



RANGELANDS  
NRM CLUSTER



IMPACTS & ADAPTATION  
I N F O R M A T I O N  
FOR AUSTRALIA'S NRM REGIONS



## Australian rangelands and climate change – invasive animals



## Citation

Pavey CR and Bastin G (2014) *Australian rangelands and climate change – invasive animals*. Ninti One Limited and CSIRO, Alice Springs.

## Copyright

© Ninti One Limited 2014. Information contained in this publication may be copied or reproduced for study, research, information or educational purposes, subject to inclusion of an acknowledgement of the source.

## Disclaimer

The views expressed herein are not necessarily the views of the Commonwealth of Australia, and the Commonwealth does not accept responsibility for any information or advice contained herein.

ISBN: 978-1-74158-243-7

Front cover image credit: Hans Boessem



An Australian Government Initiative



**NINTI ONE** RANGE  
LANDS  
CLUSTER



**Government of South Australia**  
Alinytjara Wilurara Natural Resources  
Management Board



**Government of South Australia**  
South Australian Arid Lands Natural  
Resources Management Board



**South West NRM Ltd**  
Achieving sustainable landscapes  
for rural communities



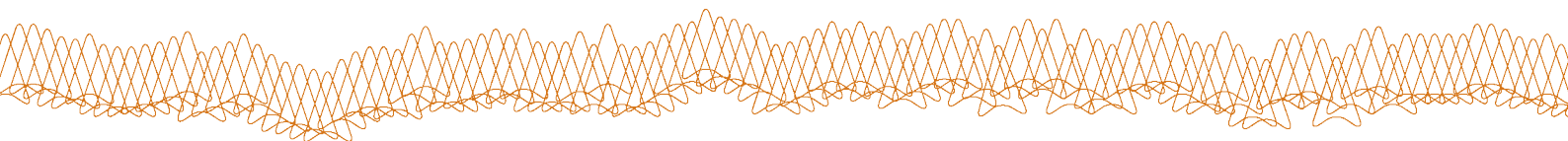
**UNIVERSITY OF  
CANBERRA**



**INSTITUTE FOR  
APPLIED ECOLOGY**



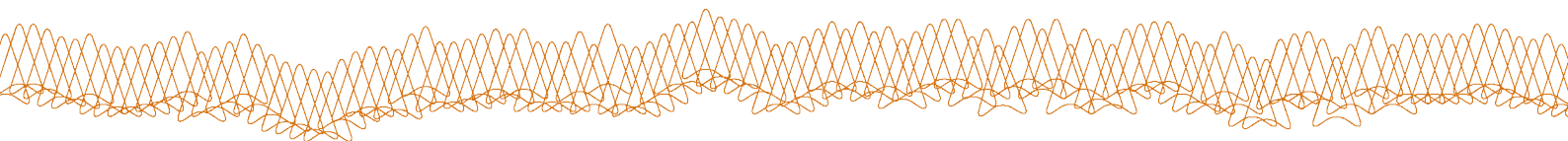
**Local Land  
Services  
Western**



# Contents

Acknowledgements.....	5
Key points.....	6
1. Introduction .....	7
2. Approach and methods .....	7
2.1 Approach.....	7
2.2 Summary of methods.....	8
2.3 Distribution and abundance .....	8
3. Problem invasive animals in the Rangelands Cluster .....	9
3.1 Feral goat .....	9
3.1.1 Introduction .....	9
3.1.2 Feral goats and climate change.....	10
3.2 Feral one-humped camel.....	11
3.2.1 Introduction .....	11
3.2.2 Feral camels and climate change .....	12
3.3 Feral horse/brumby .....	13
3.3.1 Introduction .....	13
3.3.2 Feral horses/brumbies and climate change .....	13
3.4 Feral donkey.....	13
3.4.1 Introduction .....	13
3.4.2 Feral donkey and climate change.....	13
3.5 Feral pig .....	14
3.5.1 Introduction .....	14
3.5.2 Feral pigs and climate change.....	14
3.6 Red fox.....	14
3.6.1 Introduction .....	14
3.6.2 Red fox and climate change.....	15
3.7 Feral domestic cat.....	16
3.7.1 Introduction .....	16
3.7.2 Feral cat and climate change .....	16
3.8 Dingo .....	17
3.8.1 Introduction .....	17
3.8.2 Dingo and climate change .....	18



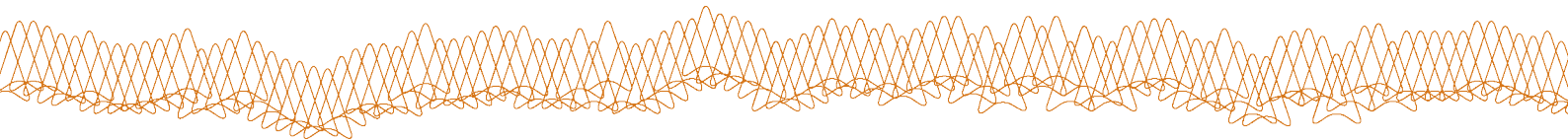


3.9 European rabbit.....	18
3.9.1 Introduction .....	18
3.9.2 European rabbit and climate change.....	19
3.10 Cane toad .....	19
3.10.1 Introduction .....	19
3.10.2 Cane toad and climate change .....	20
3.11 Summary.....	21
4. Management responses .....	21
Abbreviations.....	23
Glossary.....	24
References.....	26

## List of Figures

Figure 3.1 Average densities ( $\text{km}^{-2}$ ) of feral goats in half-degree blocks surveyed by fixed-wing aircraft across Queensland (1984–92, 2001), NSW (1993–2011), SA (1989–2011) and WA (1987–2011). .....	9
Figure 3.2 Annual exponential rate of increase of feral goats in half-degree blocks surveyed by fixed-wing aircraft across Queensland (1984–92, 2001), NSW (1993–2011), SA (1989–2011) and WA (1987–2011).....	10
Figure 3.3 Estimated feral camel densities before (top) and at the end (bottom) of the Australian Feral Camel Management Project. ....	11
Figure 3.4 Occurrence, distribution and abundance of foxes.....	14
Figure 3.5 Projected change in suitable climate space of the red fox between 1990 and 2085.....	15
Figure 3.6 Occurrence, distribution and abundance of feral cats.....	16
Figure 3.7 Current wild dog distribution in Australia. ....	17
Figure 3.8 Projected change in suitable climate space of the dingo between 1990 and 2085. ....	18
Figure 3.9 Known occurrence and potential distribution of the cane toad based on 2008 data.....	19
Figure 3.10 Projected change in suitable climate space of the cane toad between 1990 and 2085.....	20



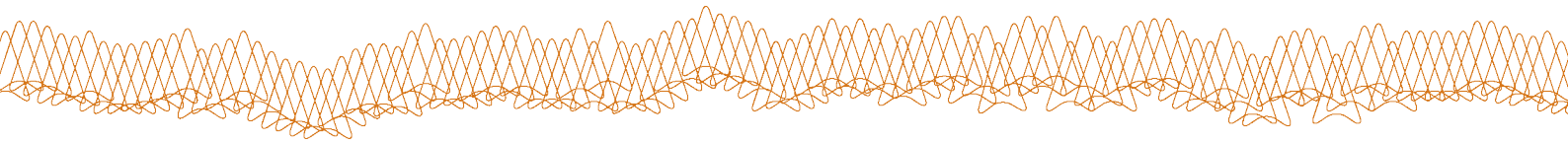


**List of Tables**

Table 3.1 Estimated 2008 feral camel population abundance and density by land-tenure type..... 12

Table 3.2 Summary of predicted changes in abundance and distribution of invasive animals covered in this report within the Rangelands Cluster region, in decreasing order of abundance change..... 21

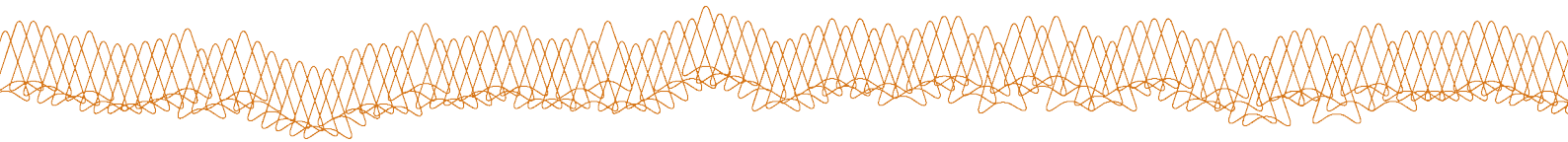
Table 4.1 Recommended future management actions for the ten species of vertebrate pests covered in this report. These actions factor in the potential impacts of climate change on the abundance and distribution of these species..... 22



# Acknowledgements

We wish to thank Jane Addison for advice and comments.

This project was funded by the Australian Government and was part of a collaboration between the Rangelands NRM Alliance, CSIRO, University of Canberra and Ninti One. Thanks to the following NRM regions for their review and input: Rangelands WA, Territory NRM, Alinytjara Wilurara NRM, SA Arid Lands NRM, Desert Channels Qld, South West NRM Qld and Western Local Lands Services. Thanks also to the members of the project's Scientific Advisory Panel for their advice and guidance: Steve Morton, Craig James, Stephen van Leeuwin, Ian Watterson, Colleen O'Malley, Daryl Green and Digby Race.

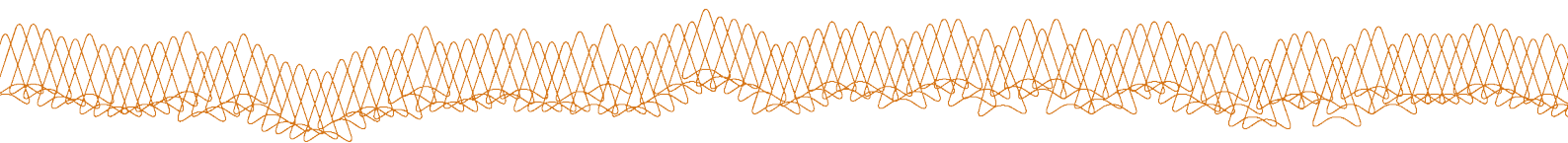


## Key points

- Ten species of significant vertebrate pest in the Rangelands Cluster region are considered in this report.
- Predicted changes in abundance and distribution with climate change indicate a decrease in the abundance and/or distribution of five species within the region (cat, goat, pig, rabbit and cane toad) with a further three species predicted to have stable abundance and distribution (camel, horse, donkey).
- Only two species, red fox and dingo, may show increased abundance and/or distribution in response to climate change.
- Management recommendations are made for each species taking into account changes in distribution and abundance with climate change.

Chris Pavey and Gary Bastin  
CSIRO





# 1. Introduction

High levels of uncertainty make it difficult to predict how climate change and biological invasions will affect ecosystems, as these changes are likely to have interacting effects that compound the uncertainty associated with each driver of change (Hellman et al. 2008; Tylanakis et al. 2008). Indeed, the very definition of invasiveness may change as previously defined invasive animals may become less invasive, previously non-invasive species may become more invasive and native species will become invasive-like as they shift their geographic distribution (Hellman et al. 2008). Species invasiveness can refer, variously, to a species that causes environmental or socioeconomic impacts, is non-native to an ecosystem or rapidly colonises and spreads (see Ricciardi and Cohen 2007). Here, we use the term to refer to non-native species (that is, those introduced to Australia post-1788) that have caused significant environmental or agricultural changes to the ecosystem or that are believed to present such a risk.

The aim of this report is to provide the highest quality climate change adaptation information on feral animal distribution and control.

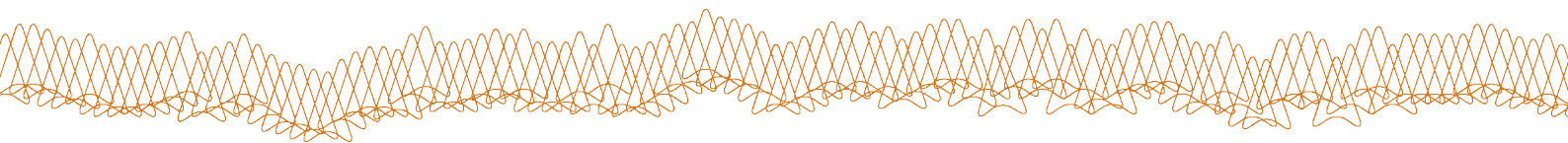
# 2. Approach and methods

## 2.1 Approach

A wide range and significant number of non-native animal species have been introduced and become established in the rangelands of Australia. Some groups of species either have limited impacts or, if impacts are high, occur within a small part of the Rangelands Cluster region. Among this group is the European honeybee (*Apis mellifera*), which has been present in Australia for about 190 years. The species is used for honey production and is of major economic value in Australia. However, it also has negative impacts on the environment although the full extent of impacts is poorly known (Paton 1996; Carr 2011). Foremost among the negative impacts is the ability to displace endemic wildlife from tree hollows along river channels in arid and semi-arid Australia. For instance, an estimate of 77.1 colonies/km<sup>2</sup> was made in riparian woodland in Wyperfeld National Park, north-west Victoria (Oldroyd et al. 1994). The common carp (*Cyprinus carpio*) is a significant freshwater pest in the Murray–Darling Basin and other rivers of NSW (West 2008); however, it occupies only a small area along the eastern edge of the cluster region. Other species in this group include the common starling (*Sturnus vulgaris*).

Another group of non-native species are those that have either no documented evidence of impact or those which are such recent migrants to Australia that the impact(s), if any, on the environment are unclear. A range of bird species, including the spotted turtledove (*Streptopelia chinensis*), are in the first category. The Asian honeybee (*Apis cerana*) is an example of a new species. It was detected in Australia for the first time in 1998 and has the potential to move in to the north-east edge of the Desert Channels region (Carr 2011).

The most invasive animals are large herbivores, mammalian carnivores and the cane toad. These species, with the possible exception of the cane toad, are having the most impact and are of greatest management concern within the Rangelands Cluster



region. Each species occupies a significant area of inland Australia. We therefore selected ten of these species to be the focus of this report. Here, we briefly describe the known recent history for the ten selected invasive animals in the Rangelands Cluster. We then comment on their likely future distribution and abundance with predicted climate change.

## 2.2 Summary of methods

Despite our choice of the most significant invasive species for consideration in this report, much is unknown about their current impacts and ecology. Even less is known about the future impacts that climate change may have on their distribution, density and ecology. To inform the report, current information on distribution, abundance and, where available, density was sourced from the references listed below.

- Annual aerial surveys of feral goats (*Capra hircus*) as part of the regular count of macropod numbers in Western Australia, South Australia, New South Wales and Queensland. These data were collated and analysed for ACRIS by Biosecurity Queensland in 2011 (Pople and Froese 2012).
- The recently completed Australian Feral Camel Management Project (AFCMP) (Ninti One Limited 2013) and the preceding foundational work on feral camel populations and their impact by the Desert Knowledge CRC (Edwards et al. 2008).
- A 2008 report on indicators of the extent and impact of ten invasive animal species for Australia compiled by the National Land & Water Resources Audit and the Invasive Animals CRC (West 2008).
- Information in the scientific literature (e.g. Caley et al. 2011).
- Unpublished modelling carried out by the Spatial Ecology group of Dr Jeremy Vanderwal within the Centre for Tropical Biodiversity and Climate Change at James Cook University. This work involves species distribution modelling (SDM) carried out using the program MAXENT. Further details are at <http://www.jjvanderwal.com/home>. In some cases using this modelling approach, the predicted and actual distributions of a species differ. Examples of this situation in the current report are the red fox

(Figures 3.4 and 3.5) and cane toad (Figures 3.9 and 3.10).

In line with the conceptual model for assessing risk posed by invasive species under climate change proposed by Sutherst (2000), gaps in the published and grey literature were bridged through using our knowledge of species physiology, habitat requirements and trophic interactions. While we make every effort to justify our extrapolations, we acknowledge that there are extremely high levels of uncertainty associated with some of these assessments.

## 2.3 Distribution and abundance

In the absence of quantitative density data (number per km<sup>2</sup>) for many species, the West (2008) report used distribution to describe the spatial pattern of an invasive species throughout an area (i.e. localised or widespread) and abundance to report relative density within a defined area (i.e. occasional, common or abundant). Data were collated from Rangelands Cluster state and territory government agencies and relevant non-government organisations. Where feasible, state and territory information was either updated or collected to facilitate accurate reporting.

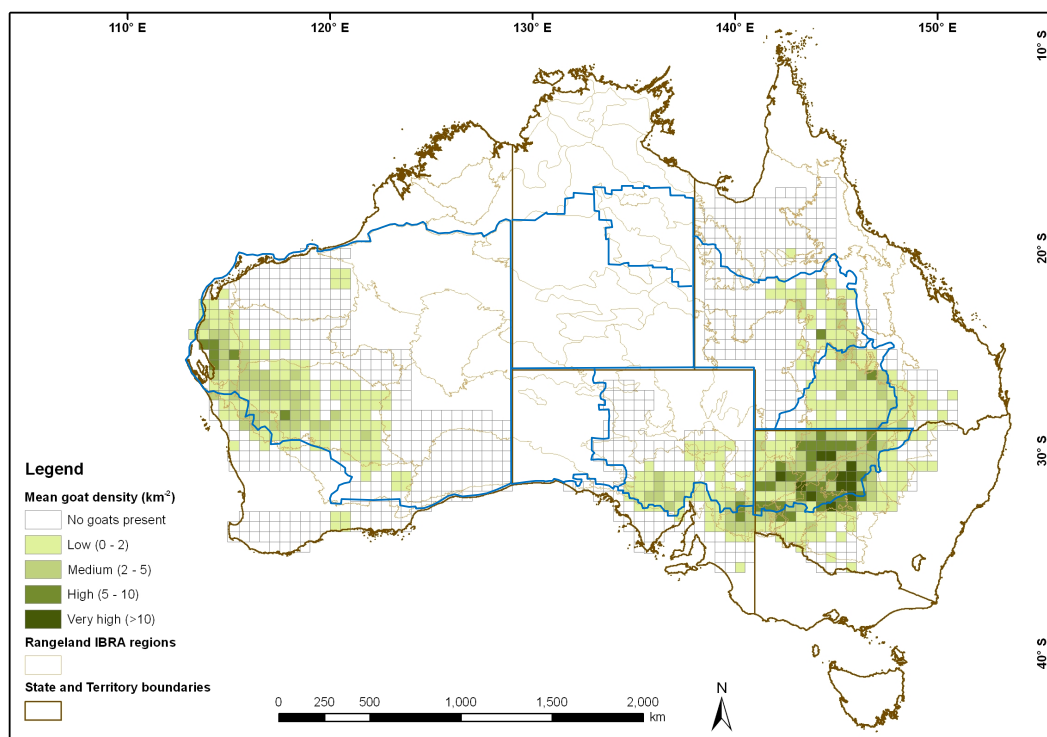
## 3. Problem invasive animals in the Rangelands Cluster

### 3.1 Feral goat

#### 3.1.1 Introduction

Key points, for NRM regions in the Rangelands Cluster, from the Biosecurity Queensland analysis of feral goat data are:

1. Aerial surveys for kangaroo management in the rangelands have also provided estimates of the density of feral goats.
2. Feral goats are present throughout most of the Western (NSW) and South West NRM (Queensland) regions (Figure 3.1). They also occur in the eastern part of the Desert Channels (Queensland), predominantly sheep-grazed SA Arid Lands and the Gascoyne-Murchison pastoral region of Rangelands WA (also extending into the Goldfields region). Mean goat density since the 1980s has been highest in the Western region of NSW.
3. The estimated feral goat population in Australia grew from 1.4 million in 1997 to 4.1 million in 2008. In 2010, there were an estimated 3.3 million feral goats in the Australian rangelands.
4. Over time, an increasing proportion of the feral goat population occurs in NSW, comprising 70% in 2010 (Figure 3.2). In 2011, there were an estimated 2.95 million feral goats in NSW.



**Figure 3.1 Average densities (km<sup>-2</sup>) of feral goats in half-degree blocks surveyed by fixed-wing aircraft across Queensland (1984–92, 2001), NSW (1993–2011), SA (1989–2011) and WA (1987–2011).**

Rangeland bioregions (brown lines) and Rangelands Cluster NRM regions (blue lines) are also shown.

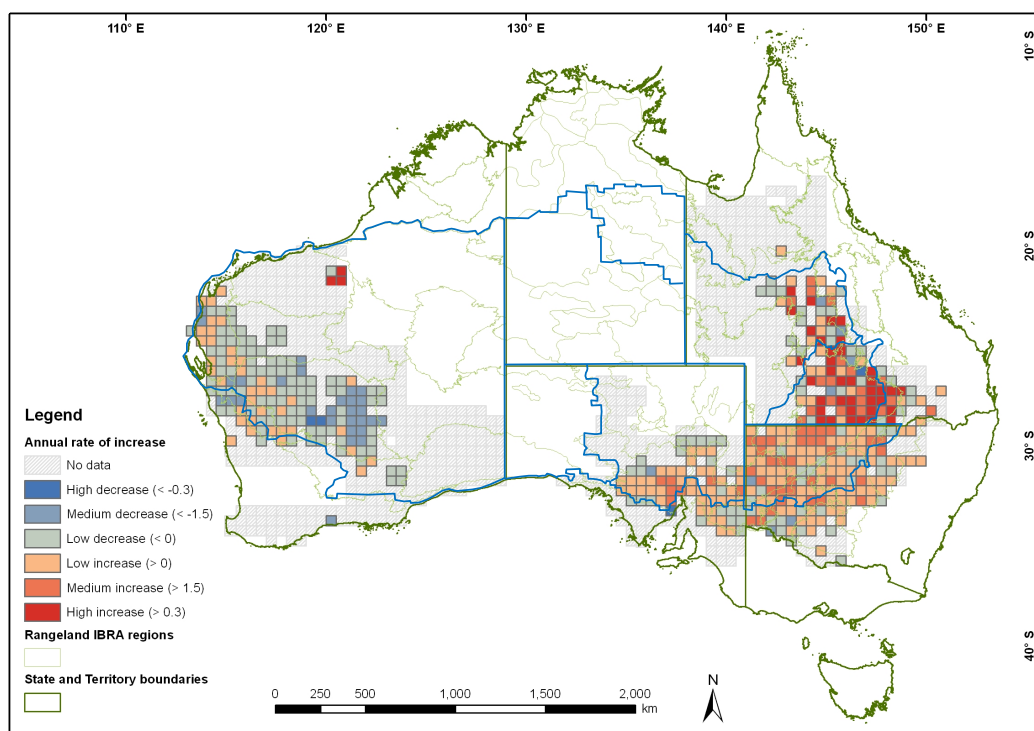
Source: Figure adapted from Figure 7 in Pople and Froese (2012).



5. A caveat to this summarised reporting is that observers cannot readily distinguish truly feral goats from domestic or managed goats during aerial surveys. This problem is growing as numbers of domestic goats and the practice of mustering feral goats into fenced paddocks increases (goats were not counted in Queensland in 2011 because of the perceived difficulty by observers in identifying feral goats).
6. Data obtained by Biosecurity Queensland from the Australian Bureau of Statistics (ABS) surveys indicate that the proportion of domestic relative to feral goats is low, suggesting the problem of misidentification is small. However, the ABS data need validation. Surveys of abattoir operators suggest much larger numbers of domestic goats than that recorded by the ABS.

### 3.1.2 Feral goats and climate change

Predicting the response of feral goats to climate change is difficult because their populations will be influenced by other factors occurring as the climate changes. These changes will include the level of control efforts for unmanaged goats. Feral goats have been controlled at various scales within the rangelands through dedicated commitment and varying levels of support funding. Examples of this include Operation Bounceback in South Australia and total grazing pressure (TGP) fencing. Further, there is evidence that restructuring of pastoral activities in the rangelands, and particularly an increase in wild dogs / dingoes, may suppress goat populations in the future. With these factors in mind, a decrease in the distribution and density of feral goats in the rangelands of NSW by 2050 is predicted by Caley et al. (2011).



**Figure 3.2 Annual exponential rate of increase of feral goats in half-degree blocks surveyed by fixed-wing aircraft across Queensland (1984–92, 2001), NSW (1993–2011), SA (1989–2011) and WA (1987–2011).**

Rangeland bioregions (green lines) and Rangelands Cluster NRM regions (blue lines) are also shown.

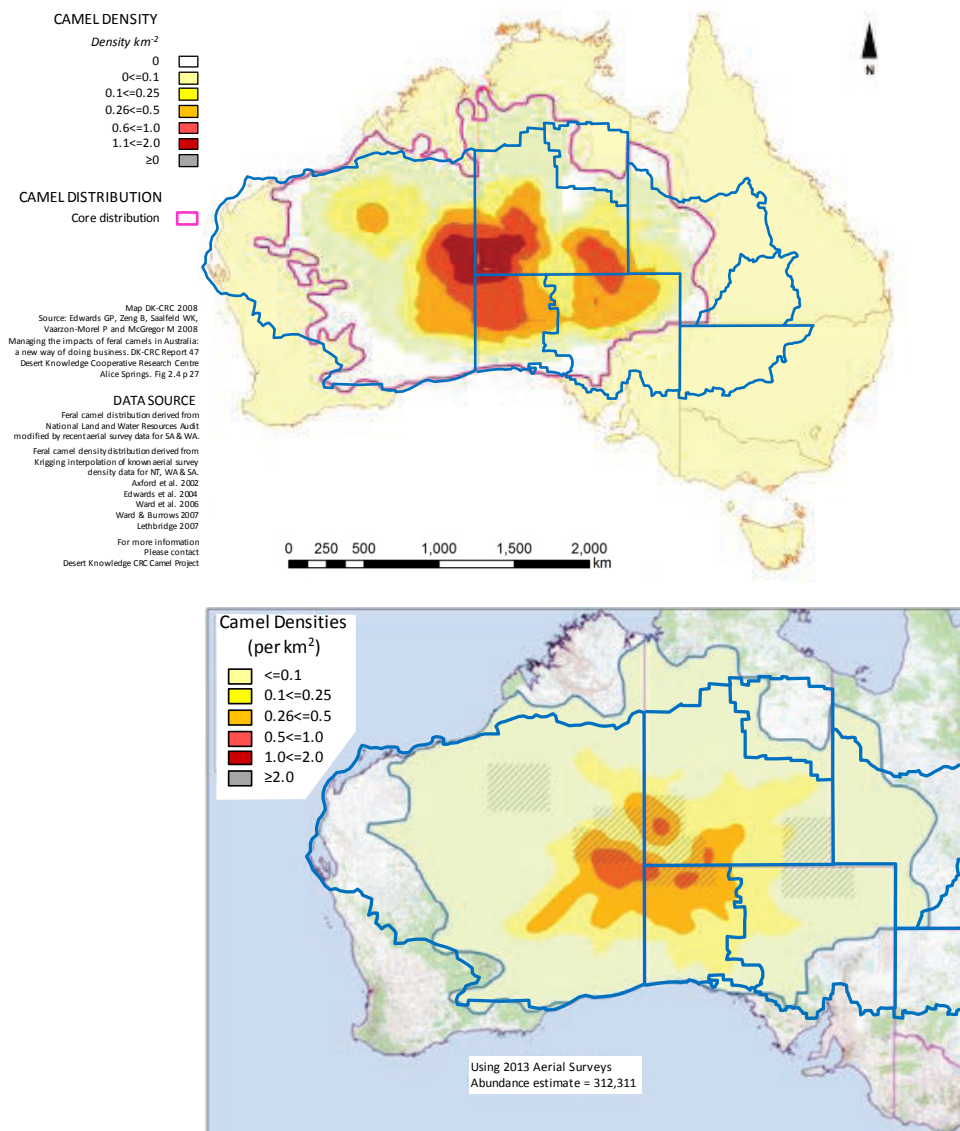
Source: Figure adapted from Figure 10 in Pople and Froese (2012).

## 3.2 Feral one-humped camel

### 3.2.1 Introduction

The population of the feral one-humped camel (*Camelus dromedarius*) in Australia was estimated at

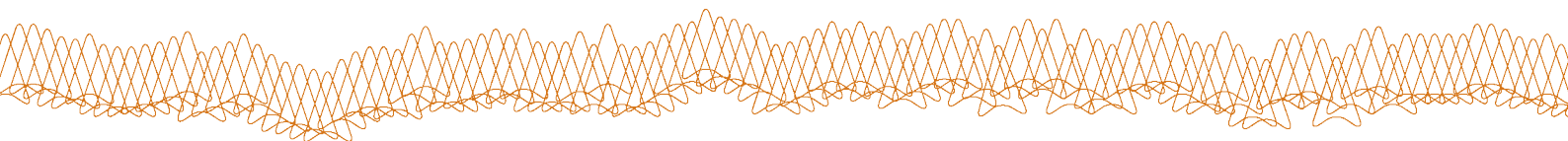
1 million in 2008, distributed over an area of 3.3 million km<sup>2</sup> (Figure 3.3, top panel) (Edwards et al. 2008) (Table 3.1). Based on available data for the NT, it was estimated that the population could double every nine years. A number of caveats applied to the population estimate. In particular, the population size



**Figure 3.3 Estimated feral camel densities before (top) and at the end (bottom) of the Australian Feral Camel Management Project.**

Blue lines show NRM regions in the Rangelands Cluster.

Source: Maps adapted from (top) Edwards et al. (2008, Figure 2.4, p. 27) and (bottom) Ninti One Limited (2013, Figure 28, p. 60).



estimate was based on a limited survey area and surveys were conducted in different areas in different years.

Edwards et al. (2008) reported that remodelling of the data used in the 2008 report provided 'a better estimate of the feral camel density outside of survey areas and ... a revised total population figure of around 600,000 in 2008'. The Australian Feral Camel Management Project (AFCMP) removed approximately 160,000 feral camels to reduce the population to an estimated 312,000 feral camels in 2013 (Figure 3.3, bottom map).

For the immediate future, Ninti One Limited (2013) advises that:

- The AFCMP density targets have been met completely in 13 of the 17 buffer zones around environmental assets (see Figure 29, p. 60, in Ninti One Limited 2013) and have largely been met in the other four buffer zones, with some sections of these four zones having densities above the targets.
- In particular, there is now a real opportunity to maintain very low densities of feral camels in the Pilbara and Simpson regions.
- Although densities in the Surveyor Generals Corner region have been reduced, they are still generally above the broad long-term target of 0.1/km<sup>2</sup>. Within this region, there are two large areas (Anangu Pitjantjatjara Yankunytjatjara and Ngaanyatjarra lands) where the landholders have expressed a strong preference for commercial use. It is hoped that strengthened capacity for commercial use will allow a level of removal that drives the density down rather than just being a sustainable offtake.

- Aerial culling in the non-commercial use zones of Surveyor Generals Corner has undoubtedly helped reduce the overall density of feral camels in this region over the life of the project, given the mobility of feral camels between commercial and non-commercial zones.

### 3.2.2 Feral camels and climate change

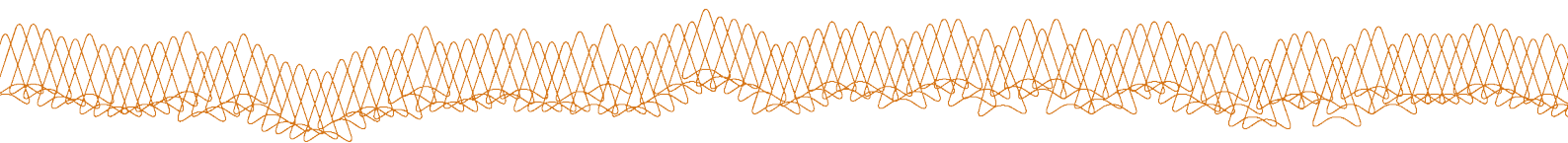
- Without continued systematic control of their numbers, feral camel numbers will again increase in the deserts and marginal/remote pastoral lands of the Rangelands Cluster.
- The AFCMP has demonstrated that planned, coordinated, collaborative control can reduce camel densities over relatively large areas. Aerial culling (shooting to waste) has to be an integral part of the control program. It is highly desirable that human capacity and skill levels required to efficiently mount and run removal operations in remote locations are maintained/enhanced.
- Further control (whether through a downscaled AFCMP or some alternative program) must transcend tenure and jurisdictional boundaries.
- Camels are adapted to the desert (thus heat tolerant) and highly mobile. Their general distribution and relative abundance is unlikely to be adversely affected by higher temperatures, continuing (or enhanced) rainfall variability and possibly more frequent and intense droughts.

**Table 3.1 Estimated 2008 feral camel population abundance and density by land-tenure type**

TENURE CLASSIFICATION	AREA (KM <sup>2</sup> )	POPULATION (%)	DENSITY (ANIMALS/KM <sup>2</sup> )
Aboriginal	783,000	415,000 (43%)	0.53
Pastoral	1,399,000	210,000 (22%)	0.15
Vacant Crown Land	813,000	236,000 (25%)	0.29
Conservation / Other	335,000	94,000 (10%)	0.28
Total	3,330,000	955,000 (100%)	0.29

Source: reproduced from Table 2.5 (p. 28) in Edwards et al. 2008)





## 3.3 Feral horse/brumby

### 3.3.1 Introduction

The horse (*Equus caballus*) arrived in Australia in 1788 as part of the First Fleet. Because much of the country was grazed without fences, escapes were common and invasive populations formed rapidly. Currently, feral populations are estimated to contain about 400,000 individuals (Australian Government 2011a). Densities can be high in some areas. For example, the Victoria River District of Northern Territory (Monsoon Cluster region) was estimated to have a density of  $0.33 \text{ km}^{-1}$  in 2006 (Saalfeld et al. 2006). A significant proportion of Australia's feral horse population is within the Rangelands Cluster region.

Feral horses can be a serious environmental issue. This impact results from erosion and damage to vegetation and, potentially, movement of weeds. The only significant natural threats are likely to be drought and severe bushfire. The Brucellosis and Tuberculosis Eradication Campaign (BTEC) led to successful control over relatively large areas in some pastoral districts (e.g. southern NT and northern SA). This process involved the shooting of wild horses as a by-catch to removal of feral/unmusterable cattle. The Northern Territory Government's declaration of a 'Pest Control Area' over the Victoria River District (Monsoon Cluster region) in 2006 with the issue of control notices to properties with required off-take targets for horses is another model for broadscale control (Saalfeld 2005; Saalfeld et al. 2006).

### 3.3.2 Feral horses/brumbies and climate change

Feral horses are likely to be minimally affected by climate change and are likely to be an ongoing or recurring problem in remote and difficult-to-manage country within the Rangelands Cluster.

## 3.4 Feral donkey

### 3.4.1 Introduction

The donkey (*Equus asinus*) was brought to Australia as early as 1866 for use as a form of transport. Anecdotal information suggests that invasive populations were present by the 1920s (Choquenot 2008). Currently, the national population is estimated to be in the millions (Australian Government 2011a). Densities can be high in some areas. For example, the Victoria River District of the Northern Territory (Monsoon Cluster region) was estimated to have a density of  $0.41 \text{ km}^{-1}$  in 2006 (Saalfeld et al. 2006). A significant proportion of the Australian donkey population is within the Rangelands Cluster region.

Feral donkeys are similar to horses in potentially being a serious environmental issue. This impact results from erosion and damage to vegetation and, potentially, movement of weeds. The only significant natural threats are likely to be drought and severe bushfire. Donkeys appear to be more tolerant to drought than horses.

### 3.4.2 Feral donkey and climate change

Donkeys are likely to be minimally affected by climate change and, similar with horses, will be an ongoing or recurring problem in difficult-to-manage country.

## 3.5 Feral pig

### 3.5.1 Introduction

Domestic pigs (*Sus scrofa*) have been present in Australia since European settlement and the invasive populations currently present are the result of escapes from domestic populations as well as deliberate introductions to the wild for recreational hunting. Feral pigs do not currently occupy all suitable available habitat in Australia. The species occupies about 38% of mainland Australia, with their distribution largely a product of the location of releases/domestic source populations. The current non-domesticated pig population in Australia is estimated at between 3.5 million and 23.5 million (Australian Government 2005).

The feral pig can seriously impact the environment through predation, habitat degradation, competition with native species and disease transmission. Habitat changes resulting from feral pig activity include destruction of plants, changes in floristic composition, decreased plant regeneration, alteration of soil structure and increased spread of weeds. Pigs prey on a range of native species including frogs, reptiles, bird chicks, eggs of birds and reptiles, invertebrates, seeds, fruit, roots, tubers, bulbs and plant foliage. Feral pigs also provide reservoirs for endemic diseases and can be vectors of exotic diseases.

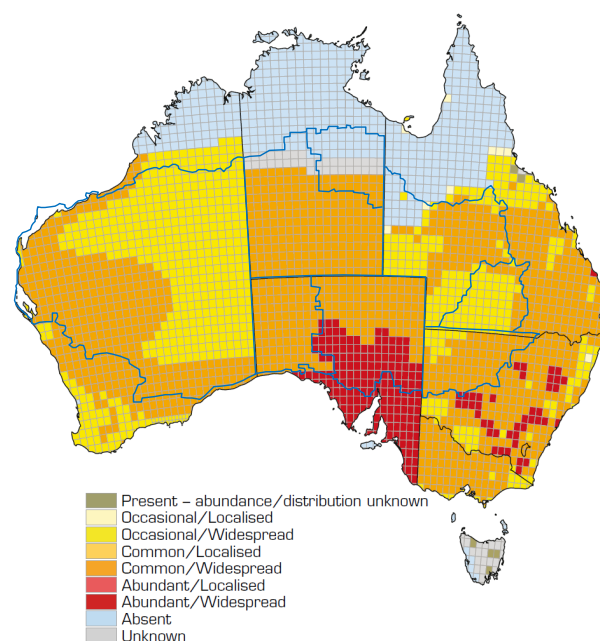
### 3.5.2 Feral pigs and climate change

The increased temperatures projected to occur within the Rangelands Cluster region are predicted to reduce the distribution of feral pigs (Caley et al. 2011). Effective management of surface water through the capping of free flowing bores and the management of water troughs will further reduce the abundance of pigs through much of the region.

## 3.6 Red fox

### 3.6.1 Introduction

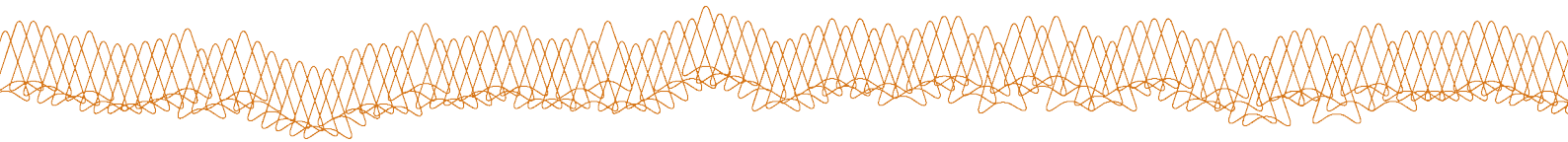
The red fox (*Vulpes vulpes*) occurs in all states and territories, including Tasmania, and inhabits an estimated 76% (i.e. 5.79 million square kilometres) of Australia (Figure 3.4). However, foxes do not appear to be capable of maintaining permanent populations in northern Australia, most likely because of physiological constraints. Therefore, they are considered to be at their northern geographic limit under current climatic conditions. Foxes occupy almost the entire Rangelands Cluster region.



**Figure 3.4 Occurrence, distribution and abundance of foxes**

Source: West 2008, p. 35

Foxes are predominantly 'occasional' to 'common' throughout their range, but they are often found in low numbers where dingoes are prevalent (Saunders et al. 1995). Population densities can reach 7.2/km<sup>2</sup> (Saunders et al. 1995). In the Rangelands Cluster region fox abundance varies with environmental conditions. After large rainfall events, pulses in primary productivity occur which result in massive increases in



some vertebrate populations such as native rodents and granivorous birds. Fox abundance remains high until vertebrate numbers crash and then populations drop although the species persists in arid areas such as the Simpson Desert during drought periods.

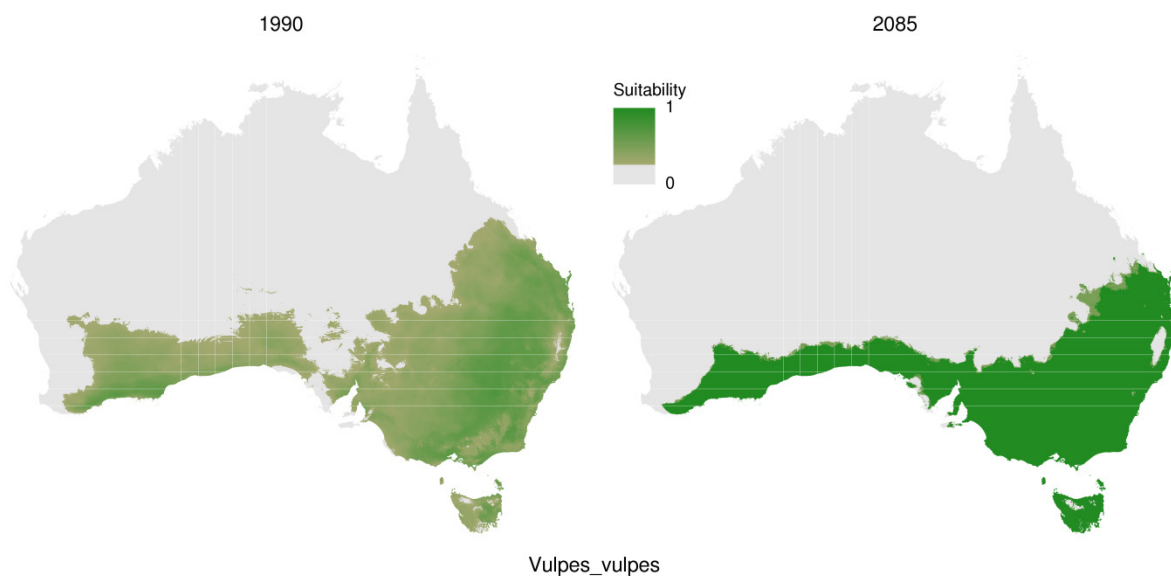
Foxes are opportunistic predators and scavengers and are a significant threat to native fauna, especially mammals (Saunders and McLeod 2007). They possess a number of attributes that allow them to occupy a wide range of habitats (Saunders et al. 1995). Foxes are effective predators of native wildlife and vulnerable livestock. Their impacts are significant, and the total cost is the highest of any pest species — an estimated \$227.5 million per year (McLeod 2004). For this reason, 'Predation by the red fox' is listed as a 'key threatening process' under the *Environment Protection and Biodiversity Conservation Act (1999)* and under NSW legislation.

Information on the trend in abundance is limited to SA and the NT. In these areas, their abundance is largely stable.

### 3.6.2 Red fox and climate change

The distribution of foxes is unlikely to change dramatically in the Rangelands Cluster region under current climate change scenarios (Figure 3.5). In Figure 3.5, the current climate space is actually less than the current distribution of the species (Figure 3.4). This indicates that the species may occupy a larger area than predicted in 2085. This information may change with more refined modelling. The density may increase moderately in some areas, including in western NSW (e.g. Caley et al. 2011).

Trophic cascades resulting from climate change may impact negatively on foxes and lead to decreases in abundance. Specifically, across broad areas of the Rangelands Cluster region dingo/wild dog abundance is predicted to increase in response to climate change and changes in management (that will lead to a decrease in dingo control). One such area is north-west NSW (Caley et al. 2011). If dingoes do keep foxes in check through direct predation and competition as predicted by much of the scientific literature (e.g. Ripple et al. 2014) then an increase in dingo/wild dog abundance will likely result in a decrease in fox abundance.



**Figure 3.5 Projected change in suitable climate space of the red fox between 1990 and 2085.**

Source: J. Vanderwal et al. unpublished data.



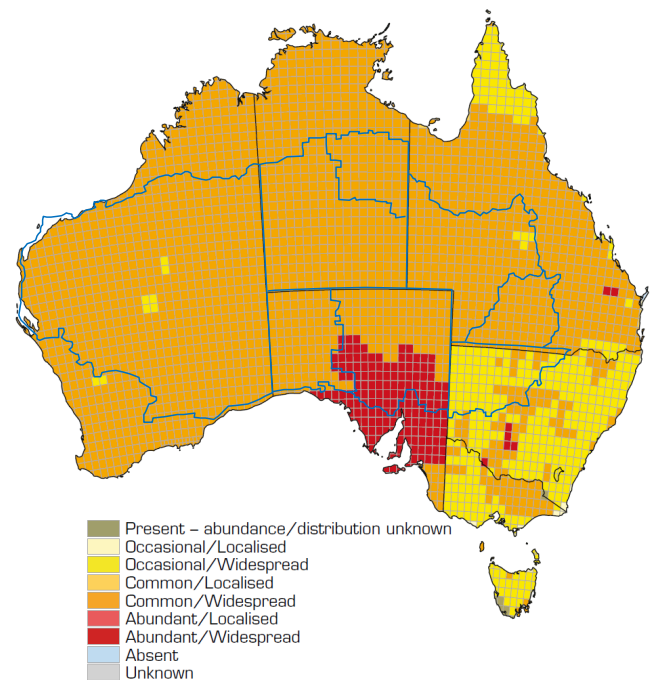
## 3.7 Feral domestic cat

### 3.7.1 Introduction

Domestic cats (*Felis catus*) were introduced to Australia either before or during European settlement. It is likely that this species had colonised most of the continent by 1890 (Denny 2008). Feral cats presently inhabit an estimated 99% (i.e. 7.54 million km<sup>2</sup>) of Australia (Figure 3.6). Feral cat populations have now established in almost every significant habitat type throughout the continent; they also inhabit numerous islands.

The feral cat population in Australia is estimated at approximately 18 million animals (McLeod 2004). Populations can reach as high as 57/km<sup>2</sup> (Dickman 1996). Over a recent two-year period, a total of 2900 feral cats were killed in Astrebla Downs National Park, western Queensland. They are highly effective predators and are responsible for predation of a wide range of native species (Dickman 1996). 'Predation by feral cats' has been listed as a 'key threatening process' in NSW and Commonwealth legislation.

Information on the trend in abundance reveals that feral cats are largely stable in SA and the NT (West 2008). In the Rangelands Cluster region, cat abundance varies with environmental conditions. After large rainfall events, pulses in primary productivity occur which result in massive increases in some vertebrate populations such as native rodents and granivorous birds. After a lag of up to six months, cat numbers increase dramatically in response to increases in prey availability. Abundance remains high until vertebrate numbers crash and then cat abundance drops, although the species persists in arid areas during drought periods.



**Figure 3.6 Occurrence, distribution and abundance of feral cats**

Source: West 2008, p. 35

### 3.7.2 Feral cat and climate change

The distribution of cats is predicted to decline across the rangelands under climate change. In some areas abundance may decrease also, such as in the rangelands of NSW (Caley et al. 2011).

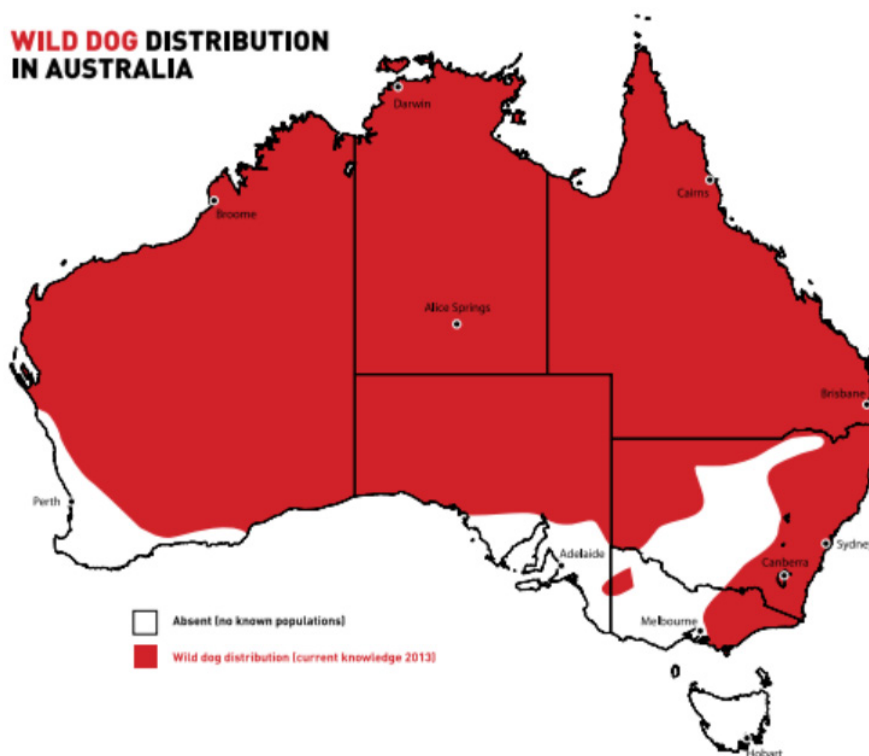
## 3.8 Dingo

### 3.8.1 Introduction

The term is used here to include the dingo (*Canis dingo*) and hybrids between the dingo and feral domestic dogs (*Canis lupus familiaris*). The term 'wild dog' is sometimes used rather than dingo (e.g. Wicks et al. 2014). Dingoes are considered to be major pests of agriculture because they kill livestock (Wicks et al. 2014). Specifically, dingo predation can reduce the profitability of sheep properties in particular and can have important negative social impacts (Allen and West 2013; Wicks et al. 2014; Forsyth et al. in press).

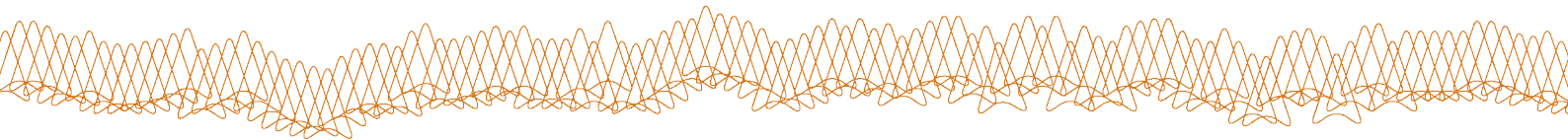
The dingo is classified as a native species and is Australia's largest land predator. It occupies most of mainland Australia, including all of the Rangelands

Cluster region (Figure 3.7). It has been present on the Australian continent for at least 3000–5000 years (Crowther et al. 2014). There is a growing body of recent research showing that the dingo has a positive role in biodiversity conservation through the control it exerts on native herbivores (especially kangaroos), introduced herbivores and the red fox (Ripple et al. 2014). This control results in a cascading effect through food webs, which results in increased survival of native small mammals, birds and reptiles. Dingo–dog hybridisation is a threat to 'pure' dingoes, and it is a further issue because of policies in some Australian jurisdictions that aim to exterminate dingo–dog hybrids. Separation of 'pure' dingoes from dingo–dog hybrids is vital if this control process is to be successful (Crowther et al. 2014).



**Figure 3.7 Current wild dog distribution in Australia.**

Source: WoolProducers Australia (2014), with material provided by Peter West (Invasive Animals Cooperative Research Centre), prepared from data collated 2006–2013.



### 3.8.2 Dingo and climate change

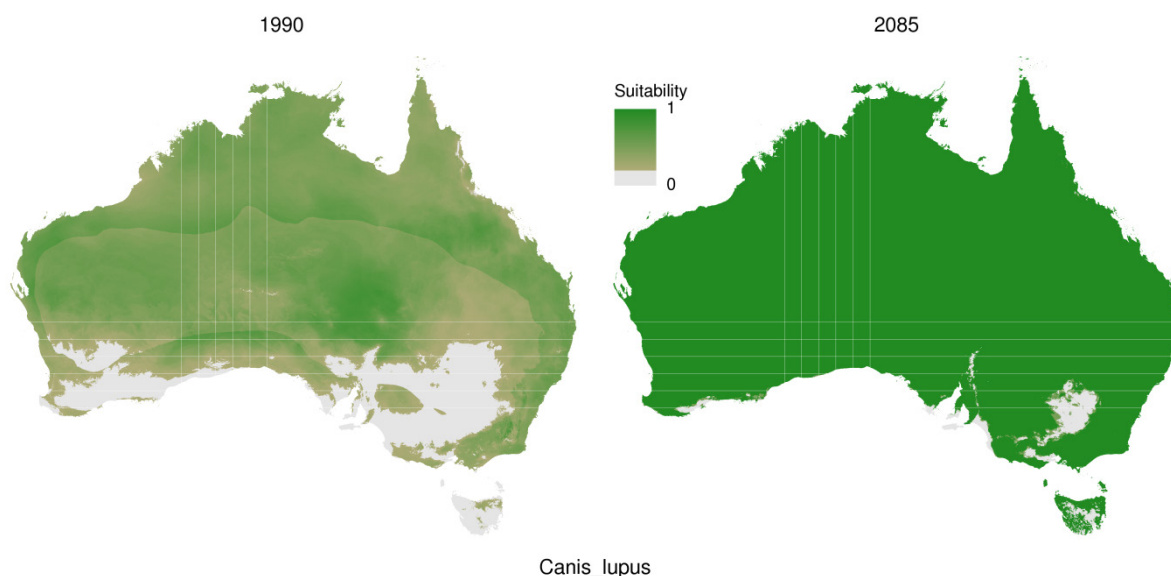
The distribution and abundance of dingoes within the Rangelands Cluster region is predicted to increase in response to both climate change (Figure 3.8) and changes in rangeland management. The expectation is that climate change will cause increases in distribution and abundance of dingoes indirectly as a consequence of changes in their prey base (Caley et al. 2011). The management changes are twofold. First, there is a growing appreciation of the positive impacts of dingoes on ecosystems and of the need to manage them appropriately as a keystone species (e.g. Ripple et al. 2014). Second, dingoes are persecuted most heavily in sheep-grazing regions. The extent of sheep grazing in the rangelands of Australia is declining steadily, as it is in other parts of the world (Forsyth et al. in press) and as this happens the need to control dingoes will decline (e.g. Caley et al. 2011).

## 3.9 European rabbit

### 3.9.1 Introduction

The European rabbit (*Oryctolagus cuniculus*) has been present in Australia since 1858, when it was introduced into the south-east of the country for sport shooting. It rapidly became established and spread and has been one of the most prominent environmental issues in Australia. The species is now widespread across the southern and central sections of the continent, including Tasmania. However, it is absent from the northern third of Australia (Williams and Myers 2008). The rabbit occurs throughout most of the Rangelands Cluster region but is absent from the extreme north.

The rabbit remains a serious environmental and agricultural pest in Australia despite the relative success of biological control agents (myxoma virus and rabbit haemorrhagic disease virus). The impact of rabbits on agricultural and horticultural production in Australia is estimated at \$206 million per year (Gong et al. 2009). Rabbits also cause significant environmental damage. Their impacts include damage to native plants and pastures, which increases the susceptibility of soils to



**Figure 3.8 Projected change in suitable climate space of the dingo between 1990 and 2085.**

Source: J. Vanderwal (unpublished data).

wind and water erosion. In addition, rabbits are a major food of introduced carnivores that prey on native wildlife.

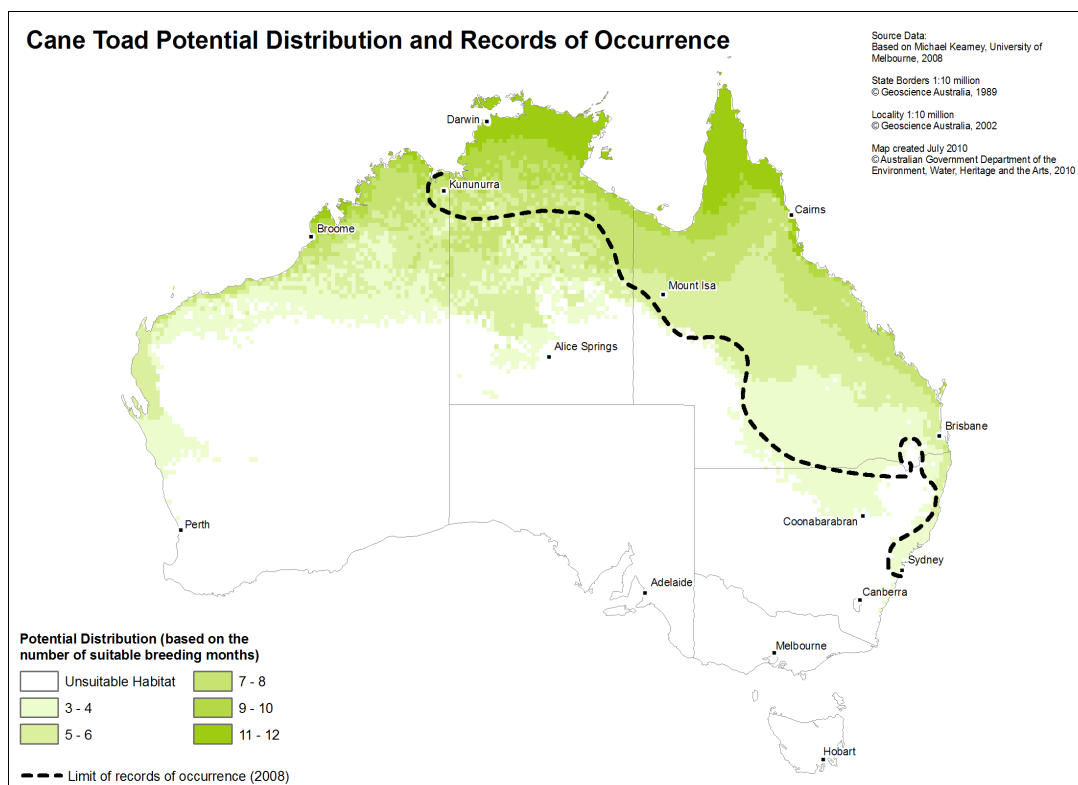
### 3.9.2 European rabbit and climate change

All predictions for climate change for the Rangelands Cluster region predict an increase in temperature. Available modelling predicts that this will have a negative impact on rabbits, with the species becoming absent from sizeable areas of the Rangelands Cluster region. This decrease is predicted to occur irrespective of whether the climate becomes hotter and wetter or hotter and drier (Caley et al. 2011). In the rangelands of NSW, the rabbit is predicted to become absent from large areas of the centre and west by 2050.

## 3.10 Cane toad

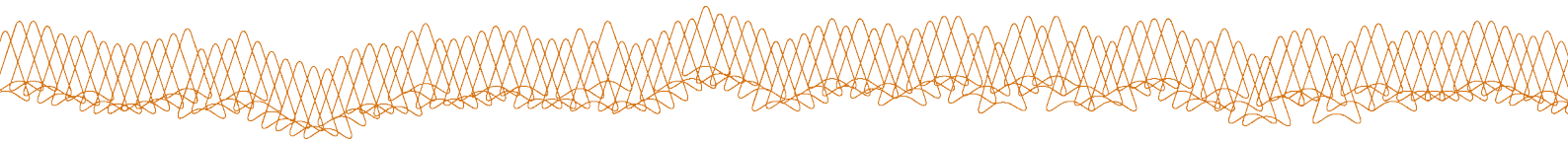
### 3.10.1 Introduction

Cane toads (*Bufo marinus*) were introduced to Queensland in 1935 to control pest beetles in sugar cane crops. Their success as a pest control agent has never been determined; however, they have become an environmentally significant and much publicised invasive species in their own right. Cane toads are presumed to cause a range of adverse impacts, primarily to native animals. A wide range of native species have been known to die following ingestion or part-ingestion of cane toads. Cane toads may also be a threat to domestic pets, because they can release toxins from their skin. However, it is clear that in some cases their impacts have been overstated (e.g. Brown et al. 2011), and the long-term impacts of cane toads are



**Figure 3.9 Known occurrence and potential distribution of the cane toad based on 2008 data.**

Source: Australian Government (2011b).



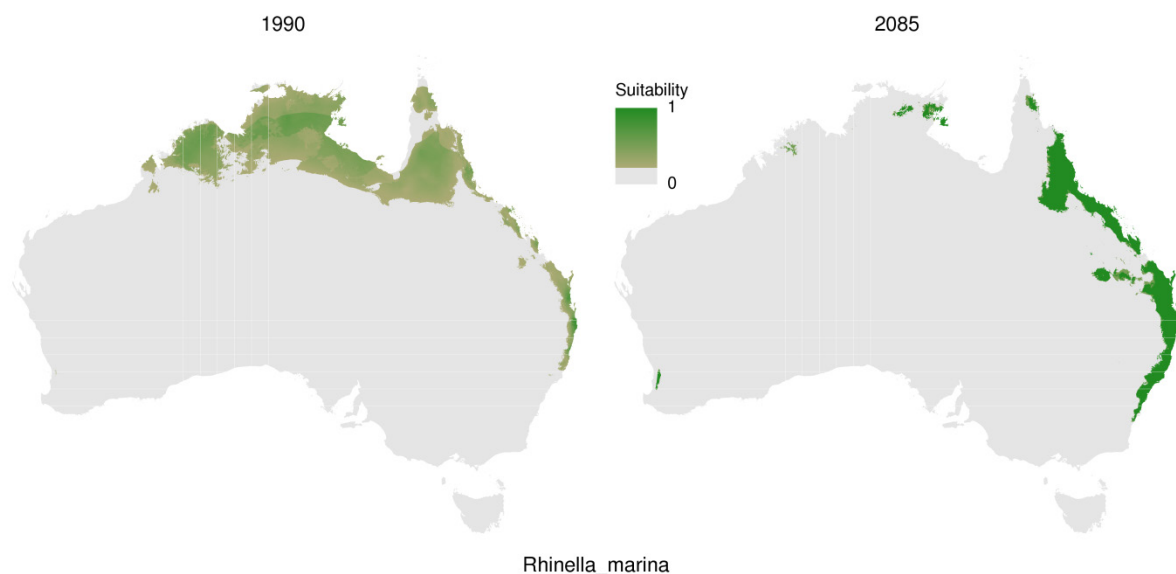
poorly understood. Cane toads are tolerant of a wide range of conditions and can produce spawn containing up to 35,000 eggs.

Cane toads continue to expand their range in Australia. Since the original release at Gordonvale in north Queensland, the species has dispersed over 2000 km west and now occurs through much of Queensland, northern NSW, the Northern Territory and into the East Kimberley in WA. In recent years, they have rapidly spread across the NT and crossed the WA–NT border in 2009. The rate of spread is estimated to be 55 km per year. They have successfully colonised several large coastal islands in Queensland and the NT and have been found in densities up to 2000 per hectare in newly colonised areas (Molloy and Henderson 2006). Flooding events hasten the rate of spread of cane toads.

Cane toads presently inhabit an estimated 20% (i.e. 1.52 million km<sup>2</sup>) of Australia. It appears likely that they now occupy a large proportion of their estimate range in Figure 3.9.

### 3.10.2 Cane toad and climate change

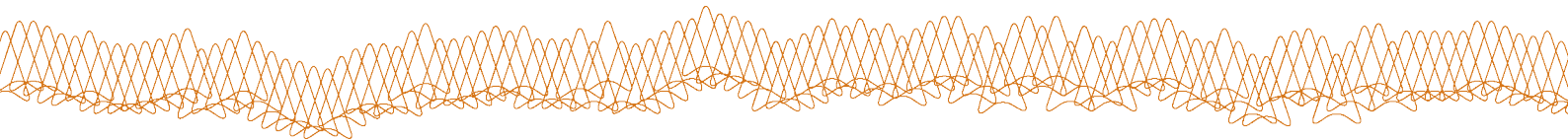
The climate space of cane toads is projected to decline significantly by 2085 under current climate scenarios. Almost all of the current range in the Kimberley area of Western Australia and the Northern Territory and most of the climate space on Cape York Peninsula will disappear, and the species will contract to the east coast. The decline in available climate space is such that it is predicted that no cane toads will likely be present within the Rangelands Cluster region (Figure 3.10).



**Figure 3.10** Projected change in suitable climate space of the cane toad between 1990 and 2085.

Source: J. Vanderwal (unpublished data).





## 3.11 Summary

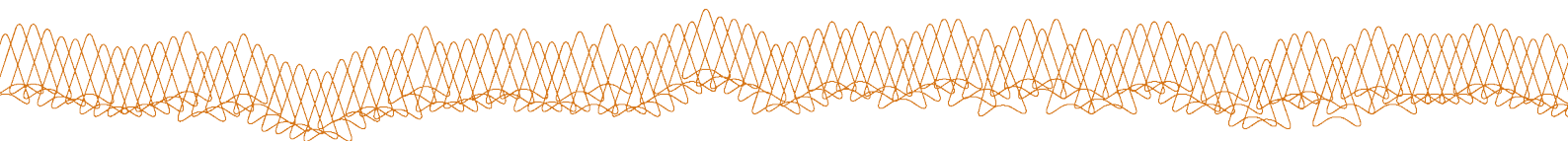
**Table 3.2 Summary of predicted changes in abundance and distribution of invasive animals covered in this report within the Rangelands Cluster region, in decreasing order of abundance change.**

SPECIES	ABUNDANCE	DISTRIBUTION	COMMENTS
Red fox	Moderate increase	Stable	Negative impact of increased dingo abundance
Feral domestic cat	Moderate decrease	Decrease	
Dingo	Increase	Increase	May be favoured by changed management involving less control activities
One-humped camel	Stable	Stable	
Feral horse	Stable	Stable	
Feral donkey	Stable	Stable	
Feral goat	Moderate decrease	Moderate decrease	Negative impact of increased dingo abundance
Feral pig	Decrease	Decrease	Predicted to increase outside rangelands
European rabbit	Decrease	Decrease	Influenced by predator abundance and continuing effective forms of biological control
Cane toad	Decrease	Decrease	Will be impacted by water management practices

## 4. Management responses

Table 3.2 (above) predicts a decrease in the abundance and/or distribution within the Rangelands Cluster region in response to climate change of five of the major pest vertebrates covered in this report. These species are the cat, goat, pig, rabbit and cane toad. A further three species are predicted to have stable abundance and distribution (camel, horse, donkey). Only two species, red fox and wild dog, may show increased abundance and/or distribution in response to climate change (Table 3.2).

As a consequence of the limited positive impacts of climate change on pest vertebrates, the management recommendations in Table 4.1 (below) are essentially in the category of 'do more of the same'.



**Table 4.1 Recommended future management actions for the ten species of vertebrate pests covered in this report. These actions factor in the potential impacts of climate change on the abundance and distribution of these species.**

SPECIES	GOAL	ACTION	TARGET REGION/SUB-REGION(S)
Goat	Exclude species from areas of high agricultural/conservation value. Implement a suite of rigorous control measures elsewhere to maintain the feral goat population at regionally low densities. This goal assumes goats are a pest rather than a resource.	Continue existing actions	Western LLS, South West Queensland, Desert Channels, SA Arid Lands, WA Rangelands
Camel	Maintain regional density target of < 0.1 camels per km <sup>2</sup> (Ninti One Limited 2013)	Continue existing actions	Desert Channels, SA Arid Lands, Alinytjara Wilurara, NT Arid Lands sub-region, WA Rangelands
Horse	Landscape-scale eradication	Continue and intensify existing actions	NT Arid Lands and NT Tablelands sub-regions, SA Arid Lands, Alinytjara Wilurara, WA Rangelands, South West Queensland, Desert Channels
Donkey	Landscape-scale eradication	Continue and intensify existing actions	NT Arid Lands and NT Tablelands sub-regions, SA Arid Lands, WA Rangelands
Pig	Prevent colonisation of new locations	Local-scale management, including preventing access to water and eradication	NT Tablelands sub-region, South West Queensland, Desert Channels, Western LLS
Fox	Landscape-scale eradication	1080 baiting Positive dingo management	All
Cat	Landscape-scale control and eradication (once methods available)	Local-scale lethal control Positive dingo management	All
Dingo	Reduce impacts on livestock production	Local-scale control of dog–dingo hybrids and feral domestic dogs, including lethal methods and exclusion fencing	All
Rabbit	Landscape-scale suppression	Continue integrated management (including poisoning, warren ripping, shooting, biocontrol)	All regions except NT Tablelands sub-region
Cane toad	Prevent colonisation of new locations	Local-scale management, including preventing access to water, and collection	NT Arid Lands and NT Tablelands sub-regions, South West Queensland, Desert Channels, Pilbara sub-region of WA Rangelands

# Abbreviations

## IN THIS REPORT

TERM	DEFINITION
ABS	Australian Bureau of Statistics
AFCMP	Australian Feral Camel Management Project
NRM	natural resource management
SDM	species distribution modelling
TGP	total grazing pressure

## IN ALL REPORTS IN THE SERIES

TERM	DEFINITION
ACRIS	Australian Collaborative Rangelands Information System
BoM	Bureau of Meteorology
BS	bare soil
CMA	Catchment Management Authority
DKCRC	Desert Knowledge Cooperative Research Centre
DSI	Dust Storm Index
EI	Ecoclimatic Index
EMU	Ecosystem Management Understanding™
ENSO	El Niño Southern Oscillation
FIFO	fly in, fly out
GAB	Great Artesian Basin
GCM	General Circulation Model
GDM	Generalised Dissimilarity Modelling
GHG	greenhouse gas
GW	Groundwater
GWW	Great Western Woodlands
IBRA	Interim Biogeographic Regionalisation for Australia
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
LEB	Lake Eyre Basin
LGM	last glacial maximum
MOF	manual observation frequency

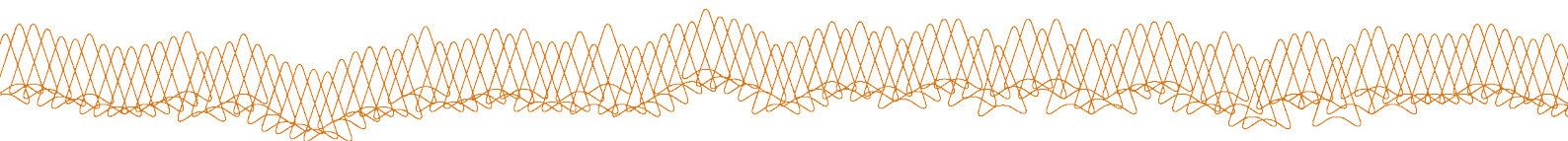
## IN ALL REPORTS IN THE SERIES

TERM	DEFINITION
mya	million years ago
NAFI	North Australian Fire Information
NCCARF	National Climate Change Adaptation Research Facility
NPV	non-photosynthetic vegetation: senescent pasture and litter
OH&S	occupational health and safety
PV	photosynthetic vegetation: green
RCP	Representative Concentration Pathways
SAAL	South Australia Arid Lands
SW	Surface water
TM	Thematic Mapper
Western CMA	Western Catchment Management Authority
Western LLS	Western Local Land Service

# Glossary

IN ALL REPORTS IN THE SERIES	
TERM	DEFINITION
Adaptive capacity	The ability to change and therefore reduce gross vulnerability; includes issues such as mobility, financial resources and education
Bioregion	A large, geographically distinct area of land that has groups of ecosystems forming recognisable patterns within the landscape
C <sub>3</sub> and C <sub>4</sub> plants	The different methods plants use to convert carbon dioxide from air into organic compounds through the process of photosynthesis. All plants use C <sub>3</sub> processes; some plants, such as buffel grass and many other warm climate grasses, also use C <sub>4</sub> processes. C <sub>4</sub> plants have an advantage in a warmer climate due to their higher CO <sub>2</sub> assimilation rates at higher temperatures and higher photosynthetic optima than their C <sub>3</sub> counterparts
Contentious species	A species that presents special challenges for determining the adaptation response to climate change, because it is both a threat and a beneficial species (Friedel et al. 2011, Grice et al. 2012)
Dust Storm Index (DSI)	The Dust Storm Index is based on visibility records made by Bureau of Meteorology (BoM) observers. The DSI provides a measure of the frequency and intensity of wind erosion activity at continental scale. It is a composite measure of the contributions of local dust events, moderate dust storms and severe dust storms using weightings for each event type, based upon dust concentrations inferred from reduced visibility during each of these event types.
DustWatch	DustWatch is a community program that monitors and reports on the extent and severity of wind erosion across Australia and raises awareness of the effects of wind erosion on the landscape and the impacts of dust on the community.

IN ALL REPORTS IN THE SERIES	
TERM	DEFINITION
Ecological refugia	Refugia defined according to the water requirements of the species they protect. The conservation significance of ecological refugia, and the priority assigned to their conservation, depends on the level of knowledge available for the species they support.
Evolutionary refugia	Those waterbodies that contain <i>short-range endemics</i> or <i>vicariant relics</i> . Evolutionary refugia are most likely to persist into the future and should be accorded the highest priority in NRM adaptation planning.
Generalised Dissimilarity Modelling (GDM)	A method of modelling based on compositional turnover of a group of species at a location; it considers whole biological groups rather than individual species
Gross vulnerability of a system	The combination of exposure and sensitivity of system
Heatwave	Continuous period beyond a week when a particular threshold temperature is exceeded
Hyporheic water flows	Below-surface flows
Indicators of exposure	Factors such as days above a certain temperature, days without rainfall, population density
Indicators of sensitivity	How sensitive a system is to hazards; indicators include the types of dwellings people live in and the percentage of the population with certain health characteristics
'No regrets' strategies	These strategies yield benefits even if there is not a change in climate
Novel ecosystem	Species occurring in combinations and relative abundances that have not occurred previously within a given biome (Hobbs et al. 2006)
Rainfall event	One or more closely spaced rainfalls that are large enough to produce a significant vegetation response



#### IN ALL REPORTS IN THE SERIES

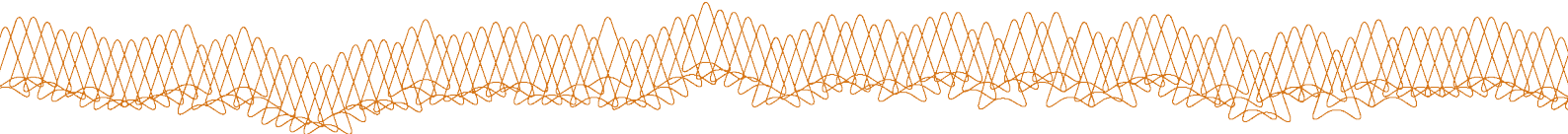
TERM	DEFINITION
Refugia	Habitats that biota retreat to, persist in and potentially expand from under changing environmental conditions
Return period	The number of days from the end of one rainfall event to the start of the next
Reversible strategies	Flexible strategies that can be changed if predictions about climate change are incorrect
Safety margin strategies	Strategies that reduce vulnerability at little or no cost
Species Distribution Modelling (SDM)	A species-specific approach whereby observational records are used to model the current potential distribution of a species
Short-range endemics	Species that occur only within a very small geographical area
Soft strategies	Strategies that involve the use of institutional, educational or financial tools to reduce species vulnerability to climatic change
Species invasiveness	A species that causes environmental or socioeconomic impacts, is non-native to an ecosystem or rapidly colonises and spreads (see Ricciardi and Cohen 2007). In the Invasive animals report it refers to non-native species (that is, those introduced to Australia post-1788) that have caused significant environmental or agricultural changes to the ecosystem or that are believed to present such a risk.
Strategies that reduce time horizons	Strategies that reduce the lifetime of particular investments
Vicariant relicts	Species with ancestral characteristics that have become geographically isolated over time





## References

- Allen BL and West P (2013) Influence of dingoes on sheep distribution in Australia. *Australian Veterinary Journal* 91(7), 261–267.
- Australian Government (2005) *Threat abatement plan for predation, habitat degradation, competition and disease transmission by feral pigs*. Department of the Environment and Heritage, Canberra.
- Australian Government 2011a. *Feral horse (Equus caballus) and feral donkey (Equus asinus)*. Accessed on 25 June 2014 at: <http://www.environment.gov.au/system/files/resources/b32a088c-cd31-4b24-8a7c-70e1880508b5/files/feral-horse.pdf>.
- Australian Government 2011b. *Threat abatement plan for the biological effects, including lethal toxic ingestion, caused by cane toads*. Accessed on 25 June 2014 at: <http://www.environment.gov.au/resource/threat-abatement-plan-biological-effects-including-lethal-toxic-ingestion-caused-cane-toads>.
- Brown GP, Phillips BL and Shine R (2011) The ecological impact of invasive cane toads on tropical snakes: Field data do not support laboratory-based predictions. *Ecology* 92(2), 422–431.
- Caley P, Tennant P and Hood G (2011) *Modelling the distribution of vertebrate pests in New South Wales under climate change*. Invasive Animals Cooperative Research Centre, Canberra.
- Carr A J (2011) *Asian Honeybee: potential environmental impacts*. Report for the Department of Sustainability, Environment, Water, Population and Communities. Sustineo Pty Ltd., Canberra.
- Choquenot D (2008) Donkey *Equus asinus*. In *The mammals of Australia*. 3rd edition. Eds. S van Dyck and R Strahan. pp. 751–752. Reed New Holland, Sydney.
- Crowther M S, Fillios M, Colman N and Letnic M (2014) An updated description of the Australian dingo (*Canis dingo* Meyer, 1793). *Journal of Zoology* 293(3), 192–203.
- Denny E (2008) Cat *Felis catus*. In *The mammals of Australia*. 3rd edition. Eds. S van Dyck and R Strahan. pp. 742–744. Reed New Holland, Sydney.
- Dickman CR (1996) *Overview of the impact of feral cats on Australian native fauna*. Report to the Australian Nature Conservation Agency, Canberra.
- Edwards GP, Zeng B, Saalfeld WK, Vaarzon-Morel P and McGregor M (2008) *Managing the impacts of feral camels in Australia: a new way of doing business*. DK-CRC Report 47. Desert Knowledge Cooperative Research Centre, Alice Springs.
- Forsyth DM, Woolnough AP, Nimmo DG, Ritchie EG, Kennedy M, Pople A and Watson I (in press). A comment on the influence of dingoes on the Australian sheep flock. *Australian Veterinary Journal*.
- Gong W, Sinden J, Braysher M and Jones R (2009) *The economic impacts of vertebrate pests in Australia*. Invasive Animals Cooperative Research Centre, Canberra.
- Hellman J, Byers J, Bierwagen B and Dukes J (2008) Five potential consequences of climate change for invasive species. *Conservation Biology* 22(3), 534–543.
- McLeod R (2004) *Counting the cost: impact of invasive animals in Australia*. Cooperative Research Centre for the Biological Control of Pest Animals, Canberra.
- Molloy KL and Henderson WR (Eds) (2006) Science of Cane Toad Invasion and Control. *Proceedings of the Invasive Animals CRC/CSIRO/Qld NRM & W Cane Toad Workshop*, June 2006, Brisbane. Invasive Animals Cooperative Research Centre, Canberra.
- Ninti One Limited (2013) *Managing the impacts of feral camels across remote Australia – final report of the Australian Feral Camel Management Project*. Ninti One Limited, Alice Springs.
- Oldroyd BP, Lawler SH and Crozier RH (1994) Do feral honey bees (*Apis mellifera*) and regent parrots (*Polytelis anthopeplus*) compete for nest sites? *Australian Journal of Ecology* 19(4), 444–450.
- Paton DC (1996) *Overview of feral and managed honeybees in Australia: distribution, abundance, extent of interactions with native biota, evidence of impacts and future research*. Australian Nature Conservation Agency, Canberra.
- Pople T and Froese J (2012). *Distribution, abundance and harvesting of feral goats in the Australian rangelands 1984–2011*. Final report to the ACRIS Management Committee. Biosecurity Queensland, Department of Employment, Economic Development & Innovation, Brisbane.

- 
- Ricciardi A and Cohen J (2007) The invasiveness of an introduced species does not predict its impact. *Biological Invasions* 9(3), 309–315.
- Ripple WJ, Estes JA, Beschta RL, Wilmers CC, Ritchie EG, Hebblewhite M, Berger J, Elmhagen B, Letnic M, Nelson MP, Schmitz OJ, Smith DW, Wallach AD and Wirsing AJ (2014) Status and ecological effects of the world's largest carnivores. *Science* 343(6167), doi: 10.1126/science.1241484.
- Saalfeld WK (2005) A successful unsuccessful feral animal management plan. *Proceedings of the 13th Australasian Vertebrate Pest Conference*, Wellington, New Zealand, p. 267.
- Saalfeld WK, Walters A and Hooper D (2006) *Aerial survey of donkey and horse populations in the Victoria River District 2006*. Technical Report. Northern Territory Department of Natural Resources, Environment and the Arts, Darwin.
- Saunders G, Coman B, Kinnear J and Braysher M (1995) *Managing vertebrate pests: foxes*. Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.
- Saunders G and McLeod L (2007) *Improving fox management strategies in Australia*. Bureau of Rural Sciences, Canberra.
- Sutherst R (2000) Climate change and invasive species: a conceptual framework. In *Invasive species in a changing world*. Eds. HA Mooney and RJ Hobbs. pp. 211–240. Washington Island Press, Washington.
- Tylianakis JM, Didham RK, Bascompte J and Wardle DA (2008) Global change and species interactions in terrestrial ecosystems. *Ecology letters* 11(12), 1351–1363.
- West P (2008) *Assessing invasive animals in Australia 2008*. National Land & Water Resources Audit, Canberra.
- Wicks S, Mazur K, Please P, Ecker S and Buetre B (2014) *An integrated assessment of the impact of wild dogs in Australia*. ABARES report number 14.4, Canberra.
- Williams CK and Myers K (2008) Rabbit *Oryctolagus cuniculus*. In *The mammals of Australia*. 3rd edition. Eds. S van Dyck and R Strahan. pp. 745–747. Reed New Holland, Sydney.
- WoolProducers Australia (2014) *National Wild Dog Action Plan: Promoting and supporting community-driver action for landscape-scale wild dog management*. WoolProducers Australia 2014, Canberra.



## Contact Details

Chris Pavey  
Land and Water Flagship  
+61 8 8950 7173  
chris.pavey@csiro.au