2921
2003	36	3745	2493
2004	31	3812	3218
2005	42	5170	3162
2006	34	4424	2151
2007	31	4178	3384
2008	48	7212	6193
2009	55	6967	5746
2010	57	7179	5367
2011	60	14030	9381
2012	42	10153	6222
2013	65	17638	11477
2014	66	19898	10808
2015	80	20722	11130

6.1.1 Kangaroo movement between government managed land and rural leases

Where there is clear evidence of either a net flow of kangaroos from government managed land (for example, 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 and Conservation Service) 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 Controlled Native Species Management Plan
- the proposed actions (and alternative options) are properly evaluated to ensure they will meet the objectives and are cost-effective.

POLICIES: Kangaroos on rural lands	
Total grazing pressure	• The total grazing pressure concept is used as the conceptual framework for managing grazing by all vertebrate herbivores (including livestock, kangaroos and feral animals) on ACT rural lands, with this continuing to be incorporated into Land Management Agreements. • Authorisation of rural culling will be directed towards reducing kangaroo grazing impact and achieving long-term sustainable densities.
Animal welfare	• The National Code of Practice for the Humane Shooting of Kangaroos and Wallabies for Non-commercial Purposes will apply to culling on rural lands. • The designation of a kangaroo cullingseason and strict requirements for obtaining and renewing a shooter's authorisation will be maintained. • Where the need can be justified, limited male-only culls may be permitted in individual leases in spring.
Records	• Authorisation holders are required to submit annual returns on the numbers of kangaroos culled. 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.

6.2 Kangaroo management on 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.

Privately owned horse agistment properties are covered by the provisions of this plan relating to rural properties. In addition to the privately managed premises, there are 17 ACT Government owned horse agistment complexes (1038 hectares in total), many close to suburbs, that are highly valued by horse owners. The ACT Government employs a contractor to manage these areas. Thus, for the purposes of this plan, the government horse paddocks are treated in the same way as other land used for rural production. All 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.

Prior to 2010 there was a practice of considering kangaroo management in the horse paddocks to be analogous to kangaroo management in nature conservation areas. The 2010 plan recommended that kangaroo management within government owned horse holding complexes should 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 reduces rural production (the same as on rural leases). The main challenge is to keep kangaroos from grazing at night in paddocks that are being spelled from horse grazing at the time.

An authorisation can be issued to shoot a set number of kangaroos under the same stringent conditions as on other rural properties where firearms safety conditions can be met. In future, those tendering for the horse paddock management contract should be encouraged to take account of the cost of kangaroo management.

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 is not clear whether the fences trialed were of the best possible design and construction for the purpose.

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 using motorbikes to occasionally herd them out of areas surrounded by leaky fences, and occasional shooting.

POLICIES: Government horse paddocks	
Total grazing pressure	• The total grazing pressure concept is used as the conceptual framework for managing grazing by all vertebrate herbivores (including horses, kangaroos and feral animals) 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.

6.3 Commercial kangaroo harvesting and utilisation of carcasses

Commercial harvesting of kangaroos is the killing of kangaroos for sale of products (meat and skins) as opposed to 'damage mitigation culling' or 'conservation culling' which are intended to limit the effect of kangaroo grazing to an acceptable level. The latter two may involve using carcasses (for example, as pet meat as is being trialled with damage mitigation culling in Victoria or to supply baits for wild dog and fox control after conservation culling in the ACT) but commercial end use is not the reason for killing in either case.

The dynamics of the herbivore–pasture system in semi-arid Australia is such that the kangaroos make little difference to the amount of pasture (Caughley 1989) so harvesting on a sustainable yield basis is preferred. Commercial harvesting has occurred in temperate areas for more than ten years (and occurred in the rangelands much earlier). This was partly because those areas have the highest densities of kangaroos and partly because the development of counting methods allowed kangaroo populations to be accurately counted in the steeper, more wooded areas with small-scale patchiness in their vegetation. In temperate grasslands, kangaroo–pasture dynamics differ significantly (Fletcher 2006b). Damage mitigation makes sense in temperate areas where kangaroo populations potentially consume a high proportion of herbage mass. There is potential for a dilemma between goals. Optimising the cull for damage mitigation requires kangaroo reductions that are far from optimal for commercial harvesting and commercial harvesting alone is unlikely to satisfy demands for damage mitigation.

The commercial harvests are controlled by state governments in Queensland, NSW, Western Australia and South Australia (wallaby harvests in Tasmania are excluded from this discussion). The Commonwealth Government controls the export of harvested products

(EPBC Act) and thereby requires each state to meet certain standards, including obtaining Commonwealth approval biennially of their macropod harvesting plan, and meeting agreed population monitoring requirements. Annual quotas are set for each of the four species which may be taken in each region of the state based on the population assessments and knowledge of kangaroo population dynamics. However, the overall numbers that are shot is actually driven by the market for kangaroo meat and skins, and is usually well below the quotas.

Significant impediments would need to be overcome for the ACT to enter the commercial harvesting system and it has not been established that the advantages to landholders or government would be significant. An alternative that appeals to many people is to use the carcasses that result from damage mitigation culling and conservation culling. This is referred to as 'carcass utilisation'.

The Victorian Government, like the ACT, has no commercial harvesting but has commenced a four-year trial of carcass utilisation. While landholders are permitted to sell their carcasses to kangaroo processors for pet meat production, export is not permitted.

The 2010 plan considered the question of commercial kangaroo harvesting in the ACT and confirmed the earlier view of the Kangaroo Advisory Committee (1997) that a commercial harvesting operation would not be pursued in the ACT in the foreseeable future. It was concluded that 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. It was also noted that market demand is being met by existing operations in other states particularly in the South-East NSW Commercial Zone which surrounds the ACT.

The New South Wales Commercial Kangaroo Harvest Management Plan 2012–2016: 2016 Quota Report (NSW OEH 2015) gives details of the quotas for the 2016 kangaroo harvest in accordance with the NSW Commercial Kangaroo Harvest Management Plan 2012–2016 (NSW OEH 2011). In 2016, the South-East NSW Commercial Zone annual quota was 192,645 Eastern Grey Kangaroos, which is 15% of an estimated population of 1,284,300 derived from aerial surveys in 2015. The state-wide quota for Eastern Grey Kangaroos in commercial zones in NSW in 2016 was 1,322,788 out of an estimated statewide population of 5.5 million (NSW OEH 2016). The number of kangaroos culled annually in the ACT is small by comparison (seeTable 9).

Currently the only situations where carcasses of kangaroos culled in the ACT are utilised are those shot during the ACT Government conservation culling program. The meat from some of these carcasses is used for the production of baits used in land management programs, such as wild dog and fox control programs. Where possible, carcasses resulting from culling programs conducted in the ACT will continue to be used for making baits. Any future proposals for the utilisation of carcasses shot during culling programs in the ACT will be considered by the government on a case-by-case basis.

Commercial harvest	• The establishment of a commercial kangaroo harvesting operation will not be pursued in the ACT in the foreseeable future. • Any future decision to introduce commercial kangaroo harvesting in the ACT would need to be based on a rigorous analysis of costs and benefits, independently reviewed.
Utilisation of carcasses	• Carcasses resulting from the culling programs conducted in the ACT will be used where possible for production of baits used in land management programs. • Any future proposals for the utilisation of carcasses resulting from culling programs in the ACT will be considered by the government on a case-by-case basis.

6.4 Vehicle collisions and collision avoidance

Objective: Vehicle-kangaroo collisions	• The incidence of vehicle-kangaroo collisions in the ACT is reduced.

The 2010 plan can be referred to for a comprehensive discussion on aspects of vehicle collisions with kangaroos. Sections 3.9.3 and 3.10 of this plan discuss the economic and social impacts of collisions with kangaroos. The ACT Government does not cull to address vehicle-kangaroo collisions. The potential for vehicle-kangaroo collisions is recognised as a management issue and areas of concern are being addressed through fencing as has been undertaken along the Tuggeranong Parkway, sections of the Gungahlin Drive Extension and Majura Parkway. Attributes to reduce the incidence of vehicle-kangaroo collisions are considered in the design of new or upgraded major urban arterial roads (see road safety policy box).

Table 10 is a summary of potential interventions to manage conflicts between vehicles and kangaroos in the ACT.

Table 10 Potential intervention actions to manage conflicts between vehicles and kangaroos

Type of intervention	Current assessment of expected practicality/effectiveness
Attributes of the road	
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.
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.
Overpasses	Less suited to the ACT due to lack of hilly terrain where major roads are constructed. High cost of construction and maintenance.

Attributes of the road	
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	
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.
Ultrasonic devices fitted to vehicles	Research has failed to demonstrate effectiveness. Impractical unless shown to be effective.
Modifying driver behaviour	
Education and awareness campaigns	Have been undertaken, though results in terms of collision reduction are uncertain. Periodic driver awareness programs are appropriate.
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.
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	
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.
Vehicle driving lights	Not suitable for urban areas. Professional drivers suggest effectiveness outside the urban area (Magnus 2006).
Culling in habitat areas adjoining high speed roads	The ACT Government does not cull to address vehicle-kangaroo collisions. This action is likely to be ineffective at a localised scale (e.g. 200 metres 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).
Improvements to car design	Several manufacturers are developing automated avoidance systems to be fitted to vehicles.

Modifying attributes of the road

Of the potential interventions shown above, the only measures taken in the ACT since 2010 involve construction of fencing and under passes along high speed roads. These were installed as part of the construction of the Gungahlin Drive Extension and Majura Parkway. Fencing was installed in 2016 along Tuggeranong Parkway. These present opportunities to monitor the success of such measures. Even in the absence of results, where kangaroo movement corridors are involved and the terrain and road design are compatible, underpasses and fencing should be incorporated in road design from the outset. However 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. Together with other information, this would enable a predictive model to be developed for new roads showing zones of high collision risk, where mitigation measures such as fences and underpasses could be deployed.

Modifying animal behaviour

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 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 below 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.

Modifying driver behaviour

Education campaigns aimed at modifying driver behaviour are probably the most practical intervention action to manage conflict between kangaroos and vehicles. 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 Australian metropolitan 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.

POLICIES: Road safety	
Modifying attributes of the road	• Inclusion of road attributes that 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 be sought with other interested organisations for such campaigns.

Social impacts of collisions between kangaroos and motor vehicles

The significant social impacts of high kangaroo populations and densities predominantly relate to road accident trauma. The social impacts of kangaroo populations are taken into consideration in authorising management actions, particularly in relation to free-ranging kangaroo populations on rural lands and along roadsides.

Inevitably, high kangaroo populations throughout the ACT will result in economic and social impacts and some residents will be affected more than others. There will always be a cost associated with maintaining large kangaroo populations, particularly in the lower elevation grassy areas close to suburbs. The 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'.

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 measure the abundance of kangaroo populations. First, a common misunderstanding must be dispelled. Whereas a dairy farmer can literally count every cow 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 because in reality the exact number of most wildlife populations is unknowable.

Ecologists estimate the population size or more commonly the density (number per square kilometre, see **Glossary**) of a population within statistical limits of precision (also called 'error') such as '+ or - 10% Standard Error'. 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, which in some cases introduces a further source of uncertainty.

However there are exceptions. Entire kangaroo populations in some small reserves in Canberra are literally counted individually using Direct Counts and Sweep Counts described below. In these cases there is still some uncertainty (error) but it is usually small. Results of these total counts are usually stated as the mean of two to four iterations of the count.

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. The four common species of kangaroos have been said to be probably the most-counted abundant wildlife in the world and there are several counting methods in use.

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.

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 transects. Strip counts are not applicable in the ACT due to its small area and localised high density kangaroo populations.

Direct 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 independent counts over a few days produce close results. Applicable sites include Crace and Mulanggari Grasslands Nature Reserves.

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. 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 nocturnal line transect counts which were much faster and cheaper. Many of the small reserves in Canberra are well suited to sweep counts and the method has developed significantly over the years. All examples now involve people moving inward from opposite sides and measures to deter kangaroos from leaving the area by crossing nearby roads. Larger areas can be attempted successfully due to use of two-way radios and GPS tracking to follow participants on a map.

Distance Sampling refers to a group of methods, of which only the 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 combined displacements on all transects, 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 the Ruwpa website.

Estimates of kangaroo density are made by **Helicopter Line Transect** every three years in the rural areas within the 39,000 sq km NSW South-East Kangaroo Management Zone (Cairns 2004; Payne 2007). 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), at night Fletcher (2006a) or from first light until kangaroos begin lying down (Conservation Research Technical Reports).

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 advantage of pellet counts in that they measure average abundance over a period of weeks whereas all other methods depend on the kangaroos being seen and recorded. The requirement to clear plots of pellets a few weeks before counting makes this method tedious and, therefore, unpopular with many researchers. There is also a risk that heavy rain washes pellets across the ground meaning the work has to start again and the initial cost of clearing the plots is wasted. 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.

APPENDIX 2: KANGAROO DENSITY ESTIMATES SINCE 2010

Methods used to estimate kangaroo densities are explained in Appendix 1.

Location	Date	Count Method	Kangaroo density (EGK/ha)	Kangaroo density SE	Population estimate	Who estimated
Aranda Bushland KMU	Winter 2010	Sweep Count: 1 component count(s)	1.29	NA	196	ACT Gov + Parkcare
Aranda Snowgums area	Spring 2013	Sweep Count: 1 component count(s)	A.N.D	NA	184	Parkcare
Australian National Botanic Gardens	Autumn 2015	Direct Count: 4 component count(s)	0.44	0.04	19	ACT Gov
Australian National Botanic Gardens	Spring 2015	Sweep Count: 3 component count(s)	0.55	0.08	23	ACT Gov
Callum Brae ext. KMU (incl. Jerra W, Isaacs, Mugga)	Spring 2013	Walked Line Transect	1.17	0.09	2374	ACT Gov
Callum Brae Nature Reserve	Autumn 2011	Pellet Count	2.94	0.41	421	ACT Gov
Callum Brae Nature Reserve	Summer 2012	Driven Line Transect	1.70	0.29	243	ACT Gov
Callum Brae Nature Reserve	Summer 2013	Walked Line Transect	1.76	0.20	252	ACT Gov
Callum Brae Nature Reserve	Winter 2014	Walked Line Transect	2.56	0.35	367	ACT Gov
Callum Brae Nature Reserve	Autumn 2015	Walked Line Transect	2.00	0.36	283	ACT Gov
Campbell Park Grasslands	Summer 2012	Pellet Count	1.94	0.48	A.N.D	ACT Gov
Campbell Park Grasslands	Summer 2014	Pellet Count	2.91	0.91	A.N.D	ACT Gov
Crace KMU	Summer 2012	Direct Count: 2 component count(s)	0.70	0.01	132	ACT Gov
Crace KMU	Autumn 2013	Direct Count: 2 component count(s)	0.77	0.00	146	ACT Gov
Crace KMU	Spring 2013	Direct Count: 1 component count(s)	1.01	NA	191	ACT Gov
Crace KMU	Winter 2014	Direct Count: 2 component count(s)	1.37	0.05	226	ACT Gov
Crace KMU	Spring 2014	Direct Count: 4 component count(s)	1.43	0.05	235	ACT Gov
Crace KMU	Autumn 2015	Direct Count: 2 component count(s)	1.51	0.02	249	ACT Gov
Dunlop Nature Reserve + Spine	Summer 2008	Direct Count: 2 component count(s)	0.60	0.07	63	ACT Gov
Dunlop Nature Reserve + Spine	Summer 2013	Direct Count: 2 component count(s)	0.57	0.04	54	ACT Gov
Dunlop Nature Reserve + Spine	Summer 2013	Direct Count: 1 component count(s)	0.83	NA	78	ACT Gov
Farrer Ridge KMU	Autumn 2011	Sweep Count: 2 component count(s)	3.07	0.00	517	ACT Gov + Parkcare
Farrer Ridge KMU	Summer 2012	Driven Line Transect	2.48	0.58	500	ACT Gov
Farrer Ridge KMU	Autumn 2012	Sweep Count: 1 component count(s)	2.53	NA	512	ACT Gov + Parkcare
Farrer Ridge KMU	Spring 2013	Walked Line Transect	2.46	0.22	496	ACT Gov
Farrer Ridge KMU	Spring 2013	Sweep Count: 2 component count(s)	2.62	0.13	530	ACT Gov + Parkcare
Farrer Ridge KMU	Winter 2014	Walked Line Transect	2.23	0.24	451	ACT Gov
Farrer Ridge KMU	Spring 2014	Pellet Count	2.72	0.40	549	ACT Gov
Farrer Ridge KMU	Spring 2014	Sweep Count: 4 component count(s)	2.54	0.03	514	ACT Gov + Parkcare
Farrer Ridge KMU	Autumn 2015	Walked Line Transect	3.40	0.28	682	ACT Gov
Googong Foreshores KMU	Winter 2011	Pellet Count	2.92	0.33	1920	ACT Gov
Googong Foreshores KMU	Winter 2013	Walked Line Transect	2.55	0.22	1715	ACT Gov
Googong Foreshores KMU	Spring 2014	Walked Line Transect	3.04	0.29	2044	ACT Gov
Googong Foreshores KMU	Autumn 2015	Walked Line Transect	2.50	0.33	1710	ACT Gov
Goorooyarroo Nature Reserve	Autumn 2011	Pellet Count	1.99	0.33	1488	ACT Gov + ANU
Goorooyarroo Nature Reserve - excluding exclosures	Winter 2010	Pellet Count	3.20	0.56	2055	ANU
Goorooyarroo Nature Reserve - excluding exclosures	Summer 2012	Driven Line Transect	1.99	0.34	1149	ACT Gov
Goorooyarroo Nature Reserve - excluding exclosures	Summer 2013	Walked Line Transect	2.08	0.38	1145	ACT Gov
Goorooyarroo - Dunnarts Flat Exclosure	Autumn 2013	Sweep Count: 1 component count(s)	1.67	NA	189	ACT Gov
Goorooyarroo - Dunnarts Flat Exclosure	Spring 2014	Pellet Count	0.28	0.07	32	ACT Gov
Goorooyarroo - Dunnarts Flat Exclosure	Spring 2014	Sweep Count: 4 component count(s)	0.83	0.03	93	ACT Gov
Goorooyarroo - Dunnarts Flat Exclosure	Spring 2014	Sweep Count: 2 component count(s)	0.99	0.04	111	ACT Gov
Goorooyarroo - Dunnarts Flat Exclosure	Autumn 2015	Sweep Count: 2 component count(s)	0.77	0.02	87	ACT Gov
Goorooyarroo - Forest Exclosure	Autumn 2013	Sweep Count: 2 component count(s)	1.05	0.01	40	ACT Gov
Goorooyarroo - Forest Exclosure	Spring 2014	Sweep Count: 4 component count(s)	0.19	0.00	7	ACT Gov
Goorooyarroo - Forest Exclosure	Autumn 2015	Sweep Count: 2 component count(s)	0.11	0.00	4	ACT Gov
Goorooyarroo - combined exclosures	Autumn 2012	Sweep Count: 1 component count(s)	0.83	NA	126	ACT Gov
Goorooyarroo KMU - excl. exclosures	Winter 2014	Walked Line Transect	0.60	0.09	616	ACT Gov
Goorooyarroo KMU - incl. exclosures	Winter 2013	Walked Line Transect	1.18	0.08	1642	ACT Gov
Goorooyarroo KMU - incl. exclosures	Summer 2013	Walked Line Transect	0.86	0.12	1200	ACT Gov
Goorooyarroo KMU - incl. exclosures	Autumn 2015	Walked Line Transect	0.80	0.18	817	ACT Gov

A.N.D = area not defined

NA - insufficient data to estimate SE

Location	Date	Count Method	Kangaroo density (EGK/ha)	Kangaroo density SE	Population estimate	Who estimated
Gungaderra KMU	Spring 2013	Sweep Count: 2 component count(s)	1.92	0.05	645	ACT Gov
Gungaderra KMU	Winter 2014	Sweep Count: 3 component count(s)	2.18	0.03	747	ACT Gov
Gungaderra KMU	Winter 2014	Walked Line Transect	2.44	0.35	888	ACT Gov
Gungaderra KMU	Spring 2014	Pellet Count	2.17	0.54	742	ACT Gov
Gungaderra KMU	Autumn 2015	Sweep Count: 2 component count(s)	2.24	0.01	765	ACT Gov
Jerrabomberra East Exclosure	Summer 2012	Direct Count: 1 component count(s)	0.00	NA	0	ACT Gov
Jerrabomberra East Exclosure	Winter 2013	Direct Count: 1 component count(s)	0.80	NA	12	ACT Gov
Jerrabomberra East Exclosure	Winter 2013	Pellet Count	0.39	0.12	6	ACT Gov
Jerrabomberra East Exclosure	Winter 2014	Direct Count: 1 component count(s)	0.33	NA	5	ACT Gov
Jerrabomberra East Exclosure	Spring 2014	Direct Count: 4 component count(s)	0.35	0.04	5	ACT Gov
Jerrabomberra East KMU	Spring 2014	Direct Count: 3 component count(s)	6.22	0.17	1450	ACT Gov
Jerrabomberra East KMU	Spring 2014	Walked Line Transect	6.64	0.53	1629	ACT Gov
Jerrabomberra East KMU	Autumn 2015	Direct Count: 2 component count(s)	6.62	0.03	1543	ACT Gov
Jerrabomberra East Nature Reserve	Summer 2012	Pellet Count	3.07	0.65	296	ACT Gov
Jerrabomberra East Nature Reserve	Winter 2013	Pellet Count	5.77	0.86	559	ACT Gov
Jerrabomberra East Nature Reserve	Winter 2014	Direct Count: 2 component count(s)	6.98	0.16	678	ACT Gov
Jerrabomberra East Nature Reserve	Spring 2014	Pellet Count	6.33	1.18	611	ACT Gov
Jerrabomberra East Nature Reserve	Spring 2014	Sweep Count: 3 component count(s)	6.10	0.64	592	ACT Gov
Jerrabomberra West Nature Reserve	Autumn 2011	Pellet Count	2.52	0.08	673	ACT Gov
Jerrabomberra West Nature Reserve - excluding exclosure	Summer 2012	Driven Line Transect	0.12	0.05	27	ACT Gov
Jerrabomberra West Nature Reserve - excluding exclosure	Summer 2013	Walked Line Transect	1.74	1.19	392	ACT Gov
Jerrabomberra West Nature Reserve - excluding exclosure	Summer 2014	Pellet Count	1.62	0.47	809	ACT Gov
Jerrabomberra West Exclosure	Summer 2013	Direct Count: 1 component count(s)	0.33	NA	5	ACT Gov
Kama Nature Reserve	Winter 2011	Pellet Count	1.54	0.75	239	ACT Gov
Kama Nature Reserve	Summer 2012	Driven Line Transect	0.61	0.18	94	ACT Gov
Kama Nature Reserve	Winter 2013	Pellet Count	0.68	0.08	106	ACT Gov
Kama KMU	Summer 2013	Sweep Count: 2 component count(s)	0.43	NA	200	ACT Gov
Lyneham Ridge KMU	Winter 2015	Sweep Count: 3 component count(s)	0.54	0.02	92	ACT Gov
MFWS - including exclosures	Spring 2013	Sweep Count: 2 component count(s)	1.09	0.04	527	ACT Gov + Parkcare
MFWS - including exclosures	Spring 2014	Walked Line Transect	0.44	0.07	213	ACT Gov
MFWS - outside exclosures	Autumn 2011	Sweep Count: 2 component count(s)	3.55	0.25	1253	ACT Gov + ANU
MFWS - outside exclosures	Summer 2012	Driven Line Transect	1.28	0.24	451	ACT Gov
MFWS - outside exclosures	Summer 2013	Walked Line Transect	0.80	0.09	282	ACT Gov
MFWS - outside exclosures	Winter 2013	Walked Line Transect	0.72	0.08	254	ACT Gov
MFWS - outside exclosures	Autumn 2015	Walked Line Transect	1.50	0.18	531	ACT Gov
MFWS - combined exclosures	Autumn 2011	Sweep Count: 1 component count(s)	1.08	NA	142	ACT Gov + ANU
MFWS - combined exclosures	Autumn 2012	Sweep Count: 1 component count(s)	1.01	NA	133	ACT Gov
MFWS - Dam Paddock Exclosure	Autumn 2013	Sweep Count: 2 component count(s)	1.17	0.05	90	ACT Gov
MFWS - Dam Paddock Exclosure	Autumn 2015	Sweep Count: 2 component count(s)	1.15	0.05	89	ACT Gov
MFWS - East Exclosure	Autumn 2015	Sweep Count: 2 component count(s)	0.00	0.00	0	ACT Gov
MFWS - Hatchet Exclosure	Autumn 2013	Sweep Count: 1 component count(s)	0.45	NA	11	ACT Gov
MFWS - Hatchet Exclosure	Autumn 2015	Sweep Count: 1 component count(s)	2.10	NA	51	ACT Gov
MFWS - NE Exclosure	Autumn 2013	Sweep Count: 1 component count(s)	0.53	NA	7	ACT Gov
MFWS - NE Exclosure	Autumn 2015	Sweep Count: 2 component count(s)	0.69	0.00	9	ACT Gov
MFWS - West Exclosure	Autumn 2015	Sweep Count: 2 component count(s)	0.17	0.17	2	ACT Gov
Mt Ainslie Nature Reserve	Autumn 2012	Pellet Count	1.18	0.17	872	ACT Gov
Mt Majura Nature Reserve	Autumn 2012	Pellet Count	1.54	0.23	781	ACT Gov
Mt Majura Nature Reserve + Antil St HP	Spring 2013	Pellet Count	1.02	0.33	598	ACT Gov
Ainslie Majura KMU	Winter 2015	Walked Line Transect	2.10	0.38	4499	ACT Gov

A.N.D = area not defined
NA - insufficient data to estimate SE

Location	Date	Count Method	Kangaroo density (EGK/ha)	Kangaroo density SE	Population estimate	Who estimated
Mt Painter KMU	Autumn 2010	Sector Count: 1 component count(s)	3.16	NA	556	Parkcare
Mt Painter KMU	Winter 2010	Sector Count: 1 component count(s)	2.72	NA	478	Parkcare
Mt Painter KMU	Autumn 2012	Sweep Count: 3 component count(s)	2.34	0.07	492	ACT Gov + Parkcare
Mt Painter KMU	Summer 2013	Sweep Count: 2 component count(s)	2.05	0.03	432	ACT Gov + Parkcare
Mt Painter KMU	Winter 2013	Sweep Count: 2 component count(s)	2.26	0.11	475	ACT Gov + Parkcare
Mt Painter KMU	Winter 2014	Sweep Count: 2 component count(s)	2.27	0.11	477	ACT Gov + Parkcare
Mt Painter KMU	Spring 2014	Sweep Count: 4 component count(s)	1.44	0.13	303	ACT Gov + Parkcare
Mt Painter KMU	Autumn 2015	Sweep Count: 2 component count(s)	1.82	0.02	382	ACT Gov + Parkcare
Mt Taylor KMU	Winter 2010	Direct Count: 1 component count(s)	1.19	NA	407	Parkcare
Mt Taylor KMU	Winter 2013	Direct Count: 1 component count(s)	1.42	NA	483	Parkcare
Mulangarri KMU	Autumn 2011	Direct Count: 3 component count(s)	0.98	0.01	180	ACT Gov
Mulangarri KMU	Summer 2012	Direct Count: 1 component count(s)	0.97	NA	179	ACT Gov
Mulangarri KMU	Summer 2013	Direct Count: 2 component count(s)	1.24	0.00	228	ACT Gov
Mulangarri KMU	Winter 2013	Direct Count: 2 component count(s)	1.37	0.00	252	ACT Gov
Mulangarri KMU	Winter 2014	Direct Count: 4 component count(s)	1.47	0.02	271	ACT Gov
Mulangarri KMU	Spring 2014	Direct Count: 2 component count(s)	1.02	0.04	188	ACT Gov
Mulangarri KMU	Spring 2014	Direct Count: 4 component count(s)	0.90	0.01	165	ACT Gov
Mulangarri KMU	Spring 2014	Pellet Count	1.50	0.38	275	ACT Gov
Mulangarri KMU	Spring 2014	Walked Line Transect	0.93	0.11	168	ACT Gov
Mulangarri KMU	Autumn 2015	Direct Count: 2 component count(s)	1.01	0.02	186	ACT Gov
National Transmission Authority	Summer 2013	Direct Count: 1 component count(s)	1.73	NA	35	ACT Gov
National Transmission Authority	Winter 2013	Direct Count: 1 component count(s)	2.15	NA	43	ACT Gov
National Transmission Authority	Autumn 2015	Direct Count: 2 component count(s)	3.60	0.10	72	ACT Gov
National Transmission Authority	Spring 2015	Direct Count: 1 component count(s)	4.15	NA	83	ACT Gov
North Mitchell Grasslands	Autumn 2015	Direct Count: 1 component count(s)	0.04	NA	1	ACT Gov
North Mitchell Grasslands	Summer 2012	Direct Count: 1 component count(s)	0.04	NA	1	ACT Gov
North Mitchell Grasslands	Winter 2013	Direct Count: 1 component count(s)	0.04	NA	1	ACT Gov
North Weston	Autumn 2015	Sweep Count: 4 component count(s)	2.25	0.14	128	ACT Gov
Queanbeyan Nature Reserve + Poplars	Winter 2014	Direct Count: 2 component count(s)	4.89	0.81	411	ACT Gov
Queanbeyan Nature Reserve + Poplars	Spring 2014	Direct Count: 3 component count(s)	5.11	0.38	429	ACT Gov
Red Hill Nature Reserve	Winter 2010	Sweep Count: 2 component count(s)	1.24	0.05	465	Parkcare
Red Hill (incl. Federal Golf Course)	Autumn 2011	Sweep Count: 1 component count(s)	1.71	NA	701	Parkcare
Red Hill (incl. Federal Golf Course)	Autumn 2012	Sweep Count: 2 component count(s)	2.16	0.06	884	ACT Gov + Parkcare
South Lawson	Spring 2012	Direct Count: 1 component count(s)	0.71	NA	118	ACT Gov
South Lawson	Spring 2014	Direct Count: 1 component count(s)	1.00	NA	166	ACT Gov
The Pinnacle KMU	Autumn 2011	Pellet Count	2.29	0.41	1141	ACT Gov
The Pinnacle KMU	Autumn 2011	Sweep Count: 2 component count(s)	2.16	0.03	773	ACT Gov + Parkcare
The Pinnacle KMU	Summer 2012	Driven Line Transect	1.26	0.60	462	ACT Gov
The Pinnacle KMU	Winter 2012	Sweep Count: 2 component count(s)	1.84	0.03	677	ACT Gov
The Pinnacle KMU	Winter 2013	Sweep Count: 2 component count(s)	1.77	0.05	650	ACT Gov + Parkcare
The Pinnacle KMU	Spring 2013	Walked Line Transect	1.23	0.90	449	ACT Gov
The Pinnacle KMU	Winter 2014	Sweep Count: 2 component count(s)	2.10	0.02	772	ACT Gov + Parkcare
The Pinnacle KMU	Autumn 2015	Sweep Count: 2 component count(s)	1.67	0.07	613	ACT Gov + Parkcare
University of Canberra	Autumn 2015	Direct Count: 4 component count(s)	0.70	0.03	68	ACT Gov
Wanniassa Hills Nature Reserve	Summer 2012	Driven Line Transect	1.24	0.60	332	ACT Gov
Wanniassa Hills Nature Reserve	Summer 2013	Walked Line Transect	4.23	1.55	1133	ACT Gov
Wanniassa Hills KMU	Summer 2013	Walked Line Transect	3.53	0.28	1760	ACT Gov
Wanniassa Hills KMU	Autumn 2013	Walked Line Transect	3.62	0.30	1803	ACT Gov
Wanniassa Hills KMU	Spring 2014	Pellet Count	1.57	0.46	784	ACT Gov
Wanniassa Hills KMU	Spring 2014	Walked Line Transect	2.35	0.36	1167	ACT Gov
Wanniassa Hills KMU	Autumn 2015	Walked Line Transect	3.20	0.46	1572	ACT Gov
Weston Park	Autumn 2015	Direct Count: 1 component count(s)	1.44	NA	75	ACT Gov
Weston Park	Spring 2015	Direct Count: 3 component count(s)	1.38	0.07	72	ACT Gov

GLOSSARY

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**.

Biomass

Biomass is the dried weight of living material. It is commonly used with a qualifying term to refer to components, as in 'herbivore biomass'. However, biomass is often used to refer to herbage mass.

Biota

Biota is a term for all the animal and plant life of a region or area.

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.

A.N.D = area not defined

NA - insufficient data to estimate SE

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.

Forb

A forb is a herbaceous (non-woody) plant that is not a grass (Scarlett et al. 1992).

Herbage mass

Herbage mass is synonymous with what agronomists call yield, and is defined as the grazable above-ground component of the pasture, including both dead and living plant parts.

Pasture

Pasture is ground layer vegetation potentially or actually subject to grazing.

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).

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).

Restoration

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 reintroduction of species or habitat elements.

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