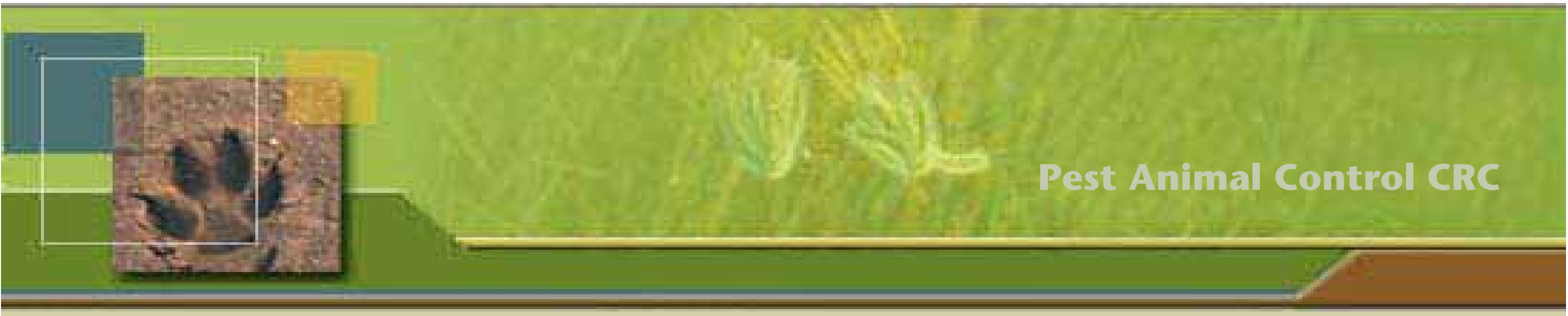

Review of the management of feral animals and their impact on biodiversity in the Rangelands

A resource to aid NRM planning

PAC CRC Report June 2005

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Pest Animal Control CRC

Natural Heritage Trust
Helping Communities Helping Australia
An Australian Government Initiative

CRC AUSTRALIA

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A report to the Australian Government Department of the Environment and Heritage prepared by the Pest Animal Control Cooperative Research Centre

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Section 1 Project brief

The Pest Animal Control Cooperative Research Centre (PAC CRC) was commissioned by the Australian Department of the Environment and Heritage to review feral animal management for biodiversity outcomes in the Rangelands. This review was undertaken to help guide future Natural Heritage Trust spending on feral pest management and control in the Rangelands.

The outcomes of the project were to:

- provide options for the Australian Government to better target its action and investment to limit the impact of feral animals on biodiversity in the Rangelands
- assist Australian Government officers to assess the adequacy and effectiveness of proposed feral animal projects in the context of the Natural Heritage Trust regional planning process
- improve the regions' ability to plan for and implement feral animal management in an integrated way to protect biodiversity.

The report achieves these outcomes by:

- summarising relevant Australian Government, State and Territory legislation, as well as government and private arrangements (Section 4);
- documenting existing methods for the management of feral animals (Section 5);
- assessing the adequacy of these methods and their applicability to the Rangelands (addressed in Sections 5 and 7);
- identifying gaps and opportunities for targeting Commonwealth action and investment in the management of feral animals in the Rangelands (Section 7).
- developing a checklist for best practice planning and management of feral animals, to assist regions to develop programs and projects, and to allow Government officers to assess those programs and projects (Section 8)
- listing rangeland feral animal management projects previously funded under the Natural Heritage Trust and other programs (Appendix 3)

The report begins with a major section that lists feral animal species found in the Rangelands, summarising their distribution and impacts on biodiversity (Section 3).

Section 2 Introduction

Feral animals have damaged biodiversity in the Rangelands on a scale unmatched on any other continent.

Australia has lost far more mammals to extinction than any other country. Nowhere in temperate Australia can an intact mammal fauna still be found. To quote from the federal government's *Action Plan for Australian Mammals* (Maxwell *et al.* 1996): 'Australia accounts for about one third of all mammal extinctions world-wide since 1600 and most extinct Australian mammals were marsupials.' Most of the extinct mammals lived in the Rangelands.

When those extinctions are analysed it becomes clear that habitat loss, often touted as the main cause of extinctions, is only a minor consideration: 'while land clearing has reduced the range of many species and is contributing to current declines, it has probably been the primary cause of extinction of only one (Maxwell *et al.* 1996)'.

The *Action Plan* explains the extinctions thus:

> 'In summary, it appears that the interaction of three factors – changes to habitat caused by introduced herbivores, homogenisation of habitat following changed fire regimes and, particularly, the spread of exotic predators – has been mainly responsible for the high extinction rate of marsupials since European settlement of Australia'.

By 'exotic predators', the authors mean foxes and cats, and the introduced herbivores include rabbits.

Apart from the loss of mammals, feral animals in the Rangelands have degraded vast tracts of habitat, promoted invasion by serious weeds, and pose an ongoing threat to rare plants and animals. Buffalo, as one example, have completely denuded some floodplain areas, caused sheet and gully erosion, and the deaths of vast paperbark forests from hydrological changes that include seawater denudation. Feral animals also cause enormous economic losses in the Rangelands by destroying crops and livestock and degrading landscapes.

The losses from feral animals would be much greater except for the enormous amounts of time, effort and money poured into pest animal control by landholders, biodiversity managers and pest agencies. Australia is a world leader at controlling feral pests for economic and biodiversity outcomes.

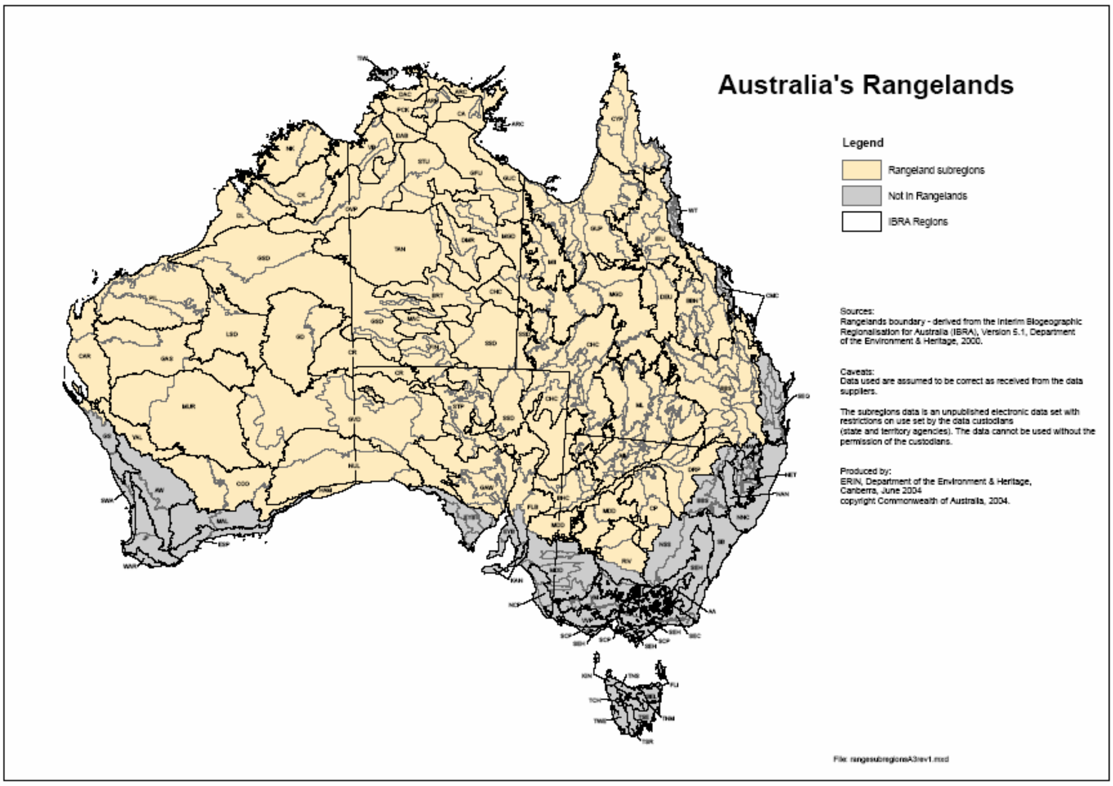
Because of this effort, the numbers of some pest species have been reduced, although other pests are increasing in number and severity of impacts. This survey has found that at least 16 species of feral animal are increasing their range within the Rangelands and another six species have become newly established. Increased effort is required to successfully manage these pests.

The federal government spends heavily on pest control to protect biodiversity. Much of that funding is channelled through the Natural Heritage Trust (NHT), managed by the Department of the Environment & Heritage (DEH). The NHT has been operating for eight years and during that period more than 300 projects with a pest management component have been funded.

This report has been produced on behalf of the Department of the Environment & Heritage to guide future NHT spending on feral animal management and control in the Rangelands.

The Rangelands are defined as those extensive regions of Australia, generally unsuitable for cropping, where grazing is the main land use. About 75 per cent of the Australian continent falls within the Rangelands.

Figure 1 Map of the Australian Rangelands



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Abbreviations:

CALM – Department of Conservation and Land Management
DNR&M – Department of Natural Resources and Mines, Queensland
EPA – Environment Protection Agency, Queensland
DPI&F – Department of Primary Industries and Fisheries, Queensland

Section 3 A status review of feral animals in the Rangelands

3.1 Species covered

House Mouse	Brown Rat	Black Rat
Dingo	Red Fox	Cat
Rabbit	European Hare	Horse
Donkey	Pig	One-humped Camel
Swamp Buffalo	Bali Banteng	Cow
Goat	Blackbuck	Fallow Deer
Red Deer	Sambar Deer	Rusa Deer
Chital Deer	Ostrich	Helmeted Guinea-fowl
Mallard	Rock Dove	Laughing Turtle-dove
Spotted Turtledove	Barbary Dove	Skylark
House Sparrow	Nutmeg Mannikin	European Goldfinch
Common Blackbird	Common Starling	Common Myna
Asian House Gecko	Flowerpot Snake	Cane Toad

3.2 Introduction

Nearly all exotic vertebrates found within the Rangelands are described here, and their impact on biodiversity is summarised. The information on impacts derives largely upon interviews with more than 40 biodiversity managers and pest managers (see page 8) working for state and federal agencies. (More than 100 reports and journal articles were consulted as well). By drawing upon a wide pool of experts working across the Rangelands, the assessments of impacts are more current than would be possible if reports and other publications were the main source of data. Indeed, many of the problems identified here are not adequately documented in the published literature. The information presented here provides the basis for Section 7 which identifies gaps in spending on feral animal management.

This chapter begins with sections that summarise each vertebrate class before describing species individually.

Species listed on Schedule 1 of the *Endangered Species Protection Act 1992*, as facing a threat or perceived threat from a particular feral animal, are listed under that feral animal. These lists have been edited to remove species that do not occur in the Rangelands. The lists are not comprehensive, and not necessarily accurate.

3.3 Mammals

Twenty two species of feral mammal are thought to occupy the Rangelands today. (The presence of one species, the Brown Rat, has not been confirmed but seems highly likely). Australia has more introduced mammals than introduced birds, reptiles, or amphibians and their overall impacts have been far greater. Foxes and cats are believed to have caused or contributed to various extinctions of marsupials and native rodents. Foxes, cats, pigs and goats pose a threat to various rare animals and/or plants, either by preying upon them or by competition and habitat degradation. Rabbits, goats, buffalo, donkeys, pigs, horses, and feral cattle – in the approximate order listed - have caused major landscape degradation. Banteng, red deer and chital deer have caused significant land degradation more locally.

Feral mammals, unlike other groups of exotic vertebrates, occur throughout the Rangelands. There are vast tracts of inland and north-western Australia that do not support introduced birds, reptiles, amphibians or fish, but there are no Rangelands areas, apart from some mangrove forests, that do not support exotic mammals. Most localities support several species, often half a dozen or more.

Feral mammals have permanently transformed Australia. Hoofed mammals are now the largest animals in most terrestrial habitats in the Rangelands. Foxes and cats are now the main mammalian predators. Most habitats are missing several native mammals because of predation by feral animals. Many landscapes are permanently eroded by feral animals. As a threatening process, feral mammals are most harmful to other mammals, and to plants. Very few birds are threatened by feral mammals within the Rangelands (the Malleefowl is a noteworthy exception). No reptiles or amphibians are threatened by feral mammals within the Rangelands, apart from marine and freshwater turtles, which lose eggs to foxes, dingoes and pigs, and the Great Desert skink, which apparently suffers predation from feral predators. Turtles appear to be particularly susceptible to egg predation from exotic mammals, and this is a major cause for concern (Section 7).

Regrettably, this survey has found that eight species of feral animal are increasing their range within the Rangelands, and two species have newly colonised (Table 1). The blackbuck and *Rattus tanezumi* (see under Black Rat) may also represent new colonists but information is lacking.

Table 1 Exotic mammals in the Rangelands that are expanding their range or newly colonising it.

Expanding in range	**Where**	**Scale of problem**
Black Rat	NT (Kakadu)	Low (?)
Red Fox	NT (?) and Qld	High (?)
Pig	NT (Top End)	Locally high
One-humped Camel	WA, NT	High
Swamp Buffalo	NT (Arnhem Land)	Locally high
Feral Cow	WA (Kimberley)	High
Fallow Deer	NSW, QLD	Medium
Chital Deer	NSW, QLD	High
New to the Rangelands	**Where**	**Scale of problem**
Red Deer	NSW, QLD	High
Rusa Deer	NSW, QLD	High
Insufficient information	**Where**	**Scale of Problem**
Blackbuck	Spreading in QLD?	Unknown
Rat (*Rattus tanezumi*)	Present in the Rangelands?	Low

3.4 Birds

Thirteen (or 14) species of feral bird occupy the Rangelands today, although very few of them use natural or semi-natural areas. Six are confined to towns and homesteads, and two barely occur within the Rangelands (Table 2). The other five make some use of semi-natural or natural habitats but only on a limited scale and within limited areas (Table 2). As well, ostriches may occur in scattered locations. Western Australia and the Northern Territory are almost free of feral birds.

Table 2 Distribution and habitat status of feral birds

Confined to towns and homesteads and their vicinity
Helmeted Guinea-fowl Rock Dove Laughing Turtle-dove Spotted Turtle-Dove Barbary Dove House Sparrow
Only marginally present within the Rangelands (on the south-eastern edge)
Skylark European Goldfinch
Widespread and found at least occasionally in semi-natural habitats
Nutmeg Mannikin – Uses disturbed woodlands and grasslands in coastal Queensland Blackbird - In towns, homesteads and disturbed riparian forest in New South Wales Common Myna – Nests in woodlands along the eastern edges of the Rangelands zone Common Starling – Widespread in the eastern half of the Rangelands, and sometimes nesting in woodland remnants

Woodlands, rainforests, and other natural habitats within the Rangelands are, almost without exception, completely free of feral birds. Feral mammals, by contrast, have invaded almost every habitat. Because of their very limited presence within natural and semi-natural areas, feral birds do not appear to be having a major impact upon biodiversity. Hybridisation between Mallards and Black Ducks is one concern, and competition between Starlings and Mynas for tree holes used by native birds is another, although no threats to any listed species were recorded. (Starlings pose a threat to vulnerable Superb Parrots, but outside the Rangelands.)

Table 3 Biodiversity Impacts of feral birds (listed in approximate order of severity)

Common Starling	Competes with declining birds for nest holes
Mallard	Hybridises with native Black Duck
Common Blackbird	Probably spreads the seeds of some serious shrubby weeds such as Boxthorn and Blackberry
Common Myna	Competes with birds for nest holes, but not known to compete with any rare species
Nutmeg Mannikin	Apparently competes with the Chestnut-breasted Mannikin (a common bird) in disturbed habitats close to towns

Although the biodiversity impacts appear minor at present, this situation could change. If Nutmeg Mannikins colonise the Northern Territory (which seems likely) they could compete seriously with the Yellow-rumped Mannikin, a bird of conservation concern. If Helmeted Guinea-fowl spread widely through the Rangelands they could exert a significant impact in a wide range of habitats due to their large size, potential abundance (as recorded in Africa) and potential to serve as a prey species for dingoes and foxes. Many of the feral birds found in the Rangelands have the potential to greatly increase their range, especially into Western Australia, although the main impact would be upon agricultural productivity and human amenity, not biodiversity.

3.5 Reptiles and amphibians

Only two foreign reptile species occur within the Rangelands and they have a negligible impact upon biodiversity. A third species of reptile may invade the Rangelands in the near future, the Red-eared Slider (see Section 7) and it can be expected to have a major impact upon wetlands.

Only one foreign amphibian has become established within Australia – the Cane Toad – and its impact has been substantial. Cane Toads prey on native fauna, compete for resources (food, shelter, breeding sites), and poison native predators. This last impact is by far the most significant, and Northern Quolls are the species most affected, with the virtual disappearance of Quolls from Kakadu National Park.

3.6 Fish

Approximately 34 exotic fish species have established populations in Australian freshwaters. The major pathway for introduction has been the ornamental fish industry, with 22 of the 34 feral fish species originating from this source through deliberate or accidental release (McNee 2002, Lintermans 2004). Other species have been deliberately introduced for aquaculture, biocontrol and recreational angling. More than twelve species of feral fish are found in the Rangelands, with the largest number of species occurring in the Ross River near Townsville, and with large numbers also occurring in the Murray-Darling Basin and the Burdekin catchment in the north-east. Tilapia, Jewel Cichlid, Blue Acara, Midas Cichlid, Burton's Haplochromus and Tench are currently rare in the Rangelands, only occur in small populations and are unlikely to have any major impacts at present.

Table 4 Exotic fish which have established wild populations in the Rangelands

Species	Distribution
Carp	NSW, SA, QLD
Goldfish	NSW, SA, QLD
Mosquito-fish	NSW, SA, QLD
Redfin Perch	NSW, SA, QLD
Tilapia	QLD, WA (Gascoyne region only)
Blue Acara	QLD
Midas Cichlid	QLD
Burton's Haplochromus	QLD
Tench	NSW (Riverina and Murray-Darling Downs)
Jewel Cichlid	NT (Darwin)

Information on the impacts of feral fish on native species is often anecdotal and fragmentary, and few conclusive studies have been conducted on their impacts on biodiversity.

3.7 Species accounts

Square brackets under 'common names' indicates an old scientific name. The arrangement of mammals in each order follows Stanger *et al.* (1998). The order of birds follows Christidis & Boles (1994).

Mammals

3.7.1 House Mouse (*Mus musculus*)

Summary

Very widely distributed within the Rangelands and often locally common, but not likely to be posing a significant threat to biodiversity, unless as a predator of seeds.

Distribution

Widespread in open arid habitats except in very dry areas far from water. During long drought periods mice are confined to damp refugial areas near permanent water. After rains and lush plant growth in arid areas they may multiply into plague numbers. They do best in areas where soils are well suited to burrowing. Scarce or absent from heavily vegetated habitats such as eucalypt forests and rainforests. Often abundant in cropping areas, most of which fall outside the Rangelands.

Native to south-west Europe.

Impacts

Although house mice are very widely distributed in Australia they are not considered to pose much of a threat to biodiversity. Earlier suggestions by Newsome and Corbett (1975) that introduced mice displaced native rodents in arid Australia have been refuted (Morton & Baynes 1985, Morton 1990).

Where remnant vegetation grows close to cereal crops, mice that multiply into plague numbers are likely to prey heavily on the seeds of those native plants that produce relatively large seeds, possibly resulting in their elimination (G, Mutze, pers. comm.). (A decline in large-seeded weeds from wheat-growing areas after plagues is attributed to this process.) This impact, if it occurs, could be serious within the Western Australian wheat belt, but would be less significant within the Rangelands where mouse plagues are smaller.

Mice may also pose an indirect threat to fauna. Smith and Quin (1996) argue that high mouse numbers during mouse plagues support elevated numbers of feral cats, which then prey heavily on rare mammals. This remains speculative, but it is accepted that mice pose a limited indirect threat to the plains-wanderer, a bird listed as endangered (NSW) or vulnerable (DEH). The principal threat to this quail-like bird is habitat loss due to cropping and inappropriate grazing, but fox predation becomes an issue where plains-wanderers occur close to rice-growing regions on the Riverine Plain of western New South Wales (Baker-Gabb 1988, Garnett & Crowley 2000). Large numbers of mice living within the rice fields support elevated numbers of foxes which also prey on Plains-wanderers. The NSW Draft Recovery Plan for the bird states, 'In this situation the need for fox control increases markedly, but it is still not as important as appropriate habitat management' (NSW National Parks and Wildlife Service 2002).

A suggestion that mice transmit fatal pathogens to native rodents (Newsome 1993) has not been supported by much evidence, although it has not been refuted either.

Mice in grain-growing areas periodically erupt into plagues, and plague mice probably prey heavily on native plants and invertebrates in farming regions, but without posing a known threat to any species. It seems plausible that mice in some areas might skew vegetation structure by preying heavily upon particular seed species, but they seldom occur in consistently high numbers in habitats of conservation significance. They prey mainly upon seeds and insects, but also take fungi and moss (Watts & Aslin 1981). Mice, along with rabbits, are blamed for damage to vegetation in the Simpson Desert in South Australia when in high numbers (Morton *et al.* 1995).

The best-documented impact of mice is to serve as an important food source for native fauna. In studies of the barn owl in the Rangelands house mice constitute as much as 97 per cent of the diet (Morton & Martin 1979). Mice are also eaten by black-shouldered kites, nankeen kestrels, kookaburras and brown snakes. Eastern brown snakes are increasing in abundance in some rural areas, and Wilson and Knowles (1988) attribute this to the ready availability of house mice, although the presence of rats and a favourable vegetation structure (pastures and low annual crops) has probably contributed as well.

The house mice in Australia include hybrids with a South-east Asian species, *Mus castaneus* (K. Aplin, pers. comm.).

3.7.2 Brown Rat (*Rattus norvegicus*)

Other name

Norway Rat

Summary

A rodent of urban environments that is unlikely to pose any threat to biodiversity.

Distribution

No records from the Rangelands were noted, but this rodent is likely to be present in Townsville, Rockhampton, Gladstone and other urban centres in Queensland. Recorded from other urban areas in eastern and southern Australia and from some rural areas.

Probably native to northern Eurasia.

Impacts

None likely.

3.7.3 Black Rat (*Rattus rattus*)

Other Name

Ship Rat

Summary

A rodent that contributes to the reproductive failure of the rare Little Tern, but which otherwise poses no apparent threat to biodiversity.

Distribution

Found in scattered populations in coastal and sub-coastal districts of the Rangelands, in urban, rural, semi-natural areas and sometimes in intact woodland, forest and mangroves.

Native to Asia.

Impacts

Although black rats are blamed for the extinctions of bird species on Lord Howe and Norfolk Islands (Garnett & Crowley 2000), and for serious declines of birds in New Zealand (King 1990), they do not appear to threaten any species with extinction in the Rangelands. They do, however, prey on the eggs and chicks of the rare little tern. Little terns nest on islands and many mainland beaches in northern and eastern Australia, but black rats are not present at many of these sites. little terns are also threatened by human disturbance, dogs, foxes, pigs, silver gulls, ravens, etc. (Garnett & Crowley 2000), with rats contributing to the high failure rate at some nesting colonies, although mainly not in the Rangelands. Rats also prey on various invertebrates, seeds, grass, tubers and fungi (Watts & Aslin 1981) but are not implicated in the declines of any of these. Nor do they appear to have displaced any native rodents (Strahan 1995).

In the Northern Territory they appear to be multiplying in numbers and expanding their range. In recent years they have been recorded at several remote sites in intact habitat in Kakadu National Park (J. Woinarski, pers. comm.). They were previously unknown in Kakadu.

Burbidge and McKenzie (1989) suggested that black rats may have eliminated native pale field rats (*Rattus tunneyi*) from habitats between Shark Bay and the Kimberley. This proposition is not entirely convincing because pale field rats have disappeared from many regions in central Australia where black rats do not occur (Watts & Aslin 1981). Morris (2000) reviewed rodent conservation in Western Australia and did not repeat this suggestion.

The black rat, as it is defined globally today, is a composite species. Unpublished research shows that there are several genetically distinct species masquerading under the one name (K. Aplin, pers. comm.), including *R. tanezumi* (Strahan 1998). It is conceivable that the black rats invading Kakadu may represent a species that is new to the Northern Territory.

3.7.4 Dingo (*Canis familiaris dingo*)

Summary

A feral animal introduced to Australia thousands of years ago, now integrated into Australian ecosystems, but which sometimes poses a threat to rare animals, notably turtles and hairy-nosed wombats. Dingoes play a positive role by suppressing various feral animals (rabbits, goats, cats, foxes) as well as overabundant kangaroos and wallabies, but their value in controlling these species is sometimes limited and overstated.

Distribution

Formerly found throughout Australia but now exterminated from most of the Rangelands in New South Wales, southern Queensland (except the far south-west) and south-eastern South Australia. Control of dingoes is most intense in sheep producing regions in Queensland, New South Wales, South Australia and Western Australia.

Dingoes, unlike foxes and cats, must drink regularly, and their range in arid areas is limited by access to water.

Dingoes were first bred in South-east Asia from an Asian subspecies of the wolf (*Canis lupus*), and introduced into Australia, presumably by Indonesian seafarers, about 3 500 to 4 000 thousand years ago.

Impacts

Dingoes are often blamed for the past disappearance from mainland Australia of the thylacine, Tasmanian devil and Tasmanian native hen (Low 1999), although Wroe and Johnson (2003-04) argue that changes in Aboriginal culture (intensification) could have caused these extinctions.

Dingoes are considered to occupy a legitimate place in Australian ecosystems. They were introduced so long ago they are now integrated into natural environments, where they help control numbers of kangaroos and wallabies which might otherwise overgraze native vegetation, and exert some control over feral rabbits, cats, foxes, pigs and especially goats. Because dingoes were introduced to Australia by people they should not, however, be called ‘native dogs’. Most dingo populations are now interbred with more recently introduced dogs.

In some situations, under changed circumstances, dingoes have become a threat to rare species. The most dramatic instance has arisen in central Queensland, where in 2000-01, dingoes killed seven critically endangered hairy-nosed wombats out of a total population of only 113 (Torr 2004). The only reserve in which the wombats occur, Epping Forest National Park, has since been fenced at a cost of $400 000 to exclude dingoes.

Another significant concern is dingoes and dogs preying on the eggs of endangered freshwater and marine turtles. Evidence has recently been obtained to show that two threatened freshwater turtles in Queensland – the vulnerable Fitzroy River turtle (*Rheodytes leukops*), and the Burnett River snapping turtle (*Elseya albigula*) – are losing most of their eggs to predators, including foxes, dingoes, dogs, pigs, cats, goannas and water rats (C. Limpus pers. comm.). This problem is considered further in Section 7. Olive Ridley turtles and vulnerable flatback turtles along the Northern Territory coast east of Darwin are also suffering from unacceptably high predation rates (R. Chatto pers. comm.). Here, dog and dingo predation is not thought to have increased, but turtle numbers have declined so seriously that any predation of eggs is significant. Ray Chatto of the Northern Territory Parks and Wildlife Commission is preparing a report on this matter which may recommend dog control at ‘hotspot’ sites, nearly all of which occur on Indigenous lands (Section 9).

Dingoes can become a threat to wildlife because of two factors: in some areas their numbers have risen because of provision of water and increased abundance of food (mainly macropods and rabbits), and because some animals are now so rare that any mortality poses a threat to their future.

Some threatened species are now so rare that dingoes are controlled along with other predators. In north-western South Australia the black-flanked rock wallaby has been reduced to three very small colonies. Foxes are implicated as the cause of this decline, but the baiting programs target dingoes as well. Dingoes were considered a significant predator of endangered Rufous hare-wallabies (Lundie-Jenkins *et al.* 1993) in the Northern Terrirory, prior to their becoming extinct in the wild because of cat predation.

Dingoes are usually valued by biodiversity managers because they exert some control over other feral animals and kangaroos. In the Tanami, dingoes prey on threatened Bilbies, but they also suppress Foxes and Cats, which are worse predators of bilbies (Glen Edwards pers. comm.). In one study in the Tanami, cat remains were found in nine per cent of dingo scats, suggesting that dingoes exercise a considerable degree of control over cats (R. Paltridge pers. comm.). The Northern Territory Parks and Wildlife Commission is testing toxic baits placed inside funnels that permit access to foxes but not cats or dingoes. The southern region of Australia, from which dingoes have largely been extirpated, corresponds with the region from which most native mammal extinctions have occurred, and in which Goats are most destructive, and the role of dingoes in suppressing fox, cat and goat numbers appears to be very significant to biodiversity.

In large intact areas, dingoes could be considered innocent until proven guilty, but where threatened fauna are disappearing from small or degraded areas, dingoes should be considered guilty until proven innocent.

3.7.5 **Red Fox *(Vulpes vulpes)***

Summary

The fox is a major predator blamed for the extinction of several marsupials and the threatened status of other species. In some situations foxes provide a benefit by controlling rabbits.

Distribution

Foxes occur throughout the southern half of Australia, as far north as the Great Sandy Desert, Tanami Desert, the Gulf country of Queensland, and north Queensland. It is most absent from Cape York Peninsula, parts of central Queensland, the Top End of the Northern Territory and the Kimberley.

Some experts contend that foxes are spreading northwards (Edwards *et al.* 2003). This could not be confirmed because the northern limit of the fox fluctuates, expanding northwards after a run of good years and contracting southwards during droughts (Strahan 1998). Surveys of the Tanami Desert in the Northern Territory in the 1980s did not record foxes, yet foxes occur there today. However, the earlier surveys, which relied on trapping and night drives, could have overlooked foxes, which are best detected by searching for their tracks (R. Paltridge pers. comm.). Traditional occupants of the Tanami remember foxes arriving in the 1940s (R. Paltridge, pers. comm.) so foxes are not new to the Tanami.

A fox was recently recorded in Lakefield National Park on Cape York Peninsula for the first time ever (J. Mitchell, pers. comm.), north of their usual range (Strahan 1998). A fox was also recorded for the first time by the Aboriginal community on the Dampier Peninsula (C. O'Malley pers. comm.). This was the only evidence that could be obtained to suggest that foxes might be moving north. Peter Mason (pers. comm.) said there is no general movement north in Western Australia, although foxes occasionally wander north as far as the Kimberley. Global warming should make it harder for foxes to expand northwards.

Native to Europe, Asia, North America and North Africa.

Impacts

Australia has lost more mammals to extinction than any other continent and foxes can be blamed for this more than any other factor. Foxes have plausibly been blamed for the extinction in the Rangelands of the following: western quoll (Kinnear *et al.* 2002), red-tailed phascogale (Kinnear *et al.* 2002, although the evidence is limited), numbat (Kinnear *et al.* 2002, Saunders *et al.* 1995), burrowing bettong (Short 1998), brush-tailed bettong or woylie (Kinnear *et al.* 2002, Short 1998), and Desert bandicoot (contra. Strahan 1998). Foxes are implicated because these mammals disappeared shortly after foxes arrived (Short 1998), or because recent fox control programs (outside the Rangelands) have led to a significant increase in marsupial numbers (Kinnear *et al.* 2002). Foxes are likely to have played a major role in other extinctions as well (e.g. lesser bilby, desert rat-kangaroo) but information is lacking because observers were few when these species disappeared.

Foxes now appear to pose a major threat to the following species, which have persisted within the Rangelands, but which are rare and threatened there: black-footed rock-wallaby (Kinnear *et al.* 2002, Saunders *et al.* 1995), yellow-footed rock-wallaby (Kinnear *et al.* 2002), brush-tailed possum (Kinnear *et al.* 2002), bush stone-curlew (Garnett & Crowley 2000), Fitzroy River turtle (*Rheodytes leukops*) and Burnett River snapping turtle (*Elseya albigula*). Foxes appear to pose a serious threat to bilbies in the Tanami and south-western Queensland, but not in the Gibson or Great Sandy Desert, where bilbies remain reasonably common despite some fox predation (C. O'Malley pers. comm.).

Foxes also prey on the following threatened species, although they do not pose the main threat to them:

- malleefowl (Garnett & Crowley 2000),
- plains-wanderer (Garnett & Crowley [2000], NSW National Parks and Wildlife Service [2002])
- little tern (Garnett & Crowley 2000),
- ground parrot (Garnett & Crowley 2000).

Foxes are also thought to pose a threat to the Great Desert skink (P. Copley pers. comm.), digging them out of their warrens. They are also thought to pose a threat to the endangered Julia Creek dunnart, and Bladensburg National Park is baited against foxes to protect the dunnart.

The significance of fox predation upon marsupial moles is now in question (J. Benshemesh pers. comm.), and these mammals may prove to be common and not in decline.

Foxes also prey heavily on the eggs of marine and freshwater turtles in Western Australia, and in Queensland, some nesting sites of marine turtles are baited to reduce fox predation, but predation remains a very serious problem in Queensland for the following species: Fitzroy River turtle, Burnett River snapping turtle, flatback turtle and green turtle (Sections 7). Other rare freshwater turtles may be at risk as well, for example the endangered Gulf snapping turtle (*Elusor lavarackorum*), but information is lacking (C. Limpus, pers. comm.). Fox predation is listed federally and in New South Wales as a threatening species, and threat abatement plans have been prepared in these two jurisdictions (Environment Australia [1999], NSW National Parks and Wildlife Service [2001]).

Key papers arguing for the role of foxes in mammal losses include Finlayson (1961), Richards and Short (1996), Short and Calaby (2001). Other explanations for the extinctions include the degradation of refugia hypothesis (Morton 1990) and the altered fire regime hypothesis, but these are losing credibility today, because native mammals that live in spinifex deserts independently of refugia have disappeared, and so too mammals from areas where Aboriginal burning was maintained.

Foxes are destructive predators partly because they engage in 'surplus killing', sometimes killing more prey than they can eat. Short *et al.* (2002) document various examples of individual foxes having killed but not eaten large numbers of rock wallabies, bettongs or other prey in a short period, and suggest that this behaviour (found also in dingoes but not cats), may help explain the rapid disappearance of various mammals after foxes first invaded.

Despite the evidence against foxes, there are circumstances under which fox control may not be warranted. Culling of foxes can result in elevated numbers of rabbits which may impose their own environmental cost (Banks *et al.* 1998). Foxes may thus have an environmental benefit and should not necessarily be controlled at sites supporting rare plants that are susceptible to rabbit browsing (P. Mahon pers. comm.). But one field experiment found that foxes (and cats) suppressed numbers of rabbits only when rabbit numbers were low because of a drought (Newsome *et al.* 1989). During a run of good years rabbit populations eventually 'escape' the control exerted by predators because they can breed continuously but carnivores only seasonally (Newsome *et al.* 1989).

The value of fox control on behalf of malleefowl in central Australia has been questioned (Peter Copley pers. comm.). The main threat to malleefowl in this region may be fire. Fox baiting (which also kills dingoes) may benefit feral cats by removing dingoes. The value of fox baiting in the New South Wales mallee has also been questioned (Joe Benshemesh pers. comm.).

Table 5 Species listed in the red fox *Threat Abatement Plan* (1999) and found within the Rangelands, for which foxes are a known or perceived threat. This list is not considered complete.

Known threat	
Scientific name	**Common name**
Leipoa ocellata	Malleefowl
Sterna albifrons	Little Tern
Macrotis lagotis	Greater Bilby
Petrogale lateralis	Black-footed Rock-wallaby
Caretta caretta	Loggerhead Turtle
Chelonia mydas	Green Turtle
Perceived threat	
Geopsittacus occidentalis	Night Parrot
Turnix melanogaster	Black-breasted Button-quail
Bettongia lesueur	Burrowing Bettong
Sminthopsis douglasi	Julia Creek Dunnart
Dasycercus cristicauda	Mulgara
Dasyuroides byrnei	Kowari
Leporillus conditor	Greater Stick-nest Rat
Onychogalea fraenata	Bridled Nailtail Wallaby
Zyzomys pedunculatus	Central Rock-rat
Dermochelys coriacea	Leathery Turtle

3.7.6 Cat (*Felis catus*)

Summary

A significant predator of reptiles and small mammals, thought to be responsible for the extinctions of native rodents and small bandicoots, and which is probably causing or contributing to the decline of other threatened species or preventing their recovery.

Distribution

Found almost throughout the Rangelands, but avoiding dense habitats such as rainforest and mangroves. Reaches highest densities in open arid environments supporting abundant small mammals (especially young rabbits) and reptiles. Usually uncommon in eucalypt forests and woodlands.

A belief that cats first colonised Australia from Dutch shipwrecks has been discounted by Abbott (2003).

Impacts

Cats have an important impact upon biodiversity, but the level of that impact remains uncertain (Dickman 1996) and contentious. Some experts believe that cats are responsible for many mammal extinctions, others dispute this. Some experts blame cats for declines in native birds but this is also disputed. The polarisation of opinions and lack of definitive studies precludes an accurate assessment of cat impacts. Cats are most likely to pose a threat as predators, but they may also compete with native fauna and transmit parasites.

The red fox is implicated in more mammal extinctions than the cat (Abbott 2003). Large tracts of the Rangelands have now lost all the native mammals (small macropods and bandicoots) within the favoured prey size of foxes. When nature reserves are baited with 1080, which targets foxes but not cats (which usually avoid baits), mammals such as rock wallabies, numbats, bettongs and quolls benefit greatly. This finding has been taken as evidence that Foxes are more harmful than cats, along with the fact that Tasmania and Kangaroo Island, which host cats but not foxes (apart from a few new arrivals) have not lost any small mammals to extinction. Many of the mammal extinctions more closely match the arrival of foxes than cats, which preceded them (Abbott 2002, Morris 2000, Short 1998). Furthermore, several dietary studies have found that cats prey largely upon young rabbits (Potter 1991).

Cats have eliminated colonies of bilbies, burrowing bettongs and Rufous hare-wallabies reintroduced to mainland sites, sometimes thwarting whole reintroduction efforts (Smith & Quin 1996). This is a serious problem, although it does not mean that cats caused the original declines because the reintroduced animals were few in numbers and naïve about predation.

However, some mammal disappearances predate the arrival of foxes and these can plausibly be attributed to cats, because they also fall within the small size range preferred by cats (up to 1 kilogram weight). They are the pig-footed bandicoot, Desert bandicoot and golden bandicoot (Abbott 2002), and various rodents (Morris 2000) including the white-footed rabbit-rat and several species of hopping mice. Smith and Quin (1996) argue that cat-caused extinctions among rodents are most plausible for species weighing up to 90 grams. However, many rodent species remain common in regions supporting cats, and some rodents were evidently declining before cats arrived. In a series of articles about conservation of native rodents appearing in the journal *Wildlife Research* in 2000 (volume 27), various threatening processes are canvassed but cats are not singled out as the worst threat. This does not mean they did not cause extinctions in the past.

The recovery plan for the endangered Julia Creek dunnart, confined to grasslands in north and central Queensland, identifies predation, principally by feral cats, as a 'key process threatening the viability of remnant populations' (Lundie-Jenkins & Payne 2004). The report notes:

> 'An investigation of the stomach contents of feral cats revealed that they were a significant predator of the Julia Creek dunnart and that predation can be locally high. It has been suggested that cats may have been responsible for the disappearance of Julia Creek dunnarts on the Lyrian property where they were once readily trapped…'

However, at Bladensburg National Park, the main reserve for Julia Creek dunnarts, cats are rarely seen, and foxes appear to pose a greater threat.

In Australia, most mammal extinctions have occurred in the southern half of the country. But many small mammals, including native rodents and bandicoots, are now declining in northern Australia, within the Kimberley and Top End (Morris 2000, Woinarski 2000, Strahan 1998). Cats may be contributing to these declines, although changes in fire regimes appear to be the main cause of decline (Woinarski I 2001), and browsing and trampling by buffalo and cattle may also pose a greater threat. Within Kakadu National Park, where rodents are declining, cats occur in very low numbers (J. Woinarski pers. comm.), but cats in low numbers may still pose a threat to declining mammals. Research is needed to determine whether cats pose a serious threat to the various rodents and bandicoots that are declining in northern Australia.

Cats are often thought to pose a serious threat to birds, yet dietary studies show that cats eat far more rabbits, rodents and reptiles than birds (Potter 1991). Garnett and Crowley (2000) assessed the conservation status of all declining birds in Australia, and listed Cats as a potential threat to only one species within the Rangelands, the enigmatic night parrot. Other potential threats to this bird include foxes, rabbits, camels, overgrazing by stock, and altered fire regimes, and cats are not clearly implicated. Because Garnett and Crowley drew upon a large pool of bird experts, their report is here considered more credible than that of Dickman (1996), who proposed on theoretical grounds that cats pose a threat to a significant number of declining birds. The perception that cats pose a dire threat to birds has arisen partly because many people see pet cats catching birds in gardens. But garden birds usually belong to abundant species, none of which are threatened by predation.

Cats in arid areas eat large numbers of reptiles, but Australia's reptiles appear to be remarkably resilient to new impacts, and very few species are listed as threatened. The Great Desert skink (*Egernia kintorei*) is one that may be threatened at some sites by cats.

Cats may also pose an indirect threat to native mammals by transmitting the protozoan parasite Toxosplasmosis. There are suggestions that Toxosplasmosis contributed to declines in quoll species (Abbott 2002), and the disease also infects bandicoots.

Cats can multiply quickly. They have a higher reproductive potential than foxes or dingoes, first breeding at ten months of age and breeding continuously under good conditions and at any time of year. They can build up numbers quickly after droughts break or during rabbit and rat plagues. They can produce three litters in a year with a litter containing as many as eight kittens. Unlike dingoes they do not need to drink. They will take prey weighing up to two kilograms, but impact falls most heavily on smaller species, especially those weighing <220 g (Dickman 1996).

Table 6 Species listed on the cat *Threat Abatement Plan* (1999) for which cats are a known or perceived threat. This list was compiled some years ago and is not considered here to be entirely accurate.

Known threat	
Scientific name	**Common name**
Lagorchestes hirsutus	Rufous Hare-wallaby
Leporillus conditor	Greater Stick-nest Rat
Macrotis lagotis	Greater Bilby
Perceived threat	
Geopsittacus occidentalis	Night Parrot
[D]*Lathamus discolor*	Swift Parrot
Leipoa ocellata	Malleefowl
Turnix melanogaster	Black-breasted Button-quail
Bettongia lesueur	Burrowing Bettong
Isoodon auratus	Golden Bandicoot
[F/D]*Dasycercus cristicauda*	Mulgara
Dasyuroides byrnei	Kowari

^*Lasiorhinus krefftii*	Northern Hairy-nosed Wombat
Onychogalea fraenata	Bridled Nailtail Wallaby
Petrogale lateralis	Black-footed Rock-wallaby
Petrogale penicillata	Brush-tailed Rock-wallaby
Zyzomys pedunculatus	Central Rock-rat

[c]Competition for food by cats
[D]Domestic cat predation
[F/D]Domestic and feral cat predation
^Predation and disease dispersal.

3.7.7 Rabbit (*Oryctolagus cuniculus*)

Summary

One of Australia's most destructive feral pests, responsible for massive loss of native vegetation and subsequent erosion, destruction of rare plant species, maintaining populations of foxes and cats, and for competition with native mammals. The Rabbit Haemorrhagic Disease (RHD) has greatly reduced rabbit numbers, but rabbits are still suppressing mulga regeneration in South Australia, and this is a serious concern.

Distribution

Widespread in the Rangelands, but absent from the far north. Most common in New South Wales, South Australia and southern Queensland, on sandy substrates. Now sparse within the Western Australian Rangelands, although once abundant on the Nullabor Plain. Abundance has been greatly reduced within the Rangelands by RHD, although numbers may be returning in some regions.

Native to Spain and Portugal.

Impacts

The rabbit is one of Australia's worst pests, and 'competition and land degradation by feral rabbits' was listed as a key threatening process under Schedule 3 of the Commonwealth *Endangered Species Protection Act 1992* (the Act). The rabbit probably contributed to the disappearance of some of Australia's extinct mammals by eating away protective vegetation, taking over burrows, competing for food, and serving as a food source for large numbers of predatory foxes and cats. Rabbits also consume rare plants, although most of the threatened species occur outside the Rangelands. They also cause erosion by removing vegetation.

Rabbits are considered competitors of the Rufous hare-wallaby (Lundie-Jenkins *et al.* 1993) - now extinct on the mainland - the rare yellow-footed rock wallaby (Dawson & Ellis 1979), the rare MacDonnell Ranges population of brushtail possum (Morton *et al.* 1995), and threatened malleefowl (Garnett & Crowley 2000). They damage habitat for slender-billed thornbills, Rufous fieldwrens and striated grasswren on the Nullabor Plain (Morton *et al.* 1995).

Rabbits have transformed the vegetation over substantial areas of Australia by consistently removing seedlings of mulga (*Acacia aneura*) and other dominant plants (Cooke 1987, Lange & Graham 1983), including belah (*Casuarina pauper*) and buloke (*Allocasuarina luehmannii*).

RHD (previously known as rabbit calicivirus), has greatly reduced rabbit numbers throughout the Rangelands, and in most regions native vegetation is responding dramatically. (The impact of RHD is reported in various papers appearing in a special issue - volume 29 [6]) - of *Wildlife Research*). But in South Australia, within the Flinders and Gammon Ranges, mulga is failing to regenerate in the presence of very low numbers of rabbits (R. Henzell, pers. comm.). There has been very little if any regeneration of mulga within these regions since rabbits entered in the nineteenth century (G. Mutze pers. comm.). Mulga is a major habitat for wildlife in arid Australia and this lack of regeneration is a serious concern. Mulga woodland in Western Australia, the Northern Territory and Queensland is regenerating, and this problem appears to be confined to South Australia and New South Wales, where mulga seedlings, under a regime of low summer rainfall, grow very slowly and remain vulnerable to rabbit predation for many years. (In mulga woodland in other states Rabbits are also more patchily distributed, especially in the north of their range where hot summers limit their range). In western New South Wales problems are evident outside the mulga zone as well. In Kinchega National Park very little recruitment of plants is occurring, and suckers produced by four species (*Acacia carneorum, Alectryon oleifolius*, *Casuarina pauper* and *Santalum acuminatum*) are not surviving browsing, leading Denham and Auld (2004) to conclude that 'the probability of successful recruitment into populations of suckering species in western New South Wales continues to be low even at very low rabbit densities'. In New South Wales the situation is compounded by large number of goats and kangaroos which contribute greatly to total browsing pressure. The problem of rabbits preventing regeneration is considered further in Section 7.1.8.

Rabbits are an important food for native birds of prey. A study around Mildura found that young rabbits were the staple food (60-92 per cent by weight) of wedge-tailed eagles, goshawks, harriers, kites and falcons (Baker-Gabb 1984). Similar results have been reported in other studies. Rabbits are also a major source of food for foxes and cats, with the latter targeting rabbit kittens. One study in western New South Wales found that rabbits made up 45 per cent of fox diets and 54 per cent of cat diets (Catling 1988). When RHD spread across Australia there were concerns that native birds of prey would decline dramatically, and that abundant foxes and cats, deprived of their main prey, would exact a heavy toll on rare native fauna. Since the spread of RHD there have been some declines in birds of prey but not to a serious extent. Rare native species are not known to have suffered from increased fox and cat predation. Holden and Mutze (2002) found that foxes ate more insects and carrion after rabbit numbers dropped, and both fox and cat numbers decreased substantially after RHD went through.

Table 7 Species listed in the rabbit *Threat Abatement Plan* (1999) for which rabbits are a known or perceived threat.

Known threat	
Scientific name	**Common name**
Mammals	
Macrotis lagotis	Greater Bilby
Plants	
Caladenia gladiolata	Orchid
Thesium australe	Austral toad-flax

Perceived threat	
Geopsittacus occidentalis	Night Parrot
#*Leipoa ocellata*	Malleefowl
Mammals	
Bettongia lesueur	Burrowing Bettong
Dasycercus cristicauda	Mulgara
#*Dasyuroides byrnei*	Kowari
Onychogalea fraenata	Bridled Nailtail Wallaby

#Rabbits attract predators to these

3.7.8 European Hare (*Lepus europaeus*)

Other names

Brown Hare, [*Lepus capensis*]

Summary

Not thought to have much impact upon biodiversity today because of its low numbers within the Rangelands, close association with farmland and avoidance of natural habitats.

Distribution

Found in the Rangelands in South Australia, New South Wales and southern and central Queensland. Absent from the more arid areas.

Native to Europe.

Impacts

During the nineteenth century Brown Hares sometimes reached very high densities, and they presumably had a harmful impact on native species. But after the spread of foxes and rabbits their numbers dropped and they do not appear to have much impact upon biodiversity today. As Jarman (1995) notes: 'The species is now closely associated with modified pastures and croplands and generally absent from unmodified native plant associations.' Hares devour seedlings planted in native regeneration projects and this may be their worse impact. They also gnaw the bark of some native trees. Rabbits are far more destructive because they occupy natural habitats, reach higher densities, feed intensively in the vicinity of their warrens and crop plants closer to the ground.

3.7.9 Horse (*Equus caballus*)

Other name

Brumby

Summary

A serious pest in some national parks, causing degradation and apparently harming threatened mammals.

Distribution

Widespread in the Rangelands of Western Australia, the Northern Territory and South Australia. Scattered herds occur in Queensland. Horses became feral around Sydney by the 1830s. Their numbers are low in Western Australia (Peter Mason, pers. comm.) and they are scarce in the Kimberley region because they are susceptible to poisoning by toxic crotalaria plants. The Northern Territory has about 265 000 (Edwards *et al.* 2003), occurring especially in the Gulf region and Victoria River District. Australia has the world's largest population of feral horses, estimated at up to 600 000.

Horses are present in various Queensland national parks, e.g. Archer Bend, Rokeby-Croll Creek, Staaten River, Mount Elliott, White Mountains, Lakefield (Dobbie *et al.* 1993) and Carnarvon national park. They are also present in Kakadu National Park.

Horses are best adapted to open plains but they also use rugged country. Habitats occupied include semi-desert plains, rocky ranges, spinifex hills, sandhill country, mulga woodland, open forest, swamps, salt plains and beaches. They must drink at least once a day in summer, or every second day in winter. They can increase in population by 20 per cent a year.

Native to North Africa but no longer occurring as a wild species.

Impacts

Horses are a major concern in some national parks, for example Kakadu (A. Ferguson pers. comm.), and Carnarvon Gorge (R. Meltzer pers. comm.) in Queensland. Land degradation from donkeys and horses is listed as 'the major environmental issue' for the Victoria River Basin, in a report on Top End Aboriginal lands (Northern Land Council 2004). Horses degrade landscapes and apparently compete with native mammals for food.

Their impacts in central Australia were studied by Mike Berman, whose findings are summarised in Dobbie *et al.* (1993) and in more detail in references therein. According to Dobbie *et al.* (1993):

> 'Impacts include fouling waterholes, accelerating gully erosion along pads, trampling and consuming native vegetation, and possibly excluding macropods from preferred habitats. Effects are most extreme during droughts when horses reach remaining food and water before cattle.'

According to Dobbie *et al.* (1993), horse density should be maintained at 0.1 per square kilometre in central Australia to minimse land damage during drought.

The removal of 30 000 Horses from the rugged West MacDonnell Ranges Park has been followed by striking recovery in numbers of threatened black-footed rock wallabies (Edwards *et al.* 2003). The horses may also have suppressed numbers of the endangered stick-nest rat (*Zyzomys pedunculatus*) (Nano *et al.* 2003). Major food plants of the rat are palatable to horses.

Horses also spread weed seeds in their dung and on their coats. In Kakadu National Park invasion by mission grass is a major management concern, and any infestations are quickly controlled. Mission grass seedlings have been found in horse dung and the concern is that horses are spreading this weed into remote parts of the park where it will proliferate before it can be found (A. Ferguson, pers. comm.).

The ecological impacts of horses have not been sufficiently studied but appear to be substantial. There are good grounds for removing them from national parks and other conservation areas. It is less clear whether removal of horses from grazing lands produces a biodiversity benefit, if their removal results in higher stocking rates of cattle. Horses mainly eat grasses, also roots, bark, buds and fruit. They are more selective than cattle, traveling further for their preferred feed, and they browse shrubs less often than cattle. They spend more time grazing than ruminant cattle. Because horses will travel further from watering points than cattle, and will use rougher country, they are able to degrade areas that are less accessible to cattle, including slopes that may serve as refuge areas, supporting rare plants and mammals. In the Victoria River District large numbers of horses have been removed, and the area is under remote sensing to see if the landscape improves, or whether cattle replace horses and maintain the high grazing pressures (G. Edwards pers. comm.).

Many Indigenous people are fond of feral horses and do not want them removed. Extensive culling has brought horses under control in some regions but numbers need reducing in other areas.

3.7.10 Donkey (*Equus asinus*)

Summary

Once a major pest in northern Australia, causing erosion and defoliation, now largely controlled at great cost, but still a major problem in parts of the Northern Territory, where it requires more attention.

Distribution

Widespread in the Rangelands of Western Australia, the Northern Territory and South Australia. Scattered herds occur in Queensland. Found mainly in hilly and rocky landscapes, especially in remote and rugged areas rarely visited by people. Donkey distribution in the Top End, as mapped in 1985, is shown in Bayliss and Yeomans (1989).

Native to North Africa.

Impacts

Donkeys once occurred at very high densities (up to 10 per square kilometre) within the Kimberley region and Victoria River region of the Northern Territory, where they were blamed for extensive erosion, especially in rugged hills (Strahan 1998). The capacity of Donkeys to denude land was reported graphically by Letts *et al.* (1979):

> '…the country [on Victoria River Downs] was denuded of vegetation, with the exception of trees, and subject to very bad soil erosion. …The recovery of this country, say 200-300 miles, within five years [of culling 28 000 donkeys] was amazing yet because of the donkeys it had previously been wasteland.'

Major culling operations have reduced donkey numbers, but they remain a major problem in the Victoria River Basin and in areas north of Katherine. A report on Aboriginal lands in the Top End identified land degradation from donkeys and horses as 'the major environmental issue' for the Victoria River Basin (Northern Land Council 2004). Furthermore, donkeys occur in very large numbers to the north and east of Katherine, on Jawoyn Aboriginal lands (Ray Whear pers. comm.). Donkey densities are especially high in the Beswick Land Trust area (397,000 ha.) and the Eva Valley Land Trust area (= Manyalluk, 174 000 ha.). Here they are known to be damaging hundreds of Aboriginal art sites when they shelter under overhangs, and they are presumably causing biodiversity losses as well. Donkeys in these areas urgently need culling.

As well, Morton *et al.* (1995) list 'degradation from donkeys and cattle' as a key threat to the integrity of the Davenport and Murchison Ranges in the Tanami region, which they identify as a highly significant refuge area for biodiversity.

Letts *et al.* (1979) documented various characteristics of donkeys that contribute to their destructiveness. They have small hooves relative to their size and weight and often damage the soil surface. They gather together in large mobs, thus concentrating the damage they cause. In hot arid environments they are hardier than any introduced mammal apart from the camel. They can move through very rough country. They can drink saltier water than cattle or horses. They are adept at excavating dry stream beds to reach water. They have very broad tastes, eating almost any kind of plant. They eat grasses to ground level then kick out their butts to eat more.

3.7.11 Pig (*Sus scrofa*)

Summary

A very damaging feral pest that degrades habitats, preys on rare fauna and flora, spreads disease, and competes with fauna for food. Of particular concern is pig predation on eggs of endangered turtles on Cape York Peninsula.

Distribution

Widespread in the Rangelands of New South Wales and Queensland. Also found in the top third of the Northern Territory, and along some river systems in Western Australia, especially in the Kimberley. Numbers are highest along river systems, especially those with associated thickly-vegetated swamps. Pigs also do well in rainforests.

Pigs cannot tolerate heat and in the hotter parts of Australia they occur only in environments providing deep shade and water for wallowing. They are thus absent from arid areas except where there are large, well-vegetated wetlands systems.

They are still spreading in the Northern Territory having only recently reached the Arafura swamp. They also appear to be expanding their range within the Victoria River basin (Northern Land Council 2004).

Native to Europe, Asia and North Africa.

Impacts

Pigs pose a major threat to biodiversity, and 'predation, habitat degradation, competition and disease transmission by feral pigs' is listed as a key threatening process under the Commonwealth EPBC Act. Many of the rare species that are threatened by pigs in the Rangelands are listed in Table 8, although the species of greatest concern may well be Olive Ridley and flatback turtles. Pigs also spread the seeds of major weeds. Their impacts are outlined in more detail below.

Table 8 Rare species found in the Rangelands and listed in the *Draft Threat Abatement Plan* (2004) as threatened by feral pigs

Known threat	
Scientific name	**Common name**
Animals	
Zyzomys palatalis	Carpentarian Rock-rat
Casuarius casuarius	Southern Cassowary
Caretta caretta	Loggerhead Turtle
Eretmochelys imbricate	Hawksbill Turtle
Natator depressus	Flatback Turtle
Scaturiginichthys vermeilipinnis	Red-finned Blue-eye
Plants	
Eriocaulon carsonii	Salt Pipewort
Ptychosperma bleeseri	Palm
Perceived threat	
Animals	
Lasiorhinus krefftii	Northern Hairy-nosed Wombat
Turnix melanogaster	Black-breasted Button-quail

Predation

Stomach contents of pigs killed on Cape York Peninsula contain a wide variety of animals, including insects, snails, slugs, centipedes, earthworms, freshwater mussels, frogs, geckoes, dragon lizards, goannas, turtle eggs, turtles, fish fingerlings, snakes and birds (Anonymous 2003). Some of these items may have been obtained as carrion. One pig stomach contained 303 frogs.

Of special concern is pig predation on the eggs of threatened turtles. On the western side of Cape York Peninsula they have been destroying 70 per cent of the eggs and hatchlings of endangered Olive Ridley turtles and vulnerable flatbacks (J. Doherty., pers. comm.), threatening these populations with extinction (C. Limpus pers. comm.). Predation is occurring along the coastline from the Jardine River to well south of Weipa. Pigs have even been seen taking turtle eggs while the turtle is laying them (M. Read). This problem is considered further in Section 7.

Pigs are also one of the predators contributing to the reproductive failure of two highly threatened freshwater turtles in central and southern Queensland – the vulnerable Fitzroy River turtle (*Rheodytes leukops*), and the Burnett River snapping turtle (*Elseya albigula*) (Section 7). In the Northern Territory pigs have been recorded preying in large numbers on freshwater turtles in receding swamps.

Pigs prey on an endangered palm (*Ptychosperma bleeseri*) near Darwin. The Wairuk Aboriginal Corporation obtained NHT funding to opportunistically eradicate pigs around palm stands.

Eggs of rare little terns are sometimes eaten. Predation upon frogs is a concern on the Currawinya and Culgoa floodplains of south western Queensland (M. Weaver pers. comm.), but no rare species are eaten.

Habitat degradation

Pigs degrade habitat by shifting soil and by removing vegetation.

More than other feral animals, they disturb the ground when they feed, grubbing up earth in pursuit of tubers, earthworms and beetle larvae. When moving and feeding they also contribute to soil compaction, trail formation, erosion, alteration to drainage patterns, destruction of vegetation, and displacement of rocks and logs. They also create wallows in which they rest. Damage can extend over vast areas. On Cape York Peninsula pigs cause 'kilometres of deep diggings devoid of all vegetation' (Anonymous 2003). Around seasonal wetlands in northern Australia pigs plough through large areas to excavate small tubers. Pig damage is most evident in wetlands, woodlands and rainforests.

Pig damage also includes destruction of vegetation including dominant plant species. In the Top End of the Northern Territory, pandanus trees once formed impenetrable thickets, but these were reduced to scattered stands of trees by buffalo (Letts *et al.* 1979). In the mid-1980s, buffalos were eliminated from many areas under the Brucellosis and Tuberculosis Eradication Campaign, and the pandanus thickets have not returned, implying that pigs on their own are preventing their re-establishment (Braithwaite 1994-5). Pigs are known to eat pandanus seedlings and shoots that sprout at the base of existing trees. Pandanus thickets are important habitat for a wide range of animals, the prickly leaves offering small animals protection against predators (Braithwaite 1994-95).

In Lakefield National Park on Cape York Peninsula, a pig- and cattle-proof fence erected around Red Lily Lagoon has resulted in lush growth within the fenced area, in marked contrast to the bare landscape outside. However, because this fence excludes cattle as well as pigs, the exact impact of each species remains unclear, although pigs can be held responsible for destruction of bulgaru beds (see below).

Pigs destroy many seedlings when they feed and sometimes they uproot shrubs and kill trees. Fensham *et al.* (1994) studied massive invasion by lantana in Forty Mile Scrub, a very important remnant of dry rainforest within the Rangelands of north Queensland, and after noting 'severe' pig damage, proposed the following scenario:

> 'The digging activities of feral pigs kill trees and open the over storey canopy. Increased light penetrating the canopy allows the proliferation of lantana. Lantana increases mid-storey fuel loads and intense fires kill remaining rainforest canopy. Mature lantana is fire tolerant and completely dominates the site.'

On Cape York Peninsula pigs (and cattle) damage the termite mounds (antbeds) in which endangered golden-shouldered parrots breed. Crowley *et al.* (2003) note: 'antbeds grow slowly, and can be damaged by pigs and cattle. Early results suggest that new antbeds may establish faster when old antbeds are lost, only in areas from which pigs and cattle have been excluded.' In an area that was monitored, antbeds decreased by 43 per cent. Another concern is pigs and cattle are grazing so much vegetation that hot fires no longer burn, leading to extensive thickening by paperbark trees (*Melaleuca viridiflora*), which offer cover to predatory butcherbirds (Crowley *et al.* 2003). Vegetation thickening also leads to death of termite mounds from shading.

On the Currawinya and Culgoa floodplains of western Queensland, there are concerns about pigs altering drainage patterns (M. Weaver pers. comm.).

Competition

Several examples are recorded of pigs competing for food with birds in northern Australia. On Cape York Peninsula, pigs dig up and eat cockatoo grass (*Alloteropsis semialata*), an important food of endangered golden-shouldered parrots, which face food shortages at certain times of year because of changes in grassland composition. Crowley *et al.* (2003) note, 'The period of food scarcity in the early wet season is therefore likely to be longer and more severe where seed production by cockatoo grass is reduced by pigs or cattle'.

When pigs plough through the mud around the edges of tropical lagoons they are often targeting the tubers of spikerush or bulgaru (*Eleocharis dulcis*), a staple food of magpie-geese and brolgas. Within the Wet Tropics, pigs are thought to compete with endangered cassowaries by consuming the fruits they eat, and the same competition may occur in the rainforests of Cape York Peninsula.

More than any other animal, pigs have a digestive system like that of humans, and they feed on many indigenous food plants, including bulgaru, native potatoes (*Ipomoea calobra*), pandanus fruits and seeds, Leichardt tree fruit, sacred lotus and lillypillies (*Syzygium* species) (Anonymous 2003).

Disease Spread

In north Queensland (and Hawaii) pigs are strongly implicated in the spread of the root-rot fungus (*Phytophthora cinnamomi*), a soil borne disease that kills trees and shrubs (Choquenot *etal.* 1995). This disease is highly destructive in many parts of coastal Australia outside the Rangelands. Within the Rangelands it is most likely to prove damaging if it reaches the rainforests on Cape York Peninsula. Pigs are active in these forests. It causes tree deaths in rainforests further south. Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*) has been listed by the federal government as a Key Threatening Process.

Pigs also carry human and livestock diseases such as tuberculosis, leptospirosis, swine brucellosis, Ross River and dengue. They are also thought to spread the cocoons of the Amazonian earthworm (*Pontoscolex corethrurus*), which is common in north Queensland rainforests and compacts soild resulting in the degradation of native flora (Low 1999).

Spread of weeds

Pigs disperse the seeds of some major weeds, including pond apple (*Annona glabra*), mimosa (*Mimosa Pigra*) (A. Ferguson pers. comm.), and mesquite (*Prosopis* species), three of Australia's 20 worst weeds. Pigs contribute to weed invasion both by spreading seeds directly (by eating weed fruits and pods and excreting the seeds) and by disturbing large areas of soil when they feed. Weeds preferentially colonise disturbed ground. On Cape York Peninsula, 'extensive trampling, digging of vegetation and ground by pigs and a succeeding invasion of weeds were observed throughout the region' (Anonymous 2003).

On the Finnis River Basin in the Northern Territory pigs are identified as an increasing problem because of their role in spreading mimosa (Northern Land Council 2004):

> 'They 'cultivate' large areas of the floodplain in search of food and this provides ideal nursery for mimosa seedlings to establish. Pigs shelter in

mimosa thickets during the day and spread the seed as they cultivate the ground during the evening. Evidence of their diggings indicate that numbers are high on the floodplain'

Summary

Pig impacts on biodiversity have not been studied in depth, leading to the suggestion by Choquenot *et al.* (1995) that pigs may be over-rated as an environmental threat. However, abundant anecdotal evidence clearly shows that pigs are having a major impact in many habitats. Environmentally, they are probably one of the most damaging of Australia's feral pests. Of greatest concern is predation on the eggs and hatchlings of endangered Olive Ridley turtles and vulnerable flatback turtles along the western coast of Cape York Peninsula, and predation on eggs of endangered Burnett River snapping turtles and Fitzroy River turtles in Queensland, which are discussed further in Section 7.

3.7.12 One-Humped Camel (*Camelus dromedarius*)

Other name

Dromedary

Summary

A large herbivore, rapidly increasing in numbers and range, which is despoiling water supplies and altering vegetation, and which is becoming a major threat to biodiversity in arid Australia. In need of more attention.

Distribution

Widespread in the western half of the Rangelands, where numbers are rapidly increasing. Spreading north through the Tanami Desert, and now recorded as far north as Kununurra (K. Saalfield, pers. comm.). In Western Australia, expanding in range in the northern Goldfields, northern Nullabor Plain, and slightly in the south Pilbara (P. Mason, pers. comm.). In Queensland, multiplying in numbers and spreading eastwards in response to drought (D. Rolands, pers. comm.). Camel distribution during the 1980s is summarised by various maps in Short *et al.* (1988), but due to different methods of assessment there is no simple way to assess changes in distribution.

During winter camels can travel long distances from water, but during summer they need access to desert waterholes or bore drains. They will chew through plastic piping and knock over tanks, windmills and fences to gain access to water. They have benefited from the provision of artificial water sources.

Impacts

Camels are often claimed not to harm the environment. Australia's leading mammal book states that 'The Camel does not seem to degrade the Australian desert environment' (Dörges & Heucke 1995). The authors of this statement, after further research, have changed their views, and they now say that camels feed on endangered plants and 'even have the potential to contribute to their extinction' (Dörges & Heucke 2003).

In truth, camels do substantial damage to natural areas, and they are multiplying rapidly. In 1969 Australia's camel population was estimated at 20,000. In 1995 it was thought to be 'up to 100 000' (Dörges & Heucke 1995). It is now estimated at 740,000 (Edwards *et al.* 2003). The Northern Territory camel population more than doubled between 1993 and 2001 and, if not controlled, will double again in about eight years (Edwards *et al.* 2003).

There is strong anecdotal evidence to show that camels alter vegetation communities by selectively browsing and removing plants; and that camels deplete and despoil scarce water supplies in remote deserts.

Browse certain plants

Because camels rarely need to drink, do not graze intensively around waterholes, are confined to remote regions, and are seldom seen by most Australians, their grazing impacts were long discounted. But camels selectively target certain plants and certain habitats, and the damage they do, although selective, can be severe.

Robinson *et al.* (2003) note:

> '…some plant species appear to be singled out by camels as dietary favourites. Most seriously affected among these are the quandong [*Santalum acuminatum*], plumbush [*S. lanceolatum*] and desert kurrajong [*Brachychiton gregorii*], which the camels break branches from to access even the highest leaves, often leading to tree death.'

Dörges and Heucke (2003) note heavy browsing of quandongs along with curly-pod wattle (*Acacia sessiliceps*) and the coral tree (*Erythrina vespertilio*), with plumbush (*S. lanceolatum*) and supplejack (*Ventilago viminalis*) also placed under heavy pressure.

The desert quandong was recently listed as a vulnerable species in the Northern Territory, and camels pose the main threat to its survival. Curly-pod wattle is also rare (Dörges & Heucke 2003). Quandongs bear an edible fruit, and they are valued by indigenous communities both as a food source and spiritually. The fruits are an important food of emus and the seeds are eaten by rodents. Quandong stems are brittle and they do not resprout after camel breakage (P. Copley pers. comm.).

Dörges and Heucke (2003) noted substantial browsing on two *Lawrencia* species and suggested that rare *Lawrencia* species would be expected to suffer from camel browsing. As noted above, they suggest that camels could contribute to the extinction of rare plants. The diets of camels overlaps heavily with those of livestock and kangaroos, but the differences can be highly significant. Dörges and Heucke (1995) note that the camel, 'can utilise thorny, bitter and even toxic plants that are avoided by other herbivorous mammals.' They can also reach much taller foliage. They can eat more than 80 per cent of the plant species they have access to, including more than 340 plant species (Dörges & Heucke 2003).

Camels were thought to be important competitors of the endangered Rufous hare-wallaby before it became extinct in the Northern Territory (Lundie-Jenkins *et al.* 1993), eating the same foods, and also denuding the vegetation used by hare-wallabies for shelter.

Camels contribute to land degradation indirectly, by breaking down fences that are meant to keep rabbits and livestock out of sensitive areas. Camels are powerful animals that can break through most farm fences, making it harder for graziers to manage overgrazing by stock (Fisher *et al.* 2004).

Depleting and despoiling water supplies

Camels despoil water sources in the desert. Robinson *et al.* (2003), writing recently about the Anangu Pitjantjatjara Lands in north-western South Australia, note:

> '…Camels are … having an increasing impact on desert water supplies. Not only do they drink large volumes of this valuable resource, they also foul rock holes and waterholes when they get stuck and die. They also contribute to increased rates of siltation in these catchments.'

They conclude that:

> 'many water supplies at rock holes and waterholes are now severely compromised by the large volumes of water being consumed by an increasing feral camel population and by a decreasing capacity of many rock-holes to hold water due to ongoing siltation (frequently accelerated by camel activity).'

Camels are causing severe degradation to Dragon Tree Soak in Western Australia (Peter Mason pers. comm.), identified by Morton *et al.* (1995) as a significant refuge for biological diversity within the Great Sandy Desert.

A camel can drink 200 litres in three minutes. Camels groups range from two to 45 individuals, averaging 11 per group (Dörges & Heucke 1995). A large group of thirsty camels can drain a rocky waterhole, leaving nothing behind for kangaroos, emus and pigeons (P. Copley pers. comm.). Where they do not drain a waterhole they can leave it unfit for other animals. Peter Kendrick (pers. comm.) has seen rock holes in the Rudall River National Park, Western Australia, up to 50 metres across, bubbling with eutrophication from camel urine and excrement.

Peter Copley (pers. comm.) speculates that camels, by depleting water supplies, could have contributed to the decline in South Australia (Garnett & Crowley 2000), of the rare princess parrot. The uncommon scarlet-chested parrot and Major Mitchell's cockatoo may also be suffering from camels depleting water supplies (Robinson *et al.* 2003).

3.7.13 Swamp Buffalo (*Bubalis bubalis*)

Other name

Water Buffalo

Summary

A large feral pest that causes massive habitat disturbance. Populations were greatly reduced in the past but are now multiplying and spreading, especially on Aboriginal lands, and this is a serious cause for concern.

Distribution

Swamp buffalo occupy the Top End of the Northern Territory, where they are mainly confined to floodplains with permanent water because of their need to drink regularly and to wallow or bathe on hot days. They can reach densities as high as 34 per square kilometre (Skeat *et al.* 1996). Bulls sometimes wander as far east as the Townsville area in Queensland, as far west as Broome in Western Australia, and as far south as the Tanami. Buffalo distribution, as mapped in 1985, is shown in Bayliss and Yeomans (1989).

Buffalo are still expanding their range in parts of the Northern Territory, for example the Victoria River Basin (Northern Land Council 2004).

Native to South East Asia.

Impacts

Buffalo are larger than cattle, more aquatic in behaviour, and more destructive in their feeding habits, and they cause massive disturbance to natural habitats when they occur in high numbers. Their impacts were summarised by McKnight (1976):

> 'Their overgrazing, trampling, and puddling cause much of the grassy plains area to be denuded during the dry season, and the under storey of adjacent woodland and forest communities is strikingly depleted. Sheet and gully erosion are accelerated and many of the dry season waterholes and billabongs have become severely silted, with obviously deleterious effects on aquatic life. The extent and seriousness of habitat deterioration cannot be measured in any meaningful way, but the results are conspicuous, and the process continues.'

Letts *et al.* (1979) in their report, *Feral animals in the Northern Territory,* provide many photographs illustrating buffalo damage to various environments. They describe 'a silt plain of about 100 square kilometres in area which is undergoing accelerated sheet and gully erosion due to overgrazing and trampling.'

Buffalo damage to Kakadu National Park is described in depressing detail by Skeat *et al.* (1996), and their review provides the most detailed overview of buffalo impacts, and also includes graphic photos.

Damage to vegetation

Especially significant are the swim channels created when buffalo push their way through muddy plains. The freshwater required by aquatic plants drains away, allowing seawater to penetrate up to 35 kilometres inland, leading to the deaths of large stands of paperbarks and associated wetland plants such as lotus lilies (Letts *et al.* 1979) and wild rice, a staple food of magpie geese (Skeat *et al.* 1996). Levees have been bulldozed into place to stop this happening but buffalo have sometimes broken them down.

Buffalo grazing and damage have an impact on many different plant species and habitat types. Buffalo deplete stands of common reed (*Phragmites* species), native hymenachne (*Hymenachne amplexicaulis*) and pandanus (*Pandanus* species). Unlike cattle, buffalo pull out plants before they eat them, thus causing greater damage (Skeat *et al.* 1996). Palms (*Livistona* species) are pushed over and the crowns eaten (Braithwaite *et al.* 1984). Erosion caused by buffalo kills paperbarks (*Melaleuca* species), Leichardt trees (*Nauclea orientalis*), and bamboo (Letts *et al.* 1979).

Buffalo (and to a lesser extent pigs) are blamed for a massive decline in the area of pandanus thickets in northern Australia. Explorer Ludwig Leichhardt saw impenetrable thickets of pandanus in the Northern Territory in 1845, but these no longer occur today (Braithwaite 1994-5). These thickets were an important habitat for a wide range of wildlife.

Buffalo also degrade monsoon rainforests, killing large trees by trampling and changing the hydrology, and promoting invasion by weeds such as hyptis and cassias

(Skeat *et al.* 1996). Braithwaite *et al.* (1984) assessed monsoon rainforests in Kakadu and reported that buffalo have a 'marked compacting influence on the soil, decrease ground vegetation abundance and generally reduce plant biomass and productivity.'

In woodlands buffalo promote a transition from perennial to annual grasses, thereby increasing the potential for soil erosion, and hotter and more frequent fires (Skeat *et al.* 1996). They also reduce the survival rate of young eucalypts.

Buffalo also trample paperbark forests.

Harm to Fauna

Buffalo impacts on fauna have not been sufficiently documented. Georges and Kennett (1989) studied the pitted-shelled turtle, a large freshwater turtle with a limited distribution, and concluded:

> 'Trampling by stock was a source of nest mortality at the Daly River… and even a misplaced human heel is sufficient to destroy many eggs in the shallow nests of *Carettochelys*. It is unlikely that many nests would survive in heavily stocked regions, and current [in 1989] moves to remove buffalo from Kakadu National Park are welcomed.'

Buffalo are thought to pose a threat to the endangered Alligator Rivers subspecies of yellow chat, a small bird, by destroying its habitat (Garnett & Crowley 2000, Northern Land Council 2004). The vulnerable water mouse, or false water rat, may also be affected (Northern Land Council 2004).

Skeat *et al.* (1996) studied various small vertebrates (bandicoots and other small mammals, reptiles, frogs) in sites containing buffalo and sites fenced to keep them out, and suggested from their data that 'high densities of buffalo were a major factor in suppressing populations of small vertebrates on the [Kakadu] floodplains'. They attributed the differences to changes in vegetative cover.

Braithwaite *et al.* (1984) studied fauna abundance in forested habitats in Kakadu, which support much lower numbers of buffalo than wetlands. They compared various forested sites with relatively high and low buffalo density and found that some fauna suffered from buffalo, other fauna was not affected, and some species benefited from buffalo activity. Fauna that suffered included sea-eagles, orange-footed scrubfowl, pheasant councals and white-gaped honeyeaters. Species that were unaffected included cuckoos, kingfishers, flying foxes and goannas. Species that benefited included barking owls and various lizards (which probably preferred an open under storey). It should be emphasised that Braithwaite *et al.* (1984) did not assess the major habitats utilised by buffalo.

Woinarski (1993) studied birds in monsoon rainforest patches in Kakadu and found that 'Bird species more typical of eucalyptus open forests were abundant in patches most disturbed by buffalo, pigs, weeds and fire'.

Spread of weeds

Buffalo spread the seeds of mimosa, hyptis and other weeds and facilitate their invasion by removing native plants and disturbing soil. In a survey of Kakadu National Park, buffalo were blamed for assisting the spread of many of the 87 weed species (Skeat *et al.* 1996). Massive spread of mimosa (*Mimosa pigra*) on the Victoria River floodplain occurred after buffalo were removed. Buffalo may have suppressed this weed by eating its seedlings.

The situation today

Buffalo numbers are much lower today than during the 1980s, when their numbers reached an estimated 350 000 (Edwards *et al.* 2003). A major reduction took place under the Brucellosis and Tuberculosis Eradication Campaign (Wilson *et al.* 1992). Concerns about buffalo impacts have fallen away since then, yet their numbers are rising quickly. The cull was concentrated in western Arnhem Land, while the smaller eastern Arnhem Land population was deemed to be disease-free and was left alone (Bowman 2003). This population has now reached high densities, is spreading into new catchments, and serious environmental degradation is under way, including the destruction of wetlands from seawater inundation. As well, buffalo are now spreading west to reclaim former habitat, including Kakadu National Park. They were removed from Kakadu in the past as part of the brucellosis campaign, but a deal was struck whereby a herd is kept in a fenced section of national park as a source of meat. This herd serves serves a valuable social role by providing meat to the community, although its management is inadequately funded. Now that buffalo are recolonising the park from outside areas the need for another cull will emerge. But community leaders may well oppose culling, even though a meat supply is guaranteed by the fenced herd.

Buffalo are a problem that needs significant investment now before their numbers rise any higher. As Edwards *et al.* (2003) observe: 'Obviously the population has enormous growth potential'. The need for a cull is discussed in detail in Section 7.

3.7.14 Bali Banteng (*Bos javanicus*)

Other name

Bali Cattle

Summary

A feral cow confined to one national park north-east of Darwin, where it causes serious environmental damage, and where a cull is urgently needed.

Distribution

Within Australia, confined to Garig Gunak Barlu National Park on Coburg Peninsula north-east of Darwin, where the population numbers between 7000 and 9000 (K. Saalfield, pers comm). It was introduced to the Northern Territory as domesticated livestock in 1845.

Native to South East Asia, where it is listed by the IUCN as endangered.

Impacts

Banteng are causing substantial damage to Garig Gunak Barlu National Park (previously called Gurig National Park). They are damaging foreshore dunes and altering vegetation structure. They browse low-hanging trees, creating a distinct browse-line (Corbett 1995). They also deplete the under story on coastal plains, and they trample wetlands at the end of the dry season (P. Fitzgerald pers. comm.). They are similar enough to domesticated cattle to damage the landscape in the same ways. After comparing plots that were fenced to exclude banteng and unfenced plots, Panton (1993) found a 'highly significant difference.' Fenced plots had 9.2 per cent herbage cover compared with only 0.7 per cent on unfenced land. A CSIRO investigation into their impacts, reported in (Letts *et al.* 1979), observed:

> '…the sandy plains appear overgrazed and trampled… In areas where these cattle congregate and shelter, ground vegetation is considerably damaged and there is a marked browse line on certain species of trees. The burrows of rodents on the sandy plains are often broken into by the feet of the cattle.'

(Letts *et al.* 1979) features photos illustrating banteng damage. The report concluded that the damage was not irreversible.

Banteng have long been recognised as an environmental problem. During the 1970s their numbers increased dramatically and many were shot to reduce their impacts (Corbett 1995). Letts *et al.* (1979) recommended that banteng be removed from the reserve, with perhaps a 'small herd of say 100 head' retained for historical reasons within a small fenced area. In 1978 the shooting stopped and a fence was run across the peninsula to limit their movements. Banteng are thus free to multiply and cause damage within the fenced area, but they cannot spread.

Their numbers are rising fast. In 1978 their population was estimated at 1 070 (Letts *et al.* 1979). In 1985 it was estimated at 1 500-3 500, equating to a density of about 2.5 per square kilometre. Today the population is estimated at 7 000 to 9 000 (K. Saalfield, pers. comm.), and a cull is urgently required. No culling occurs at present, but a few large bulls are shot each year by big game hunters operating under license.

The traditional owners of Garig Gunak Barlu do not want a cull because the banteng are a source of income, each trophy animal returning $1000-2000 to the community. The Northern Territory Conservation Commission has proposed a substantial cull of banteng females, which have no value to trophy hunters, but traditional owners oppose this because they now expect to be paid for all banteng shot on their land (K. Saalfield, pers. comm.). Only about 5 per cent of the banteng population is of trophy quality. If a cull is not undertaken the population will increase and damage to the national park will worsen.

The need for a cull has become especially urgent since Cyclone Ingrid struck the Coburg Peninsula with great force in 2005, denuding vegetation throughout the park. Culling should be undertaken because banteng are likely to starve from lack of food, and also because they will impede vegetation regeneration. This problem is discussed further in Section 7.

Banteng are one of a suite of species damaging Garig Gunak Barlu. Woinarski and Baker (2002) observed: 'In some respects, Cobourg Peninsula is managed as a large open air menagerie, with large feral mammals being one of the most conspicuous (and, for some, attractive) wildlife features of the park. The area currently supports abundant populations of feral horse *Equus cabalus*, pig *Sus scrofa*, sambar deer *Cervus unicolor*, banteng *Bos javanicus* and water buffalo *Bubalus bubalis*, mostly introduced during the nineteenth century settlements.'

In South-east Asia the wild banteng is endangered, and some experts have suggested that Australia's feral population has high conservation value (Corbett 1995, Bowman 1992). However, Australia's banteng are descended from domesticated stock brought from Bali or Timor in 1849 (Corbett 1995, Long 2003). Within Bali, banteng are the dominant domestic cow and the population is vast. Domesticated banteng are also present on Java, Sumatra, Borneo, Sulawesi, Lombok and Timor (Long 2003). If these livestock were included in total population assessments the Banteng would not qualify under IUCN criteria as endangered. Australia's feral banteng are unquestionably domesticated livestock gone wild, with a gene pool influenced by selection for domestication, and they are no more part of the threatened gene pool than the tame Banteng that pull ploughs in Indonesian rice fields.

3.7.15 Cow (*Bos taurus*)

Other names

Scrubber

Summary

A widespread feral animal which causes serious habitat degradation, especially within riparian habitats in the Kimberly region, where it is the most damaging feral pest.

Distribution

Feral cattle are widespread within the Rangelands, occurring mainly north of the Tropic of Capricorn, both in national parks, and on grazing leases that are not adequately fenced. Their numbers and range are difficult to determine because they occur in regions that also carry domesticated cattle. The distinction between feral and domesticated cattle often blurs, because domestic cattle in some areas regularly go feral, and in some places feral cattle are regularly mustered.

McKnight in 1976 reported 'sizeable mobs of wild cattle' from the Hamersley Ranges and the Ashburton and Fortescue drainages of the Pilbara, the King Leopold Ranges of the southern Kimberley, and the Gulf Country of the Northern Territory and north-western Queensland.

Feral cattle are most obvious when they occupy national parks and other reserves, although branded domestic cattle often feed in parks as well. Large numbers of feral cattle are present in Lakefield National Park on Cape York Peninsula, within all major national parks in the Pilbara, and within Prince Regent River Reserve and Drysdale River National Park in the Kimberley. Smaller numbers occur in the following national parks: Purnulu (Bungle Bungle) in Western Australia, Kakadu National Park in the Northern Territory, and Carnarvon, Homevale and other reserves in Queensland. They also occur on indigenous land in the McIllwraith Range and Lockerbie Scrub on Cape York Peninsula.

In 1979 Letts *et al.* estimated the number of feral cattle in the Northern Territory at up to 250 000, with 30 per cent of these occurring in the Darwin and Gulf districts and 15-20 per cent in the Victoria River district. Most of these were removed as part of the Brucellosis and Tuberculosis Eradication Campaign in the Kimberley and northern Gulf. McKnight (1976) proposed a much lower number ('a rough estimate') of 75 000 to 100 000 for the whole of Australia, but McKnight was capable of greatly underestimating numbers (Graham *et al.* 1986).

Feral cattle occur in woodland, semi-desert (e.g. the Tanami [Graham *et al.* 1986]), riparian forest and rainforest.

Impacts

The damaging impacts of domestic cattle under husbandry have been well documented (Landsberg *et al.* 1997, Fisher *et al.* 2004, and references therein). They include erosion, degradation of riparian zones, loss of palatable plants, increases in unpalatable plants, and spread of weeds. Feral cattle are capable of the same and other impacts whenever they achieve significant densities or concentrate around a few watering points.

Feral cattle are the most damaging feral animal in the Kimberley, where they pose a serious threat to the survival of monsoon rainforest remnants (McKenzie *et al.* 1991, T. Start, pers. comm.). Strays from pastoral leases are wandering along watercourses deep into national parks where they breed up and trample fragile riparian habitats and vine thickets (rainforests). The vine thickets are a rare and highly significant habitat, representing the rainforests that once occurred widely in the region when the climate was wetter. Cattle camp inside the thickets and damage them by browsing and trampling (P. Mason pers. comm.). By removing all the foliage within reach, feral cattle increase light levels and thereby facilitate invasion of rainforest edges and cattle trackways by exotic buffel grass (*Cenchrus ciliaris*), other weeds, or native grasses, which fuel very hot fires that kill rainforest trees. Photos of cattle damage to Kimberley rainforest are illustrated in McKenzie *et al.* (1991). In surveys conducted during the 1980s, feral cattle were found in only one of 20 vine thicket sites, but all of the sites now have feral cattle (P. Mason pers. comm.) The early surveys recorded small mammals in 30-40 per cent of traps; that rate has now dropped to one or two per cent. Feral cattle and inappropriate fire regimes are together destroying this rare habitat type (P. Mason) and the fauna it contains. McKenzie *et al.* (1991) express concerns that cattle (both feral and domesticated), by degrading large numbers of Kimberley rainforest patches, pose a threat to rainforest land snails, spiders, reptiles and birds. Other feral animals are scarce or non-existent in the sites where Kimberley rainforests grow.

In Purnulu (Bungle Bungle) National Park, damage from feral cattle was found to be severe during a survey reported in 1992. Woniarski (1992) noted ‘pandanus thickets along sections of the Ord River have been extremely degraded by cattle trampling, erosion and the spread of exotic plants (e.g. *Cenchrus* spp. *Parkinsonia*).’ Most of the cattle have since been removed.

In Lakefield National Park, feral cattle overgraze and degrade the riparian systems (J. Clarkson, pers. comm.), which are critical for wildlife. The cattle are difficult to control because the landscape is remote and difficult to access. Management problems are compounded by the large numbers of domestic cattle grazed in this national park. Many of the feral cattle are mustered under contract to nearby graziers.

In Barlee Range Nature Reserve in Western Australia, a clay pan supporting sensitive vegetation was fenced against feral cattle, Donkeys and stray cattle, but mainly to exclude feral cattle. The vegetation improved dramatically (P. Kendrick pers. comm.)

In Forty Mile Scrub National Park in north Queensland, Fensham *et al.* (1994) found that the presence of billygoat weed inside dry rainforest was strongly correlated with damage by feral cattle. Dry rainforest has very high conservation values.

In Kakadu National Park, small herds of feral cattle are valued by the traditional owners as a meat source (A. Ferguson pers. comm.). The impact of these cattle on conservation values have not been assessed but appear to be minor compared with the impacts of horses and the likely impacts of burgeoning numbers of feral buffalo.

3.7.16 Goat (*Capra hircus*)

Summary

A very damaging feral pest, increasing in numbers in Western Australia and New South Wales, and probably in Queensland, that seriously degrades habitat, eliminating rare plants and competing with rare fauna. Goats require more attention in temperate Western Australia and western New South Wales.

Distribution

Feral goats are widespread within the Rangelands, especially in arid and semi-arid regions. Very large numbers are present in some national parks, with 50 000 taken out of Yathong National Park in a year (although few now remain), and 6 000 removed from Currawinya National Park in south-west Queensland in a ten week period.

Goats prosper in sheep producing regions where dingoes have been eliminated. Feral goats are often maintained on grazing lands by landholders as an alternative source of income.

In the Pitjantjatjara lands of north western South Australia, goats have recently been released into an area they did not formerly occupy by Indigenous people (Peter Copley pers. comm.). Dingoes are likely to eliminate them.

Impacts

Goats are such serious pests that competition and land degradation by feral goats has been declared a threatening process under the EPBC Act. Goats have three kinds of impacts:

1) Habitat degradation
2) Elimination of rare plants
4) Competition with rare fauna

Habitat degradation

Goat can occur at densities of up to 40 per square kilometre (Parkes *et al.* 1996), and in high numbers they can denude vegetation, especially on rocky slopes - a preferred habitat. By standing on their hind limbs they can remove foliage high on shrubs and trees. They are more damaging than sheep because their diet is very varied, incorporating grasses and herbs, shrubs and trees.

The degradation they cause includes erosion on the steep hills, pollution of water supplies, and alteration of vegetation succession. Farmers in many sheep-producing regions are turning to goats as a second source of income, and this shift in land use practise is leading to widespread landscape degradation. In north-western New South Wales, goats are widely considered to be the worst pest.

Parkes *et al.* (1996) noted:

> 'Goat dung can be deposited around waterholes and springs to a depth of several centimetres. Dung, together with the bodies of goats that fall into the water and decompose, is likely to eutrophicate the water and have a major effect on freshwater biota… Goats can also reduce the amount of water, aggressively exclude some species…and can cause the water levels in rock holes to be so lowered as to exclude other animals or cause animals to fall in, drown, and pollute the supply.'

In Gluepot Reserve in the northern mallee lands of South Australia, goats (plus overabundant kangaroos) are inhibiting vegetation regeneration around old farm dams. The clearings created by heavy grazing pressure around dams attract Yellow-throated miners, which interbreed with endangered black-eared miners, seriously threatening their future. To secure a better future for black-eared miners various dams have been removed and regeneration attempted. Because Gluepot is an important bird-watching location, water for birds is still supplied, but in elevated troughs that prevent access to goats and kangaroos. The vegetation around remaining dams is very damaged by goat browsing.

Feral goats alter vegetation succession over wide areas by removing seedlings of favoured plants such as quandongs (*Santalum* species) and *Alectryon oleifolius.*

Elimination of rare plants

Grazing by goats poses a threat to the Baratta wattle (*Acacia barattensis*) and spidery wattle (*A. araneosa*), which are both confined to the Flinders Ranges, which support many goats. Goat grazing also poses a threat to salt pipewort (*Eriocaulon carsonii*), which grows around springs in South Australia. Goats are likely to pose a threat to other rare plants within the Rangelands but information is lacking.

Competition

Goats compete with threatened malleefowl and probably with rock-wallabies for food. Malleefowl are now confined to many mallee remnants scattered across southern Australia, and high densities of goats in some of these remove the food plants of these birds (Benshemesh 1998), as do sheep, rabbits, and overabundant kangaroos. The regions in south eastern Australia where malleefowl are doing worst tend to be those supporting goats (as competitors) and foxes (as predators) (J. Benshemesh pers. comm.).

Goats and rock-wallabies favour similar rocky environments, and goats in high numbers apparently compete with yellow-footed rock wallabies. They have a high overlap in diet (Dawson & Ellis 1979) plus the advantage of being able to stand on the hind legs to reach tall plants. Competition is most likely to be significant during droughts, when shortage of food exacerbated by goats forces rock-wallabies to forage further from safety, increasing the risk of predation by foxes and dingoes.

Table 9 Species listed in the feral goat *Threat Abatement Plan* (1999) occurring within the Rangelands, for which feral goats are a known or perceived threat. This list is incomplete.

Known threat	
Scientific name	**Common name**
Birds	
Leipoa ocellata	Malleefowl
Plants	
Acacia araneosa	Spidery Wattle
Acacia barattensis	Baratta Wattle

Drakonorchis drakeoides	Hinged Dragon Orchid
Eriocaulon carsonii	Salt Pipewort
Perceived threat	
Mammals	
Petrogale lateralis	Black-footed Rock-wallaby
Petrogale xanthopus	Yellow-footed Rock-Wallaby

The goat problem is becoming worse in temperate Western Australia and western New South Wales because landholders in degraded sheep country are encouraging goats to multiply on their land as an alternative source of income. This serious problem is considered further in section 6.

Goats may have some positive value because they will eat woody weeds.

3.7.17 Blackbuck (*Antilope cervicapra*)

Summary

An antelope that may occur in the Rangelands of Western Australia and Queensland which will cause environmental degradation if allowed to multiply.

Distribution

The presence of blackbuck in the Rangelands needs confirming, but there is thought to be one population near Wiluna in Western Australia and another on Cape York Peninsula.

Feral blackbuck previously occurred around Newmarracarra and Geraldton in Western Australia, the latter population surviving up until the 1980s.

Native to India, Nepal, Bangladesh and Pakistan.

Impacts

Nothing is known about the impact of blackbuck in Australia because it has never been investigated. However, one wild herd that was established early in the nineteenth century about 480 kilometres north of Perth, multiplied so greatly that thinning was required (Long 2003).

The presence of blackbuck within the Rangelands requires confirming. There was an early release at Wiluna in Western Australia, and unconfirmed reports are occasionally received of visitors seeing or shooting them in that district (P. Mason, pers. comm.).

In Queensland, a hunter recently told a government pest officer he was flying low over Cape York Peninsula and saw a herd of 100-200 blackbuck. This report was taken seriously and some enquiries were made to try to locate the herd, without success. In 2004 a handful of blackbuck were released onto a Cape York property in an attempt to establish a herd for safari hunting. The animals soon died or were killed.

Blackbuck were trialed as livestock by the University of Queensland at Gatton, and when this work ended the animals were sold to a game park under strict license conditions that forbade resale. Blackbuck cannot legally be held by anyone else in

Queensland, but there are concerns that some of these blackbuck may have been stolen to form illicit herds elsewhere. At best, the large herd on Cape York may be a fiction; at worst, they may be several feral herds in Queensland. The alarming rise in number of feral deer populations in Queensland suggests the possibility that many people might wish to establish blackbuck herds as well.

In India, blackbuck are minor pests of crops (Long 2003). Their impact on the landscape would probably compare to that of deer.

3.7.18 Fallow Deer (*Dama dama*)

Summary

A deer of limited occurrence within the Rangelands, capable of spreading more widely in the south, but not likely to become as a serious threat to biodiversity.

Distribution

Fallow deer are widespread in south-eastern Australia, but their distribution within the Rangelands is very limited. Herds are present near Port Augusta in South Australia, and others occur at the eastern edge of the Rangelands in northern New South Wales and the southern half of Queensland, with the most northerly colony near Rockhampton (Moriarty 2004).

Impacts

Fallow deer have little impact upon biodiversity within the Rangelands because they are present in very low numbers. Like other deer species their range has expanded dramatically as a result of recent translocations and escape from deer farms. Bioclimatic modelling indicates that fallow deer, even if they keep spreading, will be confined to the southern edges of the Rangelands, in a band extending from Shark Bay across to the Nullabor Plain and into the Mallee Lands in southern New South Wales (Moriarty 2004). Jesser (2005) suggests that the northernmost population at Rockhampton may not last because this is a cool-climate deer.

Fallow deer can become serious pests when they reach high densities. In New Zealand they 'cause severe damage to the vegetation' (Long 2003), leading to major control programs (King 1990), and in Europe they retard plant growth (Long 2003). In Australia they are recorded feeding on short grasses, sedges, rushes and wattles (Strahan 1998). Wherever fallow deer reach high densities they are likely to compete with kangaroos and wallabies for food, add to total grazing pressure, and contribute to erosion and other forms of land degradation. In a survey of landholders with wild deer (of various species) there were reports of deer degrading water quality, competing with native and domesticated grazers, and spreading weeds (Moriarty 2004). However, fallow deer are unlikely to reach high densities over most of the Rangelands.

3.7.19 Red Deer (*Cervus elaphus*)

Summary

A deer with a limited distribution, but capable of occupying a vast area within the southern half of the Rangelands, where it could be expected to contribute to serious habitat degradation.

Distribution

Red deer occur widely within south-eastern Australia, but within the Rangelands their distribution is limited. There are herds in the Port Augusta area and in north-eastern New South Wales (many populations) (Moriarty 2004). Queensland has a herd of fewer than 100 animals near Rockhampton, and two populations in the Roma-Injune-Mitchell area, totalling between 100 and 500 (Jesser 2005). There is also a population beside the Murray River in south western New South Wales (Moriarty 2004).

Native to Europe, Asia and North America.

Impacts

Very little is known about the impact of red deer in Australia. Roff (1960) reported that rutting stags of red deer in the Brisbane River catchment rub their antlers on trees and shrubs, 'sometimes removing the bark of saplings from ground level to six feet up the trunks.' In pine plantations they were killing saplings up to six metres tall. Culling has periodically occurred when they have become a pest (Jesser 2005). In a survey of landholders with wild deer (of various species) there were reports of deer degrading water quality, competing with native and domesticated grazers, and spreading weeds (Moriarty 2004).

In New Zealand, red deer are extremely damaging, removing up to 90 per cent of seedlings and saplings from forests, and probably contributing to soil erosion. According to King (1990): 'In national parks and similar mainland protected natural areas, where the native biota is supposed to be kept as near as intact as possible, red deer have already caused irreversible changes in the vegetation.' In Europe, red deer sometimes cause 'severe' damage in forests by browsing the buds of trees and stripping their bark (Long 2003). They appear on the IUCN list of 100 of the World's Worst Invasive Alien Species (Lowe *et al.* 2000).

Red deer at present may not have much impact upon biodiversity within the Rangelands, but that situation may change if they keep spreading. In 1995 only four populations were known from Australia, none of them from the Rangelands (Moriarty 2004), but today there are more than 65 populations in Australia. red deer are the species most favoured by deer farmers. Bioclimatic modelling indicates that they could occupy a large area within the Rangelands, south of the tropics, achieving highest densities in New South Wales, central Queensland, and the southern fringes of the Rangelands including the Nullabor Plain.

3.7.20 Sambar Deer (*Cervus unicolor*)

Summary

A deer capable of causing environmental change, with only one population in the Rangelands at present, but capable of occupying a very large area in northern and eastern Australia.

Distribution

A population is present in the Top End of the Northern Territory, on Coburg Peninsula, and further a field in Western Arnhem Land. The Coburg population is fenced inside Garig Gunak Barlu National Park. Deer are seldom seen in these regions (J. Woinarski & P. Fitzgerald pers. comm.), suggesting the habitat is less than ideal.

Impacts

Little is known about the impacts of sambar deer. They are closely related to rusa but slightly larger, suggesting their impacts might be very similar, but they are also more solitary, and if this equates to lower densities their impact on the landscape might be less. As noted below, rusa deer have very serious environmental impacts.

On Guam, where a feral population also occurs, heavy sambar browsing is evident on grass and shrub species (Long 2003). Sambar also eat fruit and they could compete for this resource with native frugivores.

Bioclimatic modeling indicates that if rusa deer escape from deer farms they could occupy a vast region across northern Australia (Moriarty 2004), although populations away from the coast would probably be confined to riparian corridors. In Asia they are found in rainforests, more open forests and adjoining grasslands. Rusa would contribute to the landscape degradation caused by feral horses, donkeys, buffalo and by domestic cattle.

3.7.21 Rusa Deer (*Cervus timorensis*)

Summary

A deer that causes significant environmental degradation, with a limited presence in the Rangelands at present, but capable of occupying a much larger area in northern and eastern Australia.

Distribution

Four or five populations are known from the Rangelands, one near Townsville, one west of Mackay, and one near Rockhampton (Moriarty 2004). Rusa are recorded having swum across Torres Strait (where there is a population on the islands) to the Australian mainland (Jesser 2005) and there are thought to be some on Cape York Peninsula (Wilson *et al.* 1992) although these have not been recorded recently (Moriarty 2004, Jesser 2005). There are also reports of 600 rusa being released recently onto the flood plain environment of the Gulf (Jesser 2005).

Elsewhere in Australia rusa deer are known from various sites in south-eastern and eastern Australia, including islands in Torres Strait and islands off Arnhem Land.

Native to South East Asia.

Impacts

Much is known about the impact of rusa deer because they have been studied in Royal National Park near Sydney. The damage consists of ‘overgrazing, browsing, trampling, ring-barking, dispersal of weeds… creation of trails, concentration of nutrients, exposing soils to erosion/accelerating erosion, and the subsequent degradation of water quality in creek and river systems’ (Jesser 2005). There is also a ‘significantly lower diversity and abundance of plant species’ where deer density high.

Mahood (1981), writing of this area, noted ‘extensive erosion associated with “deer tunnels” on coastal ridges’, and ‘signs of gully erosion formation of ridge sides [sic] which may have been caused by deer breaking the surface’. He recorded that rusa maintain grassland areas by preventing regeneration, and that ‘there are considerable areas beaten down to form camps and trails…’ These deer ringbark trees when they rub their antlers to remove velvet, and impede regeneration in burnt areas.

A *Deer Management Plan* for the park, published in 2002, found that ‘deer are browsing on rare and threatened plant species and having significant impacts on the diversity of threatened ecological communities within the park’ (NSW National Parks and Wildlife Service 2002). Some of the impacts recorded included significantly lower density and diversity of plant species in threatened plant communities, and rainforest patches with 70 per cent less under storey plant species. The report identified an ‘urgent need for deer numbers to be reduced’. The deer population, estimated at 2 900 in 2001, is descended from seven deer that escaped almost a hundred years ago.

On the Torres Strait islands, where their numbers are high, rusa, along with pigs and goats, ‘have caused significant environmental degradation’ (Jesser 2005).

In New Guinea, in a review of the Tonda Wildlife Management Area on the south Coast, Chatterton (1996) nominated invasive species as the worst threat to the area and listed rusa first. According local people the rusa have “moulded the whole area” by causing change in herbaceous species and through soil compaction.

Bioclimatic modelling indicates that rusa deer could establish substantial feral populations in Arnhem Land, the Top End and north Queensland, with lesser populations establishing around the Gulf of Carpentaria and along the central Queensland coast (Moriarty 2004). In these regions, rusa could contribute to the landscape degradation caused by feral horses, donkeys, buffalo and by domestic cattle.

In a Queensland Government report, Jesser (2005) proposed that all deer colonies found outside their historic range in Queensland should be declared class one pests, which would require landholders to eradicate them. If his recommendation is adopted by the Queensland Government rusa deer could be eliminated from the Rangelands.

3.7.22 <u>Chital Deer (*Axis axis*)</u>

Other names

Axis Deer, Spotted Deer, [*Cervus axis*]

Summary

A deer that is rapidly expanding in range, as a result of deliberate releases, and which has the potential to occupy most of the Rangelands, and to reduce biodiversity values.

Distribution

As recently as 1995 chital deer were known only from one feral population in Australia, near Charters Towers (Strahan 1998), but now there are at least 28 wild populations (Moriarty 2004), with about 13 in the Rangelands. These populations occur near the Gulf of Carpentaria in Queensland (two populations), in inland regions of north and central Queensland (10 populations), and in central-western New South Wales (1 population). The new populations have resulted from people freeing deer (Moriarty 2004).

Chital are native to the Indian region where they occur in forest glades and cropland.

Impacts

Chital in the Charters Towers area are 'causing significant environmental damage, with vegetation grazed to bare ground. Pest plants such as rubber vine (*Cryptostegia grandiflora*), chinee apple (*Zizyphus mauritiana*) and parthenium (*Parthenium hysterophorus*) are also flourishing in areas where chital are not adequately controlled' (Jesser 2005). Rubber vine and parthenium are two of Australia's 20 worst weeds.

A population of perhaps 2,000 chital on an island at the mouth of the Burdekin River occupies a belt of mangroves and tidal flats extending inland from the ocean, but enters cropland to feed at night. According to Jesser (2005), 'Signs of chital were seen along all water courses, including damage caused to saplings by antler rubbing. Thus the deer are causing damage to the natural environment as well as to agricultural crops.'

Bioclimatic modelling indicates that chital could occupy most of the Australian Rangelands, with populations able to establish in woodlands almost everywhere except in temperate Western Australia and the Nullabor Plain (Moriarty 2004), provided water is permanently available. Chital thus have the potential to become a major feral pest.

Birds

3.7.23 <u>Ostrich (*Struthio Camelus*)</u>

Summary

Probably present in small numbers at a couple of sites in the Rangelands, but not in sufficient numbers to have much impact on biodiversity. It is not known whether ostriches could become widespread and successful feral birds in Australia.

Distribution
Ostriches have won their freedom from time to time as a result of escapes or releases from ostrich farms. The small feral population that once occurred about 30 kilometres north of Port Augusta, in South Australia, is thought to be extinct, but a handful of birds may still survive (P. Copley, pers. comm.).

A flock of about 30 wild ostriches were seen in 2004 on a mining lease near Moura (L. Agnew, pers. comm.). A road-killed bird seen between Charters Towers-Hughendon (P. Jesser, pers. comm.) may have represented a solitary escapee or a representative of another feral colony. There are likely to be other small populations scattered through the Rangelands in areas where ostrich farming was practised. Some of these colonies may not be viable; they may not breed successfully, or they may be unable to survive future land use changes.

Native to Africa and originally to the Arabian Peninsula as well. Large numbers are kept in Australia in ostrich farms.

Impacts
Any small feral populations occurring in the Rangelands would not be having much impact. With the boom and bust cycle of ostrich farming in recent years there may have been many releases and escapes, producing new feral populations; as has happened with deer.

3.7.24 Helmeted Guinea-Fowl (*Numida meleagris*)

Summary
A bird of extremely restricted distribution within the Rangelands, with currently no impact on biodiversity, but potentially capable of invading large regions of the arid zone.

Distribution
In Western Australia a small feral population occurs around Broome (Collins 1995), but only in association with urban dwellings, the birds apparently receiving food from people.

In north Queensland guinea-fowl occur in and around Charters Towers (Britton & Britton 2000). A small breeding population (about 17 birds) has resided at All Souls' and St Gabriel's School for decades. A second colony was recorded in 1995 nine kilometres north-west of the town (Britton & Britton 2000). At both Broome and Charters Towers the birds are periodically killed by cars.

In north Queensland a small feral population occurs outside the Rangelands on Magnetic Island (Jo Wienecki pers. comm.) and a feral population once existed on Heron Island (Long 1981).

Guinea-fowl are native to Africa. In Southern Africa a feral population occurs in and around Cape Town.

Impacts
Guinea fowl at present have a negligible presence within the Rangelands and no impact upon biodiversity could be expected. But guinea fowl have formed feral

populations on various islands around the world and in South Africa (Long 1981). In Africa they occupy inland woodlands very similar to those in outback Australia, and the possibility remains that helmeted guinea fowl could become a successful feral bird within the Rangelands, although previous attempts to establish them in the wild in Australia have failed (Long 1981), perhaps because of foxes and dingoes.

3.7.25 Mallard (*Anas platyrhynchos*)

Summary
An uncommon feral duck that hybridises with black ducks

Distribution
Mallards occur widely in south-eastern and south-western Australia. Within the Rangelands they are recorded from the Riverine Plain in New South Wales, and from eastern and central Queensland (Barrett *et al.* 2004), but they are uncommon. Some of the records of this species probably refer to tame birds in town ponds rather than feral populations.

The mallard is native to Europe, Asia and North America. It is the ancestor of the domesticated duck.

Impacts
Mallards often hybridise with native black ducks. In New Zealand, where the population of native black ducks is much smaller, hybridisation is a major concern, but in Australia it is not rated as a serious issue, although it has been considered a serious concern in the past (Frith 1973).

3.7.26 Rock Dove (*Columbia livia*)

Other names
Domestic Pigeon

Summary
Widespread in urban and some rural areas in the Rangelands but unlikely to be having any significant impact upon biodiversity.

Distribution
Recorded from towns and some homesteads all over the Rangelands. Often found in rural areas where grain is grown or stored. Sometimes ventures into woodlands, grasslands and beaches near towns.

Native to Europe, Asia and North Africa, but now found as a domesticated and feral bird all over the world.

Impacts
Because it is mainly found in towns and highly modified farmland, the rock dove is unlikely to be having much impact upon biodiversity. Nesting birds may occasionally displace native animals from the cliff ledges and tree hollows they use for nesting, although most nesting takes place on buildings. Around Alice Springs, rock doves

nest in tree hollows along the Todd River, and these populations may well be displacing native birds

3.7.27 Laughing Turtle-dove (*Streptopelia senegalensis*)

Other names

Senegal Dove

Summary

Confined to the south-western edge of the Rangelands where it has no apparent impact on biodiversity.

Distribution

The laughing turtle-dove was introduced into Perth in 1898 (Long 1981), and from there it has spread widely in south-western Australia and into peripheral areas of the Rangelands, where it mainly occupies towns. It occurs in Kalgoorlie, Esperance and towns in-between, and in towns north of Shark Bay (Blakers *et al.* 1984). It is native to Africa and Asia.

Impacts

As an urban bird, the laughing turtle-dove is not thought to have any impact upon biodiversity. However, Blakers *et al.* (1984) issued a warning:

> 'The laughing turtle-dove may gradually spread through pastoral areas of the state [of Western Australia] where permanent water is available for stock. In the north it may compete with the diamond and peaceful doves, with which it is spreading into contact.'

3.7.28 Spotted Turtle-dove (*Streptopelia chinensis*)

Other names

Indian Turtledove, Spotted Dove

Summary

An urban and rural bird confined to a few towns in the Rangelands, where it has no known impact upon biodiversity.

Distribution

Recorded in the Rangelands from Alice Springs, Mt Isa, and towns north of Mackay and west of Townsville (Barrett *et al.* 2004). It colonised Alice Springs only recently as a result of deliberate releases or escapes from aviaries, and a culling program was undertaken to reduce numbers. It is likely to colonise other towns in future.

Found in suburbia, farmland, and sometimes in nearby damp gullies and woodlands. Native to Asia.

Impacts
Because it is mainly an urban bird of limited distribution the spotted turtle-dove does not appear to have a significant impact upon biodiversity within the Rangelands. Outside this region it may become competitive with native doves, although only in rural areas. Frith (1982) presented anecdotal evidence implying that turtle-doves had displaced peaceful doves and bar-shouldered doves from farmland around Lismore.

3.7.29 Barbary Dove (*Streptopelia risoria*)

Other names
Collared Dove, Collared Turtledove, [*Streptopelia decaocto*]

Summary
Presently confined to suburban Alice Springs, but potentially capable of invading rural areas in the Rangelands, although probably without exerting a major impact on biodiversity.

Distribution
A small feral population recently became established in Alice Springs, but due to a culling program only a small number remain.

Outside the Rangelands, small, recently established populations, are present in Adelaide, and these are considered by South Australian government pest experts to be beyond eradication, although it is more likely to be a question of resource allocation.

A very small feral population became established near Perth in the 1970s but was destroyed. Overseas this bird has established feral populations across most of Europe, including the British Isles, and also in China, Korea, Japan, and the USA (Long 1981). The species is native to North Africa, India and south-western Asia.

Impacts
Due to its limited presence within urban Alice Springs this species probably has no impact upon biodiversity. But based upon overseas experience, the barbary dove may become a significant feral bird in Australia in future. Barbary doves seem unlikely to spread from Alice Springs into the surrounding arid landscape, but the feral populations in Adelaide, if they are not controlled, could spread through farmland into New South Wales and Victoria establishing large populations. The vast feral populations found overseas suggest a very good capacity for colonisation. Barbary doves occupy regions in India and western Asia which are climatically comparable to the Rangelands. The barbary dove could become a competitor with native seed-eating birds, as suggested for the spotted turtle-dove in coastal areas.

3.7.30 Skylark (*Alauda arvensis*)

Summary
A bird found at the edge of the Rangelands where it has no known impacts.

Distribution

The skylark is found in south-eastern Australia, mainly outside the Rangelands. Its distribution extends marginally into the study area just north of the Murray River in South Australia (Barrett *et al.* 2004), where it occurs in low grassland. It is native to Europe.

Impacts

None expected.

3.7.31 House Sparrow (*Passer domesticus*)

Summary

A bird of towns and farms that probably has no real impact on biodiversity.

Distribution

Widespread in the eastern half of the Rangelands (Barrett 2004). It occurs almost throughout Queensland and New South Wales and is widespread in South Australia. It is confined to the eastern half of the Northern Territory. It is absent (thus far) from Western Australia, the Top End of the Northern Territory, and north-western South Australia. Native to western Asia and possibly eastern Europe.

Confined to towns and farms. Colonies are sometimes present around remote outback homesteads where the birds obtain seed around barns and livestock pens.

Impacts

Because it is so closely tied to towns and farms the house sparrow presumably has no real impact on biodiversity.

3.7.32 Nutmeg Mannikin (*Lonchura punctulata*)

Other names

Spice Finch

Summary

A small bird of coastal tropical grasslands with the potential to compete with certain native finches.

Distribution

Within the Rangelands the nutmeg mannikin is confined to tropical Queensland. It occurs along the dry tropical coastlines around Rockhampton and Townsville, and further north at Weipa and at one site on the eastern side of Cape York Peninsula (Barrett *et al.* 2004). Outside the Rangelands it occurs in coastal regions of Queensland and northern New South Wales.

Native to South East Asia, where it has probably expanded its range following habitat change and probably also as a result of aviary releases or escapes.

Impacts

This seed-eating finch has the potential to compete with native finches for grass seed. It has been blamed for declines in the chestnut-breasted mannikin, zebra finch, double-barred finch and red-browed finch (Immelmann 1965, Garnett 1988) but without strong evidence. It has a different feeding ecology from most of these species and Frith (1973) discounted an impact upon any of these birds apart from the mannikin, a closely related finch with similar feeding habitats. Immelman (1965) describes the nutmeg mannikin as a 'serious competitor with the chestnut-breasted mannikin', Frith (1973) commenting that 'This might be so, but there are no quantitative figures yet to show a decline in this species.' The two species occasionally hybridise (Immelman 1965). The nutmeg mannikin is most likely to displace the native mannikin from disturbed environments close to human settlements (Frith 1973). Even so, the chestnut-breasted mannikin remains a common bird with a very wide distribution.

In recent years the nutmeg mannikin has expanded its range. It was previously unknown from Cape York Peninsula (Blakers *et al.* 1984) but in recent years has been recorded from Weipa and from the eastern side of the Peninsula, presumably as a result of new aviary releases or escapes. This raises the prospect that the nutmeg mannikin could become established in the Top End of the Northern Territory, as a result of further aviary releases, where it would probably compete with the yellow-rumped mannikin, a species listed by the Northern Territory government as 'Near Threatened'. The two finches have matching habitat preferences. Birdwatchers who reside in the Northern Territory should be asked to look out for escapee nutmeg mannikins, and any populations that are noted should be swiftly eradicated.

3.7.33 European Goldfinch (*Carduelis carduelis*)

Summary

A bird found at the edge of the Rangelands where it has no known impacts.

Distribution

This finch is found in south-eastern Australia, mainly outside the Rangelands. Its distribution extends marginally into the study area in the New South Wales Riverina, and to the north of the Murray River in South Australia (Barrett *et al.* 2004).

Impacts

The goldfinch feeds mainly upon weed seeds and no adverse environmental impact could be expected.

3.7.34 Common Blackbird (*Turdus merula*)

Summary

A bird that sometimes spreads the seeds of exotic weeds.

Distribution

The blackbird is widespread in south-eastern Australia. Within the Rangelands it is confined to inland New South Wales and southern South Australia.

Impacts

Within the Rangelands the blackbird is largely confined to towns, homestead gardens, and riparian vegetation along the Murray River system. It is unlikely to have a noticeable impact on biodiversity except as a vector for the spread of fleshy-fruited weeds such as blackberry (*Rubus fruticosus*) and African boxthorn (*Lycium ferocissimum*). In southern Victoria it is thought to be the main agent for the spread of certain weeds, and this may hold true within the Rangelands as well.

3.7.35 Common Starling (*Sturnus vulgaris*)

Summary

A bird that competes with native birds for nest holes in trees.

Distribution

In the Rangelands it is found over much of New South Wales and temperate Queensland. It also occurs widely in South Australia, and there are scattered records from North Queensland, and a population in Alice Springs. It is absent from the western half of the Rangelands.

Impacts

The common starling competes with native birds for tree hollows in which to nest. In rural districts where few hollow trees remain, it may be contributing to declines of parrots and other hole-nesting birds. In a study conducted around Canberra, starlings and common mynas were found to be the main occupants of tree hollows in three remnant bushland sites (Pell & Tidemann 1997). Where exotic and native birds squabbled over nest sites, the starling was found to prevail most of the time over eastern rosellas but not over crimson rosellas. It proved very successful at competing with red-rumped parrots for hollows, and it may explain an observed decline in these parrots in the region.

Starlings are found mainly around urban and cropping areas, and a conservation issue is most likely to arise where a declining bird occurs in a rural setting where tree hollows are scarce. Garnett and Crowley (2000) suggest that starlings may pose a threat to the vulnerable superb parrot, which is confined to remnant woodlands and farmland in central and southern New South Wales. Adrian Manning (pers. comm.) has observed starlings and superb parrots squabbling over potential nest hollows and he found that starlings usually won these encounters. Starlings have twice been observed nesting in hollows that had previously supported nesting superb parrots. Superb parrots feed within the Rangelands of New South Wales but they breed further south or east, both in the Deniliquin area, and between Wagga Wagga and Carrathool.

Starlings also spread the seeds of fleshy-fruited weeds such as African boxthorn. Boxthorn is a serious environmental weed, although it has value on overgrazed land by providing cover for small native animals.

3.7.36 <u>Common Myna (*Acridotheres tristis*)</u>

Other names

Indian Myna

Summary

An aggressive bird, of limited but increasing distribution within the Rangelands, that competes with native birds for nest holes in trees, but which is not known to pose a threat to any rare species.

Distribution

Of limited distribution in the Rangelands, occurring along the dry tropical Queensland coast, on the Darling Downs, and on the eastern edge of the Rangelands in New South Wales (Barrett *et al.* 2004).

The common myna is expanding its range various parts of Australia, and it was not found in the New South Wales Rangelands in the 1970s (Blakers *et al.* 1984).

Impacts

The common myna is an aggressive bird that displaces other hole-nesting birds. In a study conducted around Canberra, Pell and Tidemann (1997) found that starlings and mynas were the main occupants of natural hollows, despite the presence of many native hole nesting birds. Mynas will displace native parrots from nest holes, and they were seen attacking rosellas, preventing them from entering their nest sites, and pecking inside, presumably destroying eggs and chicks.

The common myna is increasing its range in eastern Australia, leading to community concerns about its impact on native tree-nesting birds, although it is not known to pose a threat to any rare species. Mynas occur only in farmland and rural areas where they do not come into contact with many threatened birds. They prefer nesting in tree holes on the edges of forest remnants rather than deep inside (Pell & Tidemann 1997). The common myna does not appear to pose a threat to any rare bird within the Rangelands, although it may well be suppressing the numbers of some common species by commanding tree holes in regions where hollows are scarce (for example the Darling Downs).

Reptiles

3.7.37 <u>Asian House Gecko (*Hemidactylus frenatus*)</u>

Summary

A small aggressive lizard, mainly confined to urban areas, which displaces native lizards from houses, but which otherwise, has no apparent impact on biodiversity.

Distribution

Towns in northern Australia. A native of South-east Asia, this gecko first appeared in Australia when Port Essington in the Northern Territory was settled between 1838 and 1845 (Greer 2005). During the twentieth century it appeared on islands off Arnhem

Land, and by 1970 had reached Darwin. It then spread southwards to Ti Tree, travelled west into Western Australia, colonising sites in the Kimberley, and reaching Sandfire Roadhouse, halfway between Broome and Port Headland (Greer 2005). It also colonised towns in north Queensland, including Townsville and Weipa. In 1983 it appeared in Brisbane (Low 1999), possibly as a new introduction from overseas. Since then it has colonised much of the central Queensland coast, spread south into New South Wales, and moved west into some inland Queensland towns including Goondiwindi (P. Couper, Queensland Museum, pers. comm.).

This nocturnal lizard has almost certainly travelled to Australia on ships coming from Asia. In Brisbane it was first recorded at a container terminal, then at the wharves (Low 1999). It is evidently moved around Australia amongst produce and other goods.

Impacts

The Asian house gecko is mainly confined to urban areas, where it inhabits buildings and nearby walls and trees, and as such it has no impact upon biodiversity other than some displacement of the native gecko (*Gehyra dubia*). Around Darwin it occurs inside monsoon rainforest but is unlikely to be having much impact upon biodiversity apart from the consumption of some insects.

3.7.38 Flowerpot Snake (*Ramphotyphlops braminus*)

Summary

This tiny burrowing snake is confined to Townsville and coastal towns in the Northern Territory where it is very unlikely to pose any threat to biodiversity.

Distribution

Darwin, the Kimberley, towns along the Pilbara coast, and Townsville, mainly in urban gardens (Wilson & Swan 2003). Also recorded from Torres Strait islands. It is easily overlooked and is probably more widespread in urban areas than the records indicate.

Native to Asia but now found in many parts of the world.

Impacts

This small burrowing snake presumably reached Australia in pot-plants. It appears to be confined to urban areas where it is highly unlikely to have any impact on biodiversity.

Amphibians

3.7.39 Cane Toad (*Bufo marinus*)

Summary

A highly invasive animal, actively invading north-western Australia, that poisons predators and which has caused a dramatic decline in numbers of northern quolls, which are now endangered.

Distribution

Eastern and northern Queensland, extending well inland. In 1982-83, toads entered the Northern Territory, along the plains fronting the Gulf of Carpentaria, and during the last decade they reached the Top End of the Northern Territory. They are still spreading in the Northern Territory and will soon invade Darwin and northern regions of Western Australia. They are also present in northern New South Wales, and global warming will assist their southward movements.

Cane toads occupy many habitats, but they always forage on open ground where they can see nearby movement of insects and other prey. They utilise rainforests, woodlands, grasslands, swamps, mangrove fringes, beaches, dry river beds and farmland (Covacevich & Archer 1975). They shun habitats with a thick under storey (tall grass, bracken, dense shrubs) but will forage along roads and walking tracks that pass through thick vegetation.

Impacts

Cane toads prey on native fauna, compete for resources (food, shelter, breeding sites), and poison native predators. This last impact is by far the most significant, and northern quolls are the species most affected. In 2004, WWF submitted a successful nomination to have predation, competition and lethal ingestion caused by cane toads recognised as a key threatening process under the EPBC Act, largely because of the impact on northern quolls.

Poisoning of predators

Cane toads and their eggs and tadpoles are toxic to a wide range of predators including mammals, reptiles, frogs, fish, insects and snails. Many animals find cane toads distasteful and learn to avoid them. Others are poisoned fatally. When cane toads reach a new region, deaths of various predators occur. The evidence indicates that numbers of quolls, goannas, frilled lizards, and frog-eating snakes drops when cane toads arrive, although numbers of most species recover in time, although not necessarily to the original level.

The impact of toads on various predators was reviewed comprehensively by van Dam *et al.* (2002), and less completely by Crossland (1992), Crossland and Alford (1998), Burnett (1997) and Covacevich and Archer (1975). The following points can be made, drawing especially upon van Dam *et al.* (2002):

Among mammals, quolls (marsupial carnivores) are poisoned fatally when they mouth toads, and dramatic reductions in quoll numbers occur when toads invade, with quolls disappearing from some sites (Burnett 1997, van Dam *et al.* 2002). In 2005 the federal government listed the northern quoll as endangered, with poisoning from cane toads identified as the most significant threatening process. A collapse in quoll numbers has been recorded from monitored sites in Kakadu National Park. Quolls have been translocated to offshore islands to provide them with security from toads. The brush-tailed phascogale, a smaller carnivorous marsupial, may also be at risk (Northern Land Council 2004). This species had become rare in the Northern Territory even before the arrival of toads (Woinarski *et al.* 2001).

Birds rarely die from toad consumption, and no bird species is thought to have declined because of toads. Many birds have learned to utilise toads by consuming their non-toxic parts.

Goannas decline dramatically in numbers when toads invade. Populations recover many years later, but whether they reach their original densities remains unknown. Similar statements apply to frilled lizards.

Various snakes, including red-bellied black snakes, brown snakes and death adders, die if they ingest toads. Red-bellied black snakes and death adders remain uncommon in areas supporting toads, and their populations may be permanently suppressed by toad numbers. One snake, the keelback, can eat small toads, and it often prospers in wetlands where toads are common.

Freshwater crocodiles often die after eating toads. However, freshwater crocodiles are not declining in Queensland where toads are common.

Cane toad eggs and dead tadpoles proved lethal to the tadpoles of desert tree frogs, dwarf tree frogs and ornate burrowing frogs. Tadpoles appear to be unable to detect the toxins in toad eggs. In Queensland, where toads are very common, frog numbers may be suppressed to some degree, but native frogs do not disappear from sites when toads are present.

Cane toad eggs and tadpoles prove lethal to some fish but not others. Fly-specked hardyheads, banded grunters, spangled grunters and purple-spotted gudgeon are poisoned but various other fish, including saratoga and common archerfish, are not. No declines in fish numbers have been recorded, although no monitoring of fish has taken place.

Cane toad eggs and small tadpoles are lethal to some native invertebrates that prey on them but prove harmless to others. Snails, water beetle larvae, backswimmers and leeches die after consuming them. Water scorpions, giant water bugs, dragonfly larvae, freshwater prawns, crabs, crayfish, wolf spiders, ants are unharmed.

The other impacts of toads, resource competition and predation, appear to be less significant.

Competition

In New South Wales the green tree frog is thought to have declined in areas supporting toads, which may reflect competition; however, green tree frogs are sometimes common in sites supporting toads.

Crossland & Alford (1998) found that cane toad tadpoles can compete significantly with the tadpoles of the ornate burrowing frog. Toads produce far more eggs than most frogs, but competition is only likely when breeding sites are limited, which is usually not the case. Ornate burrowing frogs remain common in many sites that support toads.

Where toads are abundant they often dominate hiding places under logs and other cover (Covacevich & Archer 1975). They probably inconvenience other animals seeking cover in these situations. However, snakes and lizards will often share shelter with cane toads and the level of competition is not likely to be of great significance except in certain habitats.

Competition for food is not thought likely at the adult stage. Dietary studies show that toads mainly eat beetles, ants and termites, and that they are not obvious competitors with native frogs. But toad tadpoles (‘toadpoles’) do compete with native tadpoles in small pools. This competition would be unlikely to lead to extinctions but it might reduce frog numbers at some sites.

Predation

Although cane toads are occasionally reported eating frogs, snakes, lizards, birds, mice and other vertebrates, dietary studies, based upon dissecting large number of toad stomachs, indicate that beetles, termites and ants are their main foods. It seems very unlikely that any prey species has become rare because of toad predation at either the adult or tadpole stage.

Summary

Cane toads are often claimed to have a devastating impact upon biodiversity. Laboratory experiments demonstrate that toads and their eggs and tadpoles are poisonous to many predators. But surveys of toad-invaded areas show that nearly all predators survive alongside toads, albeit sometimes at reduced densities. The evidence suggests that predator populations sooner or later learn to avoid toads. This does not mean that the impact of toads should be downplayed. Impact should not be measured only by the loss of species. Feral animals often have a wide range of impacts upon ecosystem functioning. Cane toads are sometimes the most abundant vertebrate within a habitat, and their impacts can be wide ranging, as noted above. The cumulative effects of cane toad poisoning, competition and predation can represent a substantial impact upon ecosystem functioning, especially when it leads to reduced numbers of predators such as quolls, goannas and snakes.

The impact upon northern quolls is the most serious impact of toads yet recorded. In some regions of Queensland, quolls occur alongside toads, although mainly in rocky and upland situations where quolls probably have little contact with them. In other areas, quolls disappeared soon after toads arrived and they have never returned. The northern quoll is now listed federally as endangered. Permanent declines in populations of frog-eating snakes are another significant impact. Declines in goannas may be a third impact, but the evidence for this is less convincing: goanna densities are not easy to monitor.

Fish

3.7.40 Common Carp (*Cyprinus carpio*)

Summary

Carp are widespread throughout southern Australia where they dominate the aquatic fauna. Although perceived as the number one introduced fish threat to inland waterways, the extent of negative impacts this species has is still unclear. They have been implicated in reduction of water quality, destruction of aquatic vegetation, spreading disease and parasites, undermining banks and competition for food resources. Significant investment in carp control research and development is made in Australia. Several potential control techniques have been suggested; however current control efforts generally rely on manual extraction, poisoning, exclusion and a commercial fishery.

Distribution

Carp have become the most abundant large freshwater fish in Australia. They are widely distributed throughout south-eastern Australia and dominate fish communities throughout their range. They occur all through the Murray-Darling Basin and inland waterways of South Australia, including the Lake Eyre Basin. A survey by New South Wales Fisheries has shown that carp consist of over 80 per cent of total fish biomass within much of the Murray-Darling basin, and as high as 96 per cent in some regions. The occurrence of carp in temporary or intermittent wetlands can be highly sporadic and dependent upon the drying and wetting cycle (Gehrke *et al.* 1999). Carp have the potential to spread to many more of Australia's waterways and could become even more widespread. The preferred habitat of carp consists of warm, still water with a silty substrate that enables them to easily forage for food. Many of the inland aquatic habitats in the southern Rangelands have been disturbed by human activities such river flows alteration/regulation, nutrients enrichment and streamside vegetation clearance, creating idea environments for carp. Their broad environmental tolerances, including the ability to thrive in highly polluted or low oxygen water, allow them to prosper in these altered habitats.

Impacts

Carp in Australia now have a role as predators, prey, competitors and habitat modifiers that affect other species and ecological processes. Most perceptions of environmental damage by carp focus on their potential to impact wetlands reduce water quality and harm native fish populations. Although carp are often regarded as having a harmful effect on aquatic habitats and native species, there is little information on the overall impact they have. Limited research on environmental effects of carp has been undertaken, however many of the impacts are unclear because they can be caused by other anthropogenic activities. Carp predominantly feed by sucking in mouthfuls of mud and silt from the banks and bottom of their habitat and straining out the inedible sediment with their gill rakers and muscular soft palate. Food is also sucked from aquatic vegetation in a similar manner. There is clear evidence that carp increase water turbidity and damage many aquatic plants and some evidence that they increase water nutrient levels through their feeding behaviour. Such damage can threaten endangered species and alter ecosystem function. Carp have been suggested as one cause in the decline of several threatened species however these have not inhabited waters of the Rangelands (Koehn *et al*. 2000). Impacts on native fish fauna are less well documented, even though carp often dominate fish assemblages. Declines in native fish populations in many areas occurred prior to the introduction of carp populations. Carp may simply be taken the place of native fish that have already been displaced.

Carp compete with native species for food and habitat space such as spawning sites. Since carp spawn at lower temperatures than many native species, they spawn before many species and may exclude smaller species from their preferred spawning areas in vegetated habitats. A degree of dietary overlap occurs between carp and native species. Despite the strong likelihood of competition existing, there is currently no documented evidence of native fish species being displaced by carp in Australia (Koehn *et al.* 2000). Habitat use by carp and native species do overlap, with both using snags and areas of slow flowing water (Koehn & Nichol 1998). Another pressure on habitat use for native species may be behavioural pressure exerted by large schools of large carp, which may force smaller native fish from their preferred habitat areas. The high biomass reported for carp may have the effect of physical exclusion from habitats for native species (Koehn *et al*. 2000).

A number of parasites and disease organisms have been identified in carp. Those currently known to occur also in native fish and which pose a risk to native species include: the fungus *Saprolegnia*; the protozoans *Myxobolus*, *Trichodina*, *Ichthyobodo*, *Cheilodonella*, *Ichthyophthirius* and *Apiosoma*; the monogeneans *Dactylogyrus* and *Gyrodactylus*; the cestode *Bothriocephalus*; and the copepod *Lernaea* (Koehn *et al.* 2000).

3.7.41 English Perch (*Perca fluviatilis*)

Summary

A fish of limited distribution within the Rangelands; present across the southern half of New South Wales and south-eastern waterways of South Australia. This piscivorous fish can have significant localised impact on native species through predation as well as direct competition for food and habitat resources. Currently no management is undertaken.

Distribution

In the Rangelands, English perch occur in the south-eastern waterways of South Australia and the southern half of New South Wales in the Murray-Darling Basin. Their distribution is restricted by an aversion of high water temperatures and fast flowing waters. They prefer the still waters of lagoons, creeks and lakes, particularly where structured habitat such as submerged timber or aquatic vegetation exists. The distribution of English perch appears stable due to natural barriers created by water temperatures and velocities.

Impacts

English perch are thought to have a significant impact on native fish species in many regions. Their piscivorous nature and their tendency to form large populations are believed to be detrimental to native species through direct competition for food and habitat resources and predation of small fish (Arthington & Blühdorn 1995). Fragmentation and decline of native species has been directly correlated with English perch (Hutchinson 1991). Yet English perch do not have detrimental effect on native fish in all waterways. When food and habitat resources are abundant, native species have been able to successfully co-exist with perch, despite some predation pressure (Pen & Potter 1992). However, in waters of low productivity where competition for resources is intense, English perch represent a substantial threat and have the greatest impact (Arthington & McKenzie 1997). In regions of the Murray River in Victoria, it has been observed that depleted populations of native fish did not increase until perch numbers decreased (McKay 1984). English perch are also a known carrier of the epizootic haematopoietic necrosis virus which has shown to be highly pathogenic for many native species (Clarke *et al.* 2001). Potential exists for perch to spread this disease through populations of threatened and endangered native fish species.

3.7.42 Mosquitofish (*Gambusia holbrooki*)

Summary

Gambusia are widespread throughout the Rangelands, and become a dominant species in many waterways. They are implicated in resource competition and predation of native species and have their greatest impacts on small native fish populations, including several threatened species.

Distribution

Gambusia is the most widespread feral fish found in the Rangelands. They were originally introduced as a mosquito control vector in 1935 (Bayly & Williams 1973) however this has generally proved unsuccessful (Hambleton *et al.* 1996) and the species is now a widely distributed pest. They are very common throughout most of New South Wales, Queensland and South Australia, and are present in the south-east corner of the Northern Territory. Mosquitofish have been found in most major basins in Australia, including the Murray Darling Basin, the Lake Eyre catchment, Canning and North Dandalup catchments in Western Australia and (Arthington & McKenzie 1997). Mosquitofish are abundant in waterways where flow has been modified and restricted, and prefer to inhabit quieter backwaters out of the main current flow where fast flows occur (McKay 1984).

Impacts

Mosquitofish are thought to impact on native fish species through competition for resources, aggressive behaviour and direct predation (Lloyd 1990, Ivanoff & Aarn 1999). However, as with many introduced fish species, much of the evidence on their impacts is circumstantial. Mosquitofish have been implicated in the decline in the native fish species of an area, everywhere they have been introduced (McKay 1984). In Australia, the mosquitofish has become a dominant species in many waterways, especially near urban areas (McKay 1984, Clarke *et al.* 2001) where they survive well in disturbed environments. Arthington and Marshal (1999) found that the opportunistic feeding behaviour of mosquitofish can exert pressure on small populations of native species, particularly when prey availability is limited. Their predation on invertebrates can also result in changes in the abundance of zooplankton and phytoplankton assemblages, which in turn can have an indirect effect on planktivorous native species (Arthington & Bluhdorn 1995). Mosquitofish are also reported to exhibit antagonistic behaviour and exert predation pressure on vulnerable species (Clarke *et al.* 2001). Within the Rangelands, they have been implicated as a contributing factor in the decline of endangered red-finned blue-eye (*Scaturiginichthys vermelipinnis*), purple spotted gudgeon (*Mogurdna adspersa*) and Edgbaston Goby (*Chlamydogobius squamigenus*) (Arthington & Bluhdorn 1995, Arthington & McKenzie 1997, Unmack 2003). Further, the habitat of the Flinders Ranges gudgeon (*Mogurnda clivicola*) has recently been invaded by mosquitofish and it is feared that they may negatively impact this species. Mosquitofish pose a particular threat to many of the native desert fish species which only occur in small isolated populations around natural springs. Incursions by mosquitofish into such habitats would most likely result in strong declines and potentially localised extinctions.

3.8 New pests

New pests can be expected to invade the Rangelands in future (Table 10). Of the vertebrates, fish and birds are among the groups most likely to invade, as a consequence of pet escapes and releases. Lintermans (2004) has documented the increasing number of aquarium fish forming wild populations in Australia. The worst affected catchment is the Ross River at Townsville, where cichlids are thought to be washing into the river from outdoor ponds after torrential rains (Low 1999). Tropical catchments next to large urban centres are most at risk, because most aquarium fish are tropical. Even very remote catchments are at risk. Peter Kendrick (pers. comm.) reported recently seeing a new fish, black with reddish fins (probably a cichlid), populating a waterhole in the remote Kennedy Range National Park in Western Australia, at a popular swimming spot.

The example of barbary doves and spotted turtle-doves recently forming feral populations in Alice Springs shows that aviary releases or escapes can readily lead to new feral populations. It is a matter of grave concern that during the first half of 2005 the Department of the Environment and Heritage received two applications to amend the live import list, maintained under the EPBC Act, to include the collared dove as a household pet. The collared dove has formed feral populations in many regions of Asia and North America. It is a domesticated form of the barbary dove which has expanded its range dramatically in Europe.

Aviary releases also have the potential to spread diseases to wild birds. The more virulent forms of Newcastle Disease have the potential to cause mass deaths among wild bird populations.

Game birds are also a serious concern. As noted in section 8.3.3, the newly-created Game Council of New South Wales has a mandate to manage Californian quail, pheasant, chukhar partridge, peafowl and turkey for hunting. All of these birds can fly, so they cannot not be constrained by fencing, and all of them have formed feral populations elsewhere of the world. A feral population of chukar patridge has recently been reported from Gulgong, east of Dubbo, in New South Wales, the birds having been released for a sporting shoot (Morcombe 2000).

As well, the Rural Industries Research and Development Corporation is promoting the breeding and export of game birds, including quail, guineafowl, pheasants, and partridges, throughout their report, *Identification & Development of Opportunities for Exporting Game Birds*. Most game birds in Australia are now bred on a small scale for the domestic market, but opportunities have been identified for a massive increase in production to exploit the export market to Singapore and Hong Kong. Large escapes from game farms could easily result in the establishment of feral populations.

Among mammals, the establishment of new deer species is a grave concern. According to the bioclimatic modelling of Moriarty (2004), of the six deer presently found as feral species in Australia, hog deer and sambar deer have the greatest potential to form feral populations in the north of the country, yet neither species is presently established there. Hog deer and sambar have formed successful feral herds in Victoria, in a climate that is colder than their natural habitat in South East Asia. If they escape from captivity in northern Australia, as seems likely, their potential to spread across the landscape is much greater. Both species could form feral populations right around the coastline of Queensland, the Northern Territory and Kimberley region (Moriarty 2004). There are anecdotal reports of feral hog deer from southern Queensland (P. Jesser pers. comm.) but no confirmed populations north of Sydney.

There are also anecdotal reports of releases in Queensland of sika deer (P. Jesser pers. comm.).

Among reptiles, the pest of most concern is the red-eared slider, a freshwater turtle from North America which appears on the IUCN list of 100 of the World's Worst Invasive Alien Species (Lowe *et al.* 2000). It has formed feral populations in Asia, Europe and North America, and is considered very aggressive and competitive. A population was recently located north of Brisbane and a major eradication and publicity campaign is underway, funded by the Queensland Department of Natural Resources. Foreign turtles are readily smuggled into the country, and smuggled specimens have been turned in to the Queensland Government. Bioclimatic modelling indicates that red-eared sliders could colonise all of eastern Queensland, much of northern Australia, and the Murray-Darling catchment (Scott O'Keeffe pers. comm.). A small population occurs in a catchment near Sydney where no control efforts have been undertaken, although the turtles there appear to be scarce and rarely noted. They do best in dams and sluggish waters.

The amphibian of most concern is the black-spined toad (*Bufo melanostictus*). This amphibian, a small relative of the cane toad, has spread south from its native range in mainland South-East Asia into Indonesia and New Guinea. It thrives in farmland and other disturbed environments. In the last couple of years several of these toads have been intercepted by quarantine officers at Australian ports where they were travelling with cargo. The black-spined toad looks similar to the cane toad and a feral population could become established for some years before it was noticed. Indeed, a feral population may already be established.

Invertebrates will keep invading the Rangelands. The pest of most concern for Australia is the red imported fire ant. The eradication effort in Brisbane is proceeding successfully, although new infestations are found periodically beyond the perimeters of the mapped infestation areas. If the eradication effort fails, or if fire ants invade again, as seems inevitable, they could spread over large areas of the Rangelands, and pose a threat to rare species, for example the plains wanderer. Fire ants have now become established in Hong Kong, and the risk of new incursions will grow as they spread among our major trading partners.

Another ant of grave concern is the electric ant or little fire ant (*Wasmannia auropunctata*), from Latin America. This ant has colonised New Caledonia and other Pacific Islands and it is regularly intercepted at Australian airports. The ants are sometimes found inside prayer mats brought by people from Polynesian islands visiting Queensland for funerals. In the rainforests of New Caledonia this ant reaches extremely high densities.

Table 10 Feral pests that could establish in the Rangelands in the future

Hog Deer	Red-eared Slider
Sambar Deer	Black-spined Toad
Sika Deer	Various aquarium fish
Chukar Partridge	Red Imported Fire Ant
Ring-necked Pheasant	Little Fire Ant
California Quail	

Section 4 Legislative framework

4.1 Commonwealth legislation

The Australian Constitution does not give the Commonwealth the explicit power or authority to enact environmental laws. However, there are particular powers that may be used in reference to the environment within the Constitution. An important aspect of the Constitution is that if there is inconsistency between Commonwealth law and the law of a State or territory, the Commonwealth law prevails. Therefore, should it choose to do so, the Commonwealth has the ability to over-ride state laws in areas of constitutional competence.

The three key Commonwealth legislative instruments relating to feral species are:

- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- *Quarantine Act 1908*
- *Natural Heritage Trust of Australia Act 1997* (NHT Act).

EPBC Act 1999

EPBC Act is the key Commonwealth legislation dealing with the conservation of biodiversity. The EPBC Act provides a framework for the management of invasive species by providing for:

- the identification of key threatening processes (KTPs)
- the protection of critical habitat
- the preparation of:
  - Recovery plans
  - Threat abatement plans (TAPs)
  - Wildlife conservation plans
  - Bioregional plans
- conservation agreements
- the issuing of conservation orders
- the regulation of exports and imports of live animals and plants, wildlife specimens, and products made or derived from wildlife.

Under the EPBC Act there is provision for TAPs to be made jointly with the State or Territories or with agencies of those States or Territories. Whilst the listing of TAPs is the most direct most direct mechanism for responding to new and emerging threats, there are also other mechanisms to deal with these issues, such as policy decisions to address threats outside of the KTP listing/TAP process and collaborative and ad hoc programs. Section 301A also provides for the development of regulations for the control of non-native species. Under the EPBC Act, regulations may provide for the establishment and maintenance of a list of species, other than native species, whose members threaten or would likely threaten biodiversity. The EPBC Act established a list of species suitable for live import (the live import list) and prohibits the import of any species not on this list. The live import list is divided into two parts – Part 1 is a list of specimens that may be imported without a permit and Part 2 is a list of specimens that may only be imported with a permit, often with conditions attached. An applicant wishing to add a species to this live import list must prepare an assessment report examining the potential impacts on the environment of the proposed import against agreed Terms of Reference. The draft report is published on the DEH website for public comment and a letter is also sent to the appropriate State, territory and Australian government Ministers requesting comment. A species will be added to the live import list only when the Minister is satisfied that it will not impact on the Australian environment. The importation of potentially invasive species is not just constrained by the EPBC Act, but also other Acts, principally the Quarantine Act. EPBC Regulations may also regulate or prohibit trade in members of species between States and territories, and by constitutional corporations.

Quarantine Act 1908

The Quarantine Act provides for the responsibility of pre-border and border monitoring, detection and control arrangement in respect of humans, animals and plants. Its role is the prevention or control of the entry, establishment or spread of pests and diseases that will or could likely cause significant damage to human beings, plants, animals and other aspects of the environment. The nature of the purpose of this Act is within the scope of this report, however since the Quarantine Act is primarily administered by the Department of Agriculture, Forestry and Fisheries, it will not be considered in detail here.

Natural Heritage Trust of Australia Act 1997

The NHT Act is dedicated to repairing and replenishing Australia's natural capital infrastructure. It aims to move the management of natural resource to a more integrated and cohesive approach that will mitigate existing problems and improve land use now and for future generations. It is jointly managed by DEH and DAFF. The second phase of the NHT is seeking to deliver important resource condition outcomes including improved water quality, less erosion, improved estuarine health, improved vegetation management and improved soil condition.

Other relevant Commonwealth legislation

The *Agricultural and Veterinary Chemicals Code Act 1994* provides for the regulation of chemicals used in the control of feral species. Chemicals must be registered for use for each species to be targeted and distribution of the chemicals is to be restricted unless declared otherwise. The Biological Control Act 1987 provides for and governs the use and release of biological control agents in Australia. This Act has relevance to the rabbit myxomatosis and calicivirus as well as research into new biocontrols. Under the *Income Tax Assessment Act 1997* expenditure on preventing and treating land degradation is eligible for a rebate or a deduction. Subdivision 387-A allows for the erection of fencing to exclude feral animals from areas affected by land degradation, eradication or control of feral animals, and extension of the above activities.

Intergovernmental agreements

Partnership agreements exist between the Commonwealth and each State and territory government that aim to ensure that State policies and regulatory arrangements for environmental protection and sustainable development are consistent with national objectives and priorities.

4.2 State and Territory legislation

The State and Territories have principal responsibility for environmental management. They are free to pass legislation on all aspects of environmental protection, as long as it falls within Commonwealth constitution constraints. States and Territories have developed their legislation independently and as such different administration and responsibility arrangements occur between regions. This has led to legislative and regulatory inconsistencies between jurisdictions which will be discussed later.

Table 11 Australian legislation relevant to feral animal management

Commonwealth	*Environmental Protection and Biodiversity Act 1999* *Quarantine Act 1908* *Natural Heritage Trust of Australia Act 1997* *Agricultural and Veterinary Chemicals Code Act 1994*
New South Wales	*Prevention of Cruelty to Animals Act 1979* *Pesticides Act 1999* *Rural Lands Protection Act 1998* *National Parks and Wildlife Act 1974* *Game and Feral Animal Control Act 2004* *Threatened Species Conservation Act 1995* *Wild Dog Destruction Act 1923* *Non-indigenous Animals Act 1987*
Northern Territory	*Animal Welfare Act* *Territory Parks and Wildlife Conservation Act* *Poisons and Dangerous Drugs Act*
Queensland	*Animal Care and Protection Act 2001* *Health (Drugs and Poisons) Regulation 1996* *Land Protection (Pest and Stock Route Management) Act 2002* *Nature Conservation Act 1992* *Fisheries Act 1994*
South Australia	*Prevention of Cruelty to Animals Act 1985* *Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986* *Controlled Substances Act 1984* *National Parks and Wildlife Act 1972* *Dog Fence Act 1946* *Cat and Dog management Act 1995* *Native Vegetation Act 1991*
Western Australia	*Animal Welfare Act 2002* *Agriculture Protection Board Act 1950* *Agriculture and Related Resources Protection Act 1976* *Poisons Act 1964* *Wildlife Conservation Act 1950* *Biological Control Act 1986*
Other relevant legislation	Firearms Acts

	Occupational Health and Safety Acts Dangerous Goods or Substances Acts Dog Acts Civil Aviation Acts Income Tax Assessment Acts

The following is a brief summary of the key State legislations regarding feral animal management in Australia.

<u>New South Wales</u>

Rural Lands Protection Act 1998* and *Rural Lands Protection Amendment Act 2003

This Act sets out the provisions under which animals can become declared pests and also provides the processes and mechanisms for the control of declared pest species. The Act poses legal obligations on owners and occupiers of land, both public and private, with regards to the eradication of declared pest species.

National Parks and Wildlife Act 1974

This Act provides the legislative basis for the control of vertebrate pests in New South Wales conservation lands. One of the objects of the Act is the conservation of habitat, ecosystems and ecosystem processes, and biological diversity at the community, species and genetic levels. This can be achieved by applying the principles of ecologically sustainable development including the control of threatening processes.

Threatened Species Conservation Act 1995, Threatened Species Conservation Amendment Act 2002 and Threatened Species Legislation Amendment Act 2004

These Acts list Key Threatening Processes (KTPs) to biodiversity. The listing of an animal as a KTP results in the development of a Threat Abatement Plan (TAP) to manage, minimise and hopefully abate detrimental impacts the species have. Currently European red foxes, feral pigs, rabbits, feral deer, fire ants, gambusia and feral cats are currently listed as KTPs in New South Wales and TAPs are being developed and implemented. Threat Abatement Plans (TAPs) have only been developed for gambusia and foxes.

Wild Dog Destruction Act 1921

This Act requires landholders and occupiers in the Western Division to destroy all wild dogs upon such land and for the maintenance of the wild dog fence along the north-western parts of the New South Wales/Queensland border and the New South Wales/South Australian borders.

Prevention of Cruelty to Animals Act 1979

This Act requires that all animals are treated and controlled in a humane and ethical manner, regardless of status.

Wilderness Act 1987

This Act provides for the identification and permanent establishment and management of wilderness areas where natural processes can occur with undue anthropogenic influences.

Native Vegetation Conservation Act 1997

This Act are provides for the management of native vegetation on a regional basis in the social, economic and environmental interests of the State, and to protect native vegetation of high conservation value having regard to its contribution to such matters as water quality, biodiversity, or the prevention of salinity or land degradation, and to improve the condition of existing native vegetation, particularly where it has high conservation value.

Non-indigenous Animals Act 1987

This Act provides for the listing of non-indigenous animals into categories based on the level of control required and the risk that they pose to agriculture and the environment

Fisheries Management Act 1994

Part of this Act provides for the conservation of fish stocks and key fish habitats and the conservation of threatened species, populations and ecological communities of fish and other aquatic biodiversity. This Act also allows for the declaration of noxious fish species. Currently carp, gambusia, and tilapia are declared noxious species.

Game and Feral Animal Control Act 2004

This Act provides for the effective management of introduced species of game animals, and promotes responsible and orderly hunting of those game animals on public and private land and of certain pest animals on public land. Declared game animals include deer, pig, dog (other than dingo), cat, goat, rabbit, hare, and fox.

Queensland

Land Protection (Pest and Stock Route Management) Act 2001

This Act specifies principals for pest animal management, including integration, public awareness, best practice and prevention. It is one of the most complete pest control Acts in Australia and focuses on protecting both agricultural production and the environment, as opposed to the agricultural focus of many Acts. The *Queensland Pest Animal Strategy* is enshrined in the Act and provides an agreed framework to improve pest animal management. Designation of responsibility is one significant aspect of the Act. Land managers have the responsibility for managing pest animals on their land and local governments have had to develop a Local Government Area Pest Management Plan in consultation with State government agencies and stakeholders. Under the Land Protection (pest and Stock Route Management) Regulation 2003, feral goats, feral pigs, European red fox, rabbits, wild dogs, dingos, and feral cats. Furthermore, any species not listed under Schedule 1 of the Regulation is declared a pest.

Fisheries Act 1994

This Act covers noxious and non-indigenous fish species. The Act has provisions for declaring a fish species to be noxious, making it illegal to possess or release. Currently carp, gambusia, tilapia, and weatherloach are declared noxious species.

Animal Care and Protection Act 2001

This Act requires that all animals are treated and controlled in a humane and ethical manner, regardless of status.

Health (Drugs and Poisons) Regulation 1996

This Act provides for the regulation of chemicals used in the control of feral species. Chemicals must be registered for use for each species to be targeted and distribution of the chemicals is to be restricted unless declared otherwise.

Nature Conservation Act 1992

The object of this Act is the conservation of nature through the declaration and management of protected areas, and the protection of native wildlife and its habitat.

South Australia

Animal and Plant Control Commission (Agricultural Protection and Other Purposes) Act 1986

This Act provides for the control of pest animals for the protection of agriculture and the environment, for public safety and other purposes. Administration and implementation of the Act is the responsibility of the Animal and Plant Control Commission, with local control and policy development occurring through Animal and Plant Control Boards which are based on Council boundaries. The Boards are responsible for enforcing the Act within their locality by monitoring the distribution of proclaimed animals. Landholders have the responsibility of controlling proclaimed species on their land. The Act also allows the declaration of pest animals which currently includes deer, goats and rabbits.

Prevention of Cruelty to Animals Act 1985

This Act requires that all animals are treated and controlled in a humane and ethical manner, regardless of status.

Controlled Substances Act 1984

This Act provides for the regulation of chemicals used in the control of feral species. Chemicals must be registered for use for each species to be targeted and distribution of the chemicals is to be restricted unless declared otherwise.

National Parks and Wildlife Act 1972

This Act provides the legislative basis for the control of vertebrate pests in South Australian conservation lands. One of the objects of the Act is the conservation of habitat, ecosystems and ecosystem processes, and biological diversity at the community, species and genetic levels. This can be achieved by applying the principles of ecologically sustainable development including the control of threatening processes.

Dog Fence Act 1946

This Act provides for the construction and maintenance of a dog fence in the northern areas of the State for the purpose of preventing the entry of wild dogs into the pastoral and agricultural areas.

Cat and Dog management Act 1995

This object of this Act is to encourage responsible ownership, reduce public and environmental nuisance and to promote the effective management of dogs and cats.

Native Vegetation Act 1991

The Act provides for the management of native vegetation, to protect native vegetation of high conservation value and to improve the condition of and rehabilitate existing native vegetation, particularly where it has high conservation value.

Northern Territoy

Territory Parks and Wildlife Conservation Act 2001

This Act provides for the management of feral animals in the Northern Territory. Feral animals must be managed so that their detrimental impacts on biodiversity, population size and extent of distribution are reduced. Land owners or occupiers are responsible for the management of feral animals on their land; however they may receive assistance from the Parks and Wildlife Commission to assist them filling their obligations. All vertebrate that are non-indigenous are declared prohibited entrants into the Northern Territory unless specified in the Regulations.

Animal Welfare Act

This Act requires that all animals are treated and controlled in a humane and ethical manner, regardless of status.

Poisons and Dangerous Drugs Act

This Act provides for the regulation of chemicals used in the control of feral species. Chemicals must be registered for use for each species to be targeted and distribution of the chemicals is to be restricted unless declared otherwise.

Western Australia

Animal Welfare Act 2002

This Act requires that all animals are treated and controlled in a humane and ethical manner.

Agriculture Protection Board Act 1950

This Act provides for the Agricultural Protection Board whose primary duties are to protect agricultural industries and regulate the supply of poisons for feral animal control use.

Agriculture and Related Resources Protection Act 1976

The object of this Act is to protect primary industries and the resources related to primary industries.

Poisons Act 1964

This Act provides for the regulation of poisons and places restrictions on their use.

Wildlife Conservation Act 1950

One of the objects of this Act is the conservation of habitat, ecosystems and ecosystem processes, and biological diversity. The Act also provides for the declaration of protected species and key threatening processes.

Biological Control Act 1986

This Act governs the release and use of biological control agents in Western Australia. This Act has relevance to the rabbit myxomatosis and calicivirus as well as research into new biocontrols.

Agricultural and Veterinary Chemicals (Western Australia) Act 1995

This Act provides for the regulation of chemicals used in the control of feral species. Chemicals must be registered for use for each species to be targeted and the distribution of the chemicals is restricted unless declared otherwise.

4.3 Comments on current legislation

- The current EPBC Act arrangements concerning the development of national threat abatement plans appear adequate and effective in developing the initial framework. However, listing of key threatening processes *usually* only occurs when a species is threatened with extinction and when action to reverse this may be costly or ineffective. As one NRM person described, "Shutting the gate after the horse has bolted". The main focus generally appears to be on remnant populations and final extinction events. The long-term processes that have led to rarity and vulnerability in the first place seem to be given less countenance. Under the EPBC Act section 188(4), a process is eligible to be listed as a key threatening process if it *may* threaten biodiversity. This occurred with regards to the listing of Fire Ants as a KTP. There is a strong need for *more* attention to be paid to long-term threatening processes that may not impact upon threatened species. It would be beneficial if more threatening processes were recognised and listed prior to species becoming threatened.
- Treat Abatement Plans (TAPs) under the EPBC Act provide a national plan, however they are often not fully implemented. As more key threatening processes are listed it will be important to ensure there is adequate funding to ensure TAPs are developed (as required) and implemented, including those for invasive species.
- Introduced fish have been considered a major causal factor in the threatened status of 42 per cent of freshwater fish recovery plans. The majority of new freshwater pests are introduced through the ornamental fish trade (McNee 2002, Lintermans 2004). Fish are released into local waterways when owners no longer want them. A recent review of the aquarium fish industry has identified at least 1181 freshwater species have been recorded in Australia in the last 40 years (McNee 2002). Of these only 481 species are currently listed as permitted imports, leaving 700 species known to have been or still present in the country. Some of these species may have been imported under previous legislative regimes. However, within the current permitted live import list there are still fish species which have already established feral populations.
- The inconsistent status of pest animals across Australia is one of the key statutory and administrative arrangements that hinder effective management of the threat posed by invasive species. The status of pest animals may vary between each State or Territory, even though the principals of the legislation utilised are usually fairly similar. For example, the legal status of goats varies across Australia. Commonwealth legislation identifies feral goats as contributing to a key threatening process. Queensland, South Australia and Western Australia define feral goats as pests and prescribe actions to manage them. Other States and Territories do not define feral goats a class and do not prescribe particular action for land managers. This lack of consistency in the legal definition of what constitutes a feral goat, and variation in the requirements imposed on land managers, impede actions to ameliorate their impacts on endangered species.
- States and Territories have some regulations that insist on continuous suppression and destruction wherever particular feral animals are found. In most instances there appears to be have been little attempt to relate the costs of control to the benefits gained from lowered feral animal densities, placing an unrealistic expectation upon land managers. Instead of the unachievable goal of eradication, the wording should be altered to promote strategic management for long-term

suppression, which is the management objective of most States and Territories anyway.

Section 5 Management of feral animals in the Rangelands

5.1 General control techniques

An ideal feral animal control method should achieve a long-term reduction and be humane, target-specific, efficient, cost-effective and safe to implement. The effectiveness of a technique and benefits gained are likely to depend upon a wide range factors including the intensity and frequency of application, feral animal abundance prior to and following control, the size of an area controlled and the ability of impacted species or resources to recover (Hone 1994, Choquenot & Parkes 2000, Coomes *et al.* 2003).

The range of techniques available to manage feral animals is limited. Animals can be killed, removed, excluded, and deprived of access to water, or have their fertility reduced. Within these categories, a range of techniques have evolved to exploit the individual behavioural and physiological characteristics of each species. The main techniques are outlined below and the specific details for each species are discussed later.

5.1.1 Poisoning

The application of poisons is one of the most commonly used techniques for feral animal control in Australia. It can be cost-effective, suitable for a wide range of species, used over large areas and effectively reduce target populations by substantial amounts. The main disadvantages are that poisons are rarely target specific, can produce side effects in animals receiving sub-lethal doses, may lead to bait shyness or aversion, and the humaneness of some toxins may be questionable.

A variety of poisons have been used in Australia including arsenic, cyanide, strychnine, yellow phosphorous (CSSP), anticoagulants such as warfarin, bromodialone and pindone, and sodium monofluoroacetate (1080). The use of poisons varies with their effectiveness on targeted species, however the most commonly used are 1080, CSSP, strychnine and pindone. They are applied to a wide variety of baits that are chosen by their cost, ease of acquisition and deployment, attractiveness to the target species, and sometimes to specifically reduce non-target uptake.

One of the biggest drawbacks of poisoning can be the lack of target specificity. Often native fauna is just as likely to succumb to the effects of the poison as are the feral animals. Refinements have been made to poisoning systems to minimise non-target impacts and uptake of baits. Detailed study of animal behaviour have produced information allowing poisoning strategies to modify the delivery mechanisms and timing to the specific habits of the target species. This can substantially reduce the likelihood of non-target species consuming poisoned baits, but does not eliminate it altogether.

Secondary poisoning can occur when predators feed on the carrion of animals killed by poisoning. For example, native species such as the wedge-tailed eagle, readily feed on rabbits destroyed by poisoning. They may succumb from secondary poisoning from feeding on single prey or bioaccumulate toxins over a period of time (O'Brien *et* *al.* 1986, 1987). The use of poisons that breakdown quickly in the natural environment and in the species killed can reduce this impact greatly.

As an example of the pros and cons of using poison for control, we will explore the use of 1080 in the control of feral animals, with particular reference to baiting for foxes and wild dogs. 1080 or sodium fluoroacetate is the most widely used poison for canid control in Australia. It is a relatively new poison that has gained widespread acceptance and is used to control a variety of feral animals. Fluoroacetate actually occurs naturally in a number of Australian plants of the genera *Acacia, Gastrolobium* and *Oxylobium* (Oliver *et al.* 1977), some species of which extend from south-west Western Australia, up through the Northern Territory and down into the central highlands of Queensland (Everist 1947). The environmental fate of 1080 has been studied more extensively than any other vertebrate pesticide, particularly in New Zealand, where possum and rabbit control accounts for approximately 70 percent of the world-wide use of the toxin (Eason *et al.* 1998). These authors report that sodium fluoroacetate does not bind to soil constituents and is detoxified quickly by soil organisms, the rate depending on soil temperature and moisture. Only very small quantities are absorbed by plants so there is a negligible risk of poisoning herbivores. In Eason *et al.*'s study (1998) none of 857 surface water samples collected immediately after aerial baiting programs for rabbits or possums exceeded the acceptable concentration for drinking water. Because of very low concentration of 1080 applied to the environment, and the rapid biodegradation of the toxin, wild dog baiting is very unlikely to cause environmental hazards.

The natural occurrence of 1080 in Australian flora benefits its use, particularly in Western Australia where some native fauna have evolved tolerance to the toxin (King *et al.* 1981, McIlroy 1986, King & Kinnear 1991). McIlroy (1981) tested a number of native species potentially at risk of poisoning during 1080 baiting campaigns. On a weight-for-weight basis, native mammals were more tolerant of 1080 than dogs. Birds and reptiles were even more tolerant. This native tolerance allows 1080 to be used with lower risk to native species in such areas. King (1989) assessed the northern quoll (*Dasyurus hallucatus*) as being the species most likely to be at risk during baiting campaigns for wild dogs. King radio-tracked a sample of northern quolls during a wild dog baiting campaign and found that all survived, despite conditions of apparent food shortage and potentially enhanced vulnerability. He concluded that populations of northern quolls faced little risk from wild dog baiting campaigns. However in south-eastern Australia (mainly outside the Rangelands), where 1080 tolerance has not developed, species such as the tiger quoll (*Dasyurus maculatus*) and other carnivorous marsupials, and some rodents and birds may be at risk from fox and dog management programs (McIlroy 1992, McIlroy & Gifford 1992, Korn *et al.* 1992). This suggests that there may be implications of negative impacts on native fauna in areas of the Rangelands where 1080 does not naturally occur in vegetation. Despite these differences in tolerance to 1080 within the Australian fauna, this toxin remains the best choice throughout the continent (McIlroy *et al.* 1986, McIlroy & Gifford 1992).

5.1.2 Shooting

Shooting of pest animals can occur either from the air or from the ground. Aerial shooting from helicopters is a very effective way to manage feral animals in inaccessible or remote terrain. Where possible, it is often employed after populations have been reduced thorough other techniques, usually trapping and mustering. When animal densities are high it can be a cost-effective way to quickly reduce animal numbers, however at lower densities the cost per animal can become prohibitive. It is one of the most effective techniques where considerable numbers of animals have to be controlled over large expanses, and is probably one of the best control techniques for large feral herbivores in the Rangelands.

Ground shooting is also commonly used as a means of controlling pests. It can be time consuming and labour intensive, and injured animals cannot be easily followed and finished off, as can be done with aerial shooting. It is mainly of value when species or communities of high conservation value need protecting. Ground shooting is generally restricted to areas with easy access and is often undertaken opportunistically. Recreational hunting for feral animals is commonly undertaken on private lands with the blessing of the landholder. It reduces the cost of feral animal control, but rarely provides effective control by itself, and needs to be incorporated into an integrated strategy. It can be particularly useful in assisting with follow-up control, especially where localised eradication is the objective.

5.1.3 Trapping

A wide variety of traps are used to capture feral animals. This ranges from individual leg traps, snares and cage traps up to large fenced enclosures with one-way entrances. Steel-jawed leg traps were once commonly used to capture smaller feral animals such as dogs, cats, foxes and rabbits. These traps are generally considered inhumane, non-target specific and are now banned from use in several states. A modern version called a soft-jaw trap is sometimes used instead. It operates in a similar manner, having a trigger that when trodden on releases a set of jaws to hold the animal. The soft jaw traps do not fully close, instead holding the animal through pressure between the rubber-lined jaws. These traps are generally not used for feral animal control in large areas because they are time consuming, not target-specific, expensive and rarely have a significant impact on the feral animal population. They can play a role in capturing difficult or wary animals in particular circumstances, such as within an enclosed nature reserve where poison baiting cannot be implemented.

Larger fenced traps can have a more significant impact on feral animal populations. The traps consist of an enclosed yard or cage with a one way entrance. This may be a one-way gate or a jump-down ramp over which animals cannot escape. For feral pigs the traps are usually baited with carcasses to lure the pigs in. In the case of herbivores, most self-mustering traps are located around watering points where the animals must come to drink. Often the entrance to these traps is left open so that the animals can become accustomed to the traps presence. When enough animals frequent the trap, the one-way entrances are installed and the animals caught. These traps are particularly effective in the arid zones of the Rangelands where water sources can be scarce. It is important that animals not be contained too long within these traps for humane reasons. They will quickly run out of food and become stressed. The trapped animals are shot or transported away live. One of the major advantages of live feral trapping animals is that costs from the exercise can be partially offset through the sale of the animals.

5.1.4 Mustering

Commercial mustering of feral animals is commonly undertaken in the Rangelands. The animals can be mustered using helicopters, vehicles, motorbikes or by horseback. A combination of ground and aerial mustering is an effective way of moving herds and mobs over large distances into yards. The helicopter initially locates and musters the animals away from inaccessible terrain towards where the yards are set. Once the animals are near the yards the mustering is undertaken by the ground crew on horses and motorbikes. One of the benefits of mustering is that animals can often be sold to offset the cost of the operation. However, mustering is usually only effective at relatively high feral population densities. The use of Judas animals can help locate feral groups and make the technique more effective. Olsen (1998) reports that mustering efficiency of varies greatly. In Western Australia an average muster yield between 30-40 percent of feral goats, whilst in the Flinders Ranges of South Australia, approximately 80 percent of goats can be taken on an average muster. Mustering is quite often used to reduce population numbers before beginning and aerial cull, decreasing the expense of the operation.

5.1.5 Judas technique

The use of radio-telemetered individuals to locate animals with which they associate has been developed as a control technique for strongly gregarious species such as goats, donkeys, camels, horses and water buffaloes (Henzell 1987, Taylor & Katahira 1988, Allen 1991, Williams & Henzell 1992, Dobbie *et al.* 1993, Olsen 1998). An animal is captured through trapping, mustering or tranquiliser dart and a radio-collar is fitted. The radio-collared 'Judas' animal is then released and joins up with, and is used to locate, groups in the area. Generally, it is best to use local feral animals as the Judas because they are familiar with the area and are already part of the social structure of the target herds or mobs. The Judas animal is often clearly marked so that during aerial culling it can be avoided. The technique is usually used for low density populations or for survivors of other control campaigns that have become particularly wary. The method is particularly useful when the management objective is local eradication. It has been used to eradicate local populations of feral goats in Australia, for example, in small areas of the Adelaide Hills in South Australia, (Henzell 1987, Williams & Henzell 1992). The main disadvantage of the approach is that the equipment is very expensive and requires skilled operators to work effectively

5.1.6 Fencing

Since the early days of European settlement, fencing has been the most common method used to exclude feral animals from an area. Probably the best known fence is the dingo fence that stretches 5614 kilometres from Queensland through New South Wales across South Australia to the Great Australian Bight. The fence divides the southern and eastern sheep grazing lands from cattle and dingo country. Exclusion fencing is increasingly being used as a tool to protect areas of high conservation value from the threats posed by vertebrate pest species.

There are many types of fences used to exclude pests. They include conventional stock fencing, electric fencing and purpose built fences to protect conservation reserves. Fences have been used to break up areas into manageable blocks for control and have been used to exclude animals from watering points and so concentrate them at watering points where traps have been set. They can also slow dispersal, making control on the protected side more feasible and economic. Electric fencing is relatively cheap compared with conventional stock fencing. It is particularly useful for short-term exclusion of pests. Conventional fencing is expensive and can be penetrated by determined efforts. Purpose built exclusion fencing is expensive to construct and can be time-consuming to monitor and maintain. However, there are a considerable number of native species that would potentially benefit from the provision of an enclosure free of feral predators or competitors.

Exclusion fencing is being increasingly used to protect areas of high conservation value or to create 'islands' of protected habitat for native fauna. It has proven a particularly valuable tool in aiding the reintroduction of threatened species to areas from which they have been previously eliminated by threatening processes, including the predatory and competitive impacts of feral animals (e.g. Dufty *et al.*1994, Gibson *et al.*1994, Short *et al.* 1994, Moseby & O'Donnell 2003, Long & Robley 2004). They are used mainly to exclude foxes and cats, and sometimes dogs. The design of an exclusion fence must be specific to the behaviour of the animals it aims to exclude, as well as taking into consideration the native animals it encloses and those that may be affected by its presence. There are also a variety of environmental and landscape features to be considered that may reduce the effectiveness or durability of a fence (Long & Robley 2004). It is generally understood that no fence is likely to be 100 percent effective 100 percent of the time. Seventy percent of the 20 fence managers surveyed by Long & Robley (2004) felt that their fence was sufficiently effective despite most being breached occasionally by feral animals (only three fences reported no known breaches). It is necessary to determine whether exclusion fencing is necessary and can feasibly achieve the desired conservation outcomes, and whether it is a cost-effective management tool that can be adequately resourced. To maximise the effectiveness of a fence, lethal feral animal control programs are often conducted in the surrounding buffer area to reduce the frequency with which the fence is challenged. These generally take the form of poison baiting programs, but can include shooting, mustering, warren ripping and a range of other techniques.

The use of fencing for the exclusion of feral animals has been reviewed by Coman & McCutchan (1994) and Long & Robley (2004). These reviews provide the specific details necessary to design and implement effective exclusion fences and should be viewed for more detailed information. Fencing has more applicability in temperate Australia than in remote regions of the far north, where fires, cyclones, and a limited workforce to maintain them limit their value. Large feral animals are difficult to exclude with fencing. Camels, buffalo and pigs often push through them. Trials are currently underway to fence desert rock holes from camels using high-strength materials. Fencing has been proposed as a method of stopping cane toads from reaching Western Australia, but the proposals are unrealistic.

5.1.7 Water source control

The control of access to water, particularly artificial watering points and artesian bores, provides can provide a very effective management tool for feral animals in arid and semi-arid regions of the Rangelands. Artificial watering points are so numerous in the arid and semi-arid Rangelands of Australia that their spacing is rarely more than 10 kilometres apart (James *et al.* 1997). This water benefits all large herbivores, allowing them to survive in habitats that would not otherwise be suitable and has allowed feral animals to expand their ranges further into these harsh environments (Parkes *et al.* 1996). This has led to a much greater total grazing pressure, which has irrevocably changed the character of the landscape (James *et al.* 1997). Landsberg *etal.* (1997) found that many native species were disadvantaged by providing water and recommended that artificial waters be closed to address this problem. Closing artificial water points is possible in conservation areas after unwanted herbivores have been removed by humane methods (Parkes *et al.* 1996). While the permanent closure of artificial water points may be an option on the conservation estate, it is not an option on land being managed for livestock production. In these latter areas the focus will need to be on improved management of water points to minimise waste and more effectively manage livestock and grazing pressure.

Current efforts to cap the bores throughout the Great Artesian Basin are likely to contribute in time to more effective management of both domestic livestock and feral animals. Activities such as bore-capping, bulldozing of dams and fencing of dams to exclude goats, or converting dams into other methods of providing water to stock that excludes ferals will restrict feral animals to regions surrounding natural water sources. The animals will become more localised in their distribution, aggregating around these watering points, improving the efficiency and ease of control techniques.In all cases the impact of improved management or closure of water points on non-target species would need to be assessed before taking this action.

5.1.8 Biocontrol

Biological control is sometimes regarded as a 'holy grail' of vertebrate pest control. Indeed, there is some justification for its revered status because of the extraordinary success of its two applications, both against the European rabbit: myxoma virus in 1950 and rabbit hemorrhagic disease in 1995. Myxoma virus, first proposed for rabbit control in Australia in 1908, caused a massive pandemic in the 1950s before dual evolution of the rabbit and the virus lessened its impact. The introduction of a second vector, the Spanish rabbit flea, gave myxoma virus a boost in the 1960s. Despite the reduction in its effectiveness over half a century, myxoma virus is still responsible for death of about half of the rabbits born in Australia today.

Rabbit hemorrhagic disease (RHD), more commonly referred to as calicivirus in Australia, emerged as a new disease of domestic rabbits in the 1980s. It potential as a biological control was recognised and the disease was extensively studied in Spain and then in high security facilities in Australia. During ecological studies on Wardang Island off the coast of South Australia, the virus moved to the mainland. Despite the initial inadvertent release, a hugely successful campaign was able to be put in place and, as a result, the Australian rangelands have benefited from a decade of significantly reduced rabbit populations. The availability of the Natural Heritage Trust enabled a considerable amount of on-the-ground follow-up to RHD to be conducted. Warren ripping has no doubt been an important adjunct to RHD in a number of areas.

One study suggests that RHD has delivered in the order of $4.5 billion of value to the Australian nation, although the actual amount varies considerably on whether the vegetation that is not utilised by rabbits is utilised by livestock or becomes a carbon store. What ever the actual figure, there is no doubt that the return on the nation's R&D investment of approximately $12 million has been phenomenal – in the hundreds of thousands to one. This sort of investment return justifies the very high regard for biological control. Myxoma virus, being more effective and working from a much higher baseline for half a century, may well have returned the nation more than $100 billion in benefits.

The problem with biological control of vertebrates is that it is exceptionally rare. The two cases above are virtually the only examples available (RHD was introduced legally into New Zealand following the Australian experience, again with beneficial results; myxoma virus was introduced into Europe following the Australian experience and had a devastating impact on native European rabbit populations). The rarity of a success means that concentrating on biological control alone is a very risky strategy. It is unlikely to succeed. However, the rewards from a success are so huge that biological control deserves inclusion in any R&D program related to pest animal control over vast areas such as the Australian rangelands.

Are new generation biological controls possible?

For over a decade, Australian researchers have looked extensively at the possibility of creating new biological control products through the use of genetic modification. This work has been conducted principally through the Vertebrate Biological Cooperative Research Centre (CRC) and its successor organization, the Pest Animal Control CRC. From July 2005, a new CRC, the Invasive Animals CRC will carry forward some of this work.

5.1.9 Fertility control

The genetic modification approach to developing new biocontrol products for vertebrates has concentrated on fertility control of the feral mammals. Fertility control has the potential to be one of the most effective management techniques for managing feral animals. The techniques currently available are only suited to the management of small, isolated populations because they are labour intensive and require each animal to be treated individually. Research is currently being undertaken, both in Australia and overseas, on fertility controls for a number of feral animal species. There are three main methods of manipulating fertility in mammals: surgical, chemical and immunological. Surgical contraception is not practical for large scale use since large numbers of animals would need to be captured, operated on and then released. Chemical and immunological controls hold more promise for broad-scale control.

Chemical contraception

Traditional chemical strategies are potentially effective but are difficult to deliver to wild animal populations, are not species-specific and can have undesired side effects, especially on reproductive behaviour. Research is continuing into developing contraceptions that are encapsulated in baits that have the potential to be tailored to the specific feeding behaviours of each animal.

Immunocontraception

Immunocontraception as a means to control fertility in free-ranging animals has gathered a growing number of advocates in recent decades. This method aims to modify how specific proteins involved the reproductive process are recognised by the immune system. If the immune system is tricked into thinking that these proteins are foreign material antigens, it will intervene and mount an antibody response that attacks the protein and interferes with its role in reproduction. This strategy has the potential to be highly specific to both species and the reproductive process and can involve antigens that will not affect reproductive behaviour. Immunocontraceptives can potentially be spread through self-disseminating viruses. For example, current research into immunocontraception in rabbits investigates genetically modifying a strain of myxoma virus to carry the vaccine. This virus should disseminate through the rabbit population like the other myxoma strains, and those infected will receive the vaccine and become sterile. Researchers are also investigating the potential for vaccines to be delivered on baits using freeze-dried viruses. The benefits of self-disseminating immunocontraceptions over those requiring delivery via baits include that they will have low on-going control cost once released and successfully established in feral populations, and will spread to and persist in remote and inaccessible regions where using baits for vaccine delivery would prove costly, difficult or dangerous.

5.1.10 COPs and SOPs and humaneness

Current approaches to management tend to focus primarily on lethality and cost-effectiveness and less on humaneness. Sharp & Saunders (2004) developed a series of Standard Operating Procedures (SOPs) for feral animal control that discuss animal welfare impacts for target and non-target species, describes the techniques and their application and cover operators health and safety aspects (Table 12). They are also developing a range of Codes of Practice (COPs) that cover the management of a species and include information such as humanness, efficacy, cost-efficiency, and target specificity of available techniques. Species covered by these COPs include:

- feral cats
- feral goats
- feral horses
- feral pigs
- foxes
- rabbits
- wild dogs

These SOPs and COPs should be followed in any feral animal management program.

Table 12 Standard operating procedures for the management of feral animals. Developed by Sharp & Saunders (2004).

SOP No.	Title
GENERAL	
GEN001	Methods of euthanasia
GEN002	Care and management of dogs used in the control of pest animals
RABBITS	
RAB001	Inoculation of rabbits with RHDV
RAB002	Ground baiting of rabbits with 1080
RAB003	Aerial baiting of rabbits with 1080
RAB004	Ground baiting of rabbits with Pindone
RAB005	Diffusion fumigation of rabbit warrens
RAB006	Rabbit warren destruction using ripping
RAB007	Rabbit warren destruction using explosives
RAB008	Trapping of rabbits using padded-jaw traps
RAB009	Ground shooting of rabbits
FOXES	
FOX001	Ground baiting of foxes with 1080
FOX002	Aerial baiting of foxes with 1080
FOX003	Ground shooting of foxes

SOP No.	Title
FOX004	Fumigation of fox dens
FOX005	Trapping of foxes using padded-jaw traps
FOX006	Trapping of foxes using cage traps
PIGS	
PIG001	Trapping of feral pigs
PIG002	Aerial shooting of feral pigs
PIG003	Ground shooting of feral pigs
PIG004	Use of Judas pigs
PIG005	Poisoning of pigs with 1080
DOGS	
DOG001	Trapping of wild dogs using padded-jaw traps
DOG002	Trapping of wild dogs using cage traps
DOG003	Ground shooting of wild dogs
DOG004	Ground baiting of wild dogs with 1080
DOG005	Aerial baiting of wild dogs with 1080
CATS	
CAT001	Ground shooting of feral cats
CAT002	Trapping of feral cats using cage traps
CAT003	Trapping of feral cats using padded-jaw traps
GOATS	
GOA001	Ground shooting of feral goats
GOA002	Aerial shooting of feral goats
GOA003	Mustering of feral goats
GOA004	Trapping of feral goats
GOA005	Use of Judas goats
DEER	
DEE001	Ground shooting of feral deer
BIRDS	
BIR001	Shooting of pest birds
BIR002	Trapping of pest birds
HARES	
HAR001	Shooting of hares
HORSE	
HOR001	Ground shooting of feral horses
HOR002	Aerial shooting of feral horses
HOR003	Mustering of feral horses
HOR004	Trapping of feral horses

5.1.11 Integrated management strategies

There are no individual control techniques or 'silver bullets' that will eradicate any species of feral animal, except those (such as deer) that are confined to small populations. Instead, control programs are most effective if a variety of methods are used together. For example, rabbit control can involve the release of biological controls such as calicivirus or myxomatosis, warren ripping or fumigation, poisoning campaigns, removal of fallen branches or rock piles where rabbits can hide and hunting with ferrets or guns. If a number of these methods are used, particularly when rabbit numbers are low, much better results can be expected than if only one method is tried. The COPs listed above provide more detail for specific species on how the implementation of various techniques can lead to greater control of feral animals.

Where possible, integration of management strategies between feral species should also occur, to increase the environmental benefit to an area and minimise control costs.

Operation Bounceback

Operation Bounceback is a large-scale ecological restoration project in the northern Flinders, Gammon and Olary Ranges that focuses on the restoration of ecological resources principally through the control of feral animals. The program has provided significant support to rural landholders that led to a major reduction in feral goat populations on pastoral properties within the region. Individual properties, such as Plumbago Station in the Olary Ranges, have also been recognised for their efforts to protect the natural environment through feral animal control. Operation Bounceback has also supported a significant community effort in the eradication of an invasive environmental weed, wheel cactus.

By far the most damaging feral species in the region, the rabbit, was also targeted by the program. A reduction in rabbit numbers met with limited success, until the arrival of the rabbit calicivirus in November 1995. The virus wiped out over 80 percent of the rabbit population, and a program of ripping up their warrens has continued so that the animals cannot get re-established in the area. As a result of the reduction in rabbit numbers, the number of foxes and feral cats also dropped dramatically. The loss of so many rabbits, a key source of food for these animals, meant that the foxes and cats readily turned to the baits that have been laid out since 1994.

The continuation of Operation Bounceback and similar landscape-scale ecological restoration is a key strategic direction for ensuring the long term survival of South Australia's species and ecosystems.

5.1.12 Pest or resource – the value of commercial harvesting

One of the most confounding issues in the management of feral animals is their value as a resource to sections of the community. A classic example of this is the harvesting of goats in western New South Wales. Many farmers regard goats as a secondary source of income and as such make no efforts to control them, other than to muster them for market when prices are high. Some farmers have actually relied on income from the sale of goats to sustain them through the recent drought (Saunders pers. comm.). In these areas there is intense social pressure not to control them as a feral species, regardless of the biodiversity impact they are having. In other areas of the country, commercial harvesting is integrated into existing control strategies. In the northern Rangelands, water buffalo, donkeys, goats and wild horses are typically mustered before an aerial cull. This reduces the number of animals needed to be shot and provides revenue to reduce the control costs.

It is frequently suggested that industries be set up for feral animals. However, harvesting feral animals commercially generally has little long-term effect in reducing population numbers. One reason for this is that commercial harvesting is only profitable in easily reached areas where feral animal populations are high. It ceases as soon as numbers drop. The harvested animals are often quickly replaced by those moving in from surrounding unharvested areas. This level of control may be suitable for agricultural production, but is rarely at a level suitable for the conservation of biodiversity, particularly when threatened or endangered species are involved. Another problem is that those contracted to harvest feral animals from national parks may leave some behind as breeding stock, rather than removing them all, to guarantee themselves a future supply. A third problem is that talk about income from harvesting encourages landholders to view feral animals as resources rather than problems. This is particularly a problem on Indigenous lands. Thus, commercial harvesting should only be used as a tool within an integrated strategy rather than as a primary management option. It is discussed further in the sections on camels and Indigenous lands in Section 6.

5.1.13 Managing the impact not the feral number

In the past, much of the management efforts have been focussed on reducing the feral animal population, with little heed paid to how effectively their impacts were mitigated. A management strategy was considered successful if there was a high 'body count' or if few ferals could be detected. Instead, the management of feral animals should be undertaken to minimise or mitigate their impacts on biodiversity, primary production or other socio-economic factors. By gaining a clear understanding of the density-dependent impacts a feral species has on the environment, it is possible to more cost-effectively manage that species. If density-dependent impact information is available, a threshold level of population density can be set where the impact the species has is acceptable if eradication is not feasible. Unfortunately, the environmental impacts of feral animals are often poorly understood, and density dependent damage curves are unavailable for the majority of species. Research into this information is urgently required to enable the limited resources available for feral animal control to be most effectively utilised.

5.1.14 Monitoring – assessing the effectiveness

Accurate monitoring is an essential component of any feral animal control program. Monitoring the impacts of a program is necessary to determine the effectiveness of the program in meeting its objectives and any incidental effects on non-target species. The most commonly measured variable is feral animal population density and this relates to the historical approach of managing the feral animal density and not impact. Although a useful measure, monitoring of the feral animal population without investigating its changing impacts on the environment may give misleading conclusion of achievement of the programs goals. If the objective of the program is to reduce the impact of a feral species, then the impact of feral species is one of the variables that must be measured. Unless density-dependent impact information is available, other measures are required. One of the problems with monitoring programs is that the results of a control program may not be clearly evident for years. Quick measures of control program impact can include the change in the abundance of feral animals in an area or changes in the population size of a threatened species. However, monitoring needs to continue over a long time frame to ensure that sudden changes in pest or fauna numbers are not due to some other factor (such as drought or above average rains), and to detect long term improvements in ecosystem health and viability. This requires that continual funding and support be available for monitoring to detect the changes as they occur.

Adequate monitoring also allows the cost effectiveness of different control techniques to be assessed. By recording resource investments into each control technique or strategy, relative cost-effectiveness may be determined. Adaptive management can then allow this information to be incorporated into future control efforts.

5.2 Management of feral buffalo

For many years, the feral buffalo has supported several industries: meat for human consumption (local and international), pet meat, hides, horns, animals for live export and game hunting. Over nine decades from the 1880s, some 700 000 animals were harvested, on foot, from horseback and eventually from four-wheel drive vehicles, but the feral buffalo continued to multiply and spread (Ford 1982). Some Aboriginal communities in Kakadu use buffalo for food and have negotiated permission to maintain a fenced herd. The two main control methods for buffalo are commercial mustering and aerial shooting.

Commercial mustering

Farming of redomesticated herds is increasing and they are now farmed in all states. Feral buffalo are relatively easily domesticated. The buffaloes are initially captured usually by catching individuals with specially adapted vehicles, by self-trapping onto feed or water, or by herding into yards by vehicles, helicopters, horses or motorbikes. Mustering by helicopter is widely used because it allows herds to be moved from areas difficult to reach from the ground and minimises direct contact between the animals and vehicles.

Aerial shooting

The major conservation control method for buffalo has involved the use of helicopters as a shooting platform, which allows large numbers of animals to be shot quickly and easily in the otherwise inaccessible habitat (Boulton & Freeland 1991). This is the most cost-effective method of control and most culling is timed to take place after commercial harvesters have removed as many animals as economically viable (Ramsay 1994). In the mid 1980s culling of buffalo by mass shooting from helicopters under BTEC was very successful in controlling buffalo in many areas of the NT (Freeland & Boulton 1990), virtually eradicating the species from areas such as Kakadu National Park. The BTEC program ended in 1997 and buffalo are now no longer heavily controlled in the Top End (Kakadu Board of Management and Parks Australia 1999) and their numbers are rapidly increasing.

Ground shooting and recreational hunting

Some opportunistic ground shooting occurs, however most control efforts are made by aerial shooting. Buffalo are seen as one of the premier game species in Australia for recreational hunting and several professional hunting operators offer trips to remote parts of the Northern Territory or own large tract of land where hunts can be conducted. A large number of international game hunters visit Australia to shoot buffalo because it is one of the few locations where the animals occur in high enough numbers in the wild and can legally be shot. Some Indigenous communities run hunting safaris to supplement their income and the shot game is often utilised for food. Buffalo are also shot by community members for food. However, the number of buffalo shot by hunters is far too small to contribute in any meaningful way to buffalo control.

Fencing

Feral buffalo have a reputation for breaking conventional fences. The tendency is to go through or under, rather than over the obstacle. Electric fencing has been used to successfully exclude feral buffalo in parts of the Northern Territory, however environmental conditions, such as flooding, may quickly damage or destroy such fences. They are really only practical for use as a short term control option.

Judas buffalo

The gregarious nature of buffalo lend them to being ideal candidates for the 'Judas' approach. Captured animals can be fitted with robust radio-collars and released. The animal then rejoins the herd with the radio-collar highlighting their location. This may be a useful follow-up strategy after mustering and aerial culling, to detect and destroy small remnant herds in highly valued conservation areas.

Biological control

One possibility for biological control is the introduction of a round worm that is known to destroy up to 30 percent of new buffalo calves in Asia. The worm is passed from the mother to the calf via her milk and resides in the calf's intestine causing disturbances, which in severe cases result in death. The worm is already present in the cattle population in New South Wales, but is not known if this would be an effective means of buffalo control for the Northern Territory (Freeland 1992).

Current control efforts

NT - Little management effort is currently invested in buffalo. In national parks aerial culling occasionally occurs when numbers are high, however little off-reserve control occurs. Most off-reserve control is based on problem animal management and is conducted by the Parks and Wildlife Comission at the bequest of land managers. Small scale commercial mustering and safari hunting both occur in the Arnhem Land region.

QLD - Currently no control occurs

WA - Currently no control occurs except for the shooting of an occasional problem animal

Management of buffalo in the Rangelands

Water buffalo numbers are rising rapidly following the BTEC cull in the 1980s and this is a matter of grave concern (see Section 6). Management actions should be applied now to maintain low buffalo densities, instead of waiting until numbers rise and the cost of control increases substantially. Aerial culling is by far the most effective method to control the buffalo in remote regions. Mustering could be used prior to culling in more accessible areas to help partially offset the control costs. Judas buffalo could be used to help locate herds and reduce searching times from helicopters.

Summary of the effectiveness of feral buffalo control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Hunting and harvesting	Moderate	High	High	Low to moderate	Low	Sale of animals offsets costs of control Incentive for control	Not possible in inaccessible or remote locations Small impact on population
Aerial shooting	High	High	High	High	High	Allows broad-scale control over remote, difficult to access areas.	Not applicable to all habitats and particularly expensive at low feral buffalo densities.
Ground shooting and recreational hunting	Low	Unknown	High	Low	Low	Target specific control Income from recreational hunters	Difficult in remote areas, difficult to locate buffaloes Confined to easily accessible locations Low removal rate
Judas buffalo	High	Low	High	Low	Moderate	Allows targeted control of small residual populations of buffaloes and the location of remote herds	Expensive and requires a high level of proficiency. Not applicable at high populations densities.
Fencing	High	Low	Unknown	Low	Moderate	Allows excellent protection of small areas of land	Requires continuing maintenance and cannot be applied across large remote areas
Biological control	Unknown	Unknown	Unknown	High	Unknown	Unknown, but possibly low cost implementation through self-dissemination.	Impact on commercial buffalo industry especially export market

5.3 Management of cane toads

Currently there is no practical method for containing or eradicating cane toads. To mitigate the impact of cane toads, a number of northern quolls have been relocated to toad-free offshore islands. They will provide a breeding source for re-introduction if the mainland populations of northern quoll succumb to the presence of the cane toads. A publicity campaign has also been undertaken to educate and inform the public about the cane toad problem. As part of this campaign, a competition is being run in the Northern Territory to design a new cane toad trap. In light of the lack of effective control technologies, research is now underway on a new range of potential techniques.

Traps and barriers

Present efforts to control cane toads are based on physical capture and destruction. A range of cane toad traps have been commercially produced through the community based organisation, Frogwatch. Current traps are of only limited effectiveness because they only work in a small area and require constant emptying. Research has demonstrated that some of the pheromones produced by cane toads can be used as effective attractants. Michael Tyler, at the University of Adelaide, has shown that when a minute quantity of a male pheromone is placed on a pad, female toads will move towards the pad and remain there. Application of toad specific pheromones to traps could greatly enhance their efficiency.

Cane toad-proof exclusion fencing has been proposed to prevent the spread of toads into the highly valued Coburg Peninsula and other areas. As with most feral exclusion fencing, it would be expensive to install and maintain, may severely restrict the movements of non-target species, and is very unlikely to prevent toad movement in the long-term. Furthermore, it would be impractical to extend over large areas and may only have value in helping conserve small, high-value, threatened communities against the influx of cane toads.

Measures to prevent the expansion of cane toad range may include surrounding barge landings with a cleared area combined with toad proof fences (as has been done for the Tiwi Islands) artificial refuges and watering points (that can be frequently monitored), attractants such as lights or chemical attractants. Natural barriers or bottlenecks should be identified to help control toads. On the mainland, narrow points for migration should be investigated to identify the most strategic points to efficiently control cane toads.

Biocontrol

A range of biocontrol options are currently being investigated. CSIRO has extensively investigated the possibility of a naturally occurring, toad-specific pathogen. Although a highly desirable control solution, akin with myomatosis, ten years of research has failed to identify a suitable candidate pathogen. Ongoing support for biocontrol agents should be continued, as this provides the most effective long term threat abatement measure. Such a mechanism must undergo comprehensive testing to ensure that the control is completely toad specific, with no risk of mutating to become virulent to native anuran species. CSIRO is currently investigating a biocontrol for cane toads, based on genetically engineering a gene to interfere with tadpole metamorphosis (Robinson pers. comm.). This would then be disseminated through the population via

a genetically engineered virus and is long-term, complex, high-risk research. There are significant technical challenges to be overcome and once the technology is technically feasible, it still will have major hurdles in becoming registered as a GMO product and gaining public acceptance for release.
Another form of biocontrol that is being investigated involves population manipulation. These genetic technologies are being developed by the Universities of Queensland and Newcastle, and will attempt production of male-only offspring (*Daughterless technology* – see carp management section) or male sterility. Again this research is high risk and will have to run the GMO gauntlet.

Toxins

Recently, the Queensland Government has provided funding for research into a cane toad control and toad-specific toxins. This research will be undertaken by the Invasive Animals Cooperative Research Centre and hopefully fill the strategic gap between high-cost, high risk, long timeframe programs, and the low-tech local application work currently being explored or used (e.g. traps and barriers). The research aims to explore and understand the chemical and microbial ecology of cane toads, and to use this knowledge to develop strategies for enhancing the success of baiting and trapping programs. The study will assess the full suite of toxic chemical constituents as well as their natural occurrence against a range of variables. Knowledge of the molecular structure and distribution of venom constituents, along with their mode of action, will reveal a selection of potential biological targets able to support the development of toad specific poisons. The research will also assess bacteria and fungi that naturally occur on cane toads, including those that have been reported to be pathogenic and lethal to susceptible toads. Analysis of the metabolites produced by these microbes would reveal many toxic chemical classes including some that have coevolved high specificity against toads.

Current management

NT - Community based trapping efforts and education form the basis of current cane toad management.

QLD - Current management of cane toads is based around community education, trapping and removal of egg masses. The lack of a suitable broad-scale control measure hinders control.

WA – Although not yet present in the state, WA has developed *The State Cane Toad Initiative*, begun in December 2004, which aims to ensure that any cane toads brought into WA accidentally don't become established, and to fight the spread of cane toads towards WA while biological control is being developed.

Management of cane toads in the Rangelands

The lack of effective techniques that can be feasibly applied at a broad-scale has resulted in unsuccessful management of cane toads. Their distribution is still spreading and does not look like stabilising in the near future. The best strategy at the moment is to continue community education and encourage the collection and destruction of both toads and their eggs in urban areas. Until the current and proposed research provides more effective management tools, little more can be done to minimise their environmental impact.

Summary of the effectiveness of cane toad control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Toxins	Low	Unknown	Variable	Moderate	Potentially moderate	Relatively target specific control applicable across broad areas of land in a cost effective manner.	Potential non-target impacts. Delivery difficulties.
Barrier fencing	Moderate	Low	Low	Low	Low	Prevention of range expansion	Requires continuing maintenance and cannot be applied across large remote areas Tadpoles may move across the barrier in water flows Impact on movement of native species
Trapping	Moderate	Low	Moderate	High	Low	Allow targeted control of feral pig populations in localised areas	Generally requires road access. Difficult to apply in remote areas due to high labour requirements. Constant need to empty traps
Biological control	Unknown	Potentially high	Unknown	High	Potentially high	Unknown, but possibly low cost implementation through self-dissemination.	Impact on other native anurans Cost of research

5.4 Management of feral camels

Current management of feral camels focusses on three main strategies; culling, harvesting and exclusion fencing. The approach is largely ad hoc and a strategic approach has yet to be developed and implemented. The Australian populations of feral camels are increasing dramatically. Populations are estimated as doubling every six to eight years. To maintain stability, at least 10 percent of the population has to be taken out each year (Dörges & Heucke 1995). There are many issues to consider if we intend to effectively manage feral camels and their impacts across Australia in the longer-term. Edwards *et al.* (2004) highlight how the scale of the management effort required to stabilise and/or reduce populations is directly related to the size of the feral camel population - in the face of an increasing population, the longer the delay, the greater the effort required.

Shooting

In South Australia and Western Australia in recent years, ground-based and aerial shooting have been used to reduce feral camel populations on national parks and pastoral leases in the north of the state (Environment SA). Similarly, limited aerial culling of feral camels has been undertaken on pastoral leases in the Northern Territory at the behest of managers. Here, aerial shooting is carried out by trained personnel employed by the Parks and Wildlife Service with the cost of helicopter hire and ammunition being met by the land manager. Although the aerial shooting of large animals like horses and camels is a highly emotive issue, it is the most effective and humane technique in remote, inaccessible situations (Edwards *et al.* 2004). The fact that feral camels are highly mobile, have extensive home ranges and are distributed at low densities over large uninhabited areas has made extensive culling programs practically and economically difficult for landholders.

Commercial harvesting

Wild-harvest is a management option that removes a small number of camels from the wild and can provide limited income for land managers. Some meat is produced from feral camels in the Northern Territory, but there is no major Australian market for camel products, and commercial harvesting has no prospect of reducing camel numbers in the near future, if ever. In the Northern Territory and Western Australia, a small industry based on the harvest and live export of feral camels has been developing since the early 1990's (Edwards *et al.* 2004), although in the Northern Territory it is dependant upon substantial government subsidy. Harvesting is usually achieved through trapping or mustering using helicopters, motorbikes, horses or other vehicles. The animals are then contained in either fixed or portable yards. The advantage of portable yards are that they can be moved to areas where camels are present, reducing the distance animals are herded and they can be set up in locations that prevent the camels from seeing them until it is too late for efficient evasion. The disadvantages of portable yards are that they are not as strong as fixed yards, and their distance from transport may significantly extend the time animals are contained, thus increasing the animals' stress. Fixed yards are generally stronger and located nearer to transport, however increased mustering times and animal wariness and evasiveness can reduce their effectiveness. Trap yards can also be located around water sources and left open to allow animals to familiarise themselves with the structure. When the time comes for the camels to be harvested, the one-way gates are set and the camels will be trapped with minimal effort. This technique may not work where camel herds are dispersed and densities are low, or because the water requirements of camels cause them to visit the water holes only infrequently. Construction of a purpose-built export abattoir could open up new markets for camel meat with the added benefit that all camels, irrespective of size and sex, could be utilised all year round. Commercial harvesting will not control camel numbers; however it may play a part in an integrated control strategy and allow for cost-offsetting.

Fencing

Appropriate fencing can effectively exclude feral camels, but it does not reduce their population number, just shifts the point of impact to less valuable areas. However, appropriate use of fencing may help conserve areas of high conservation value by limiting excluding the feral animal impacts. South of Uluru-Kata Tjuta National Park, Northern Territory, attempts have been made to fence off culturally important waterholes to prevent them being fouled by feral camels. (Dörges & Heucke 1995) At the main reference area Newhaven, enclosure studies were undertaken. To protect highly preferred food plants from camel browsing, a stand of *Acacia sessiliceps* was fenced in with 'camel proved' fence. Furthermore a claypan which was regularly used by the camels as a watering point was fenced in, using the same material. Both experiments proved successful. The tested 'camel proved' fence is of the following design:

> A standard cattle fence (three lines barbed wire) is extended in height to at least 1.6 metres. The additional top wire is made visible by adding light reflecting objects (i.e. empty beer cans). These are put on small pieces of plain wire (like pearls on a string) which are then tied onto the top barbed wire. The result is a higher, much more visible and on windy days even audible fence.

Camels can be excluded from certain areas through the use of electric fences, although they must be properly designed and easily visible to the camels or there is the risk of substantial damage to the fences. Recommendations for electric fence design and construction for camel control are available from some state agencies (e.g. Bertram 1996).

Judas camel

Any systems to improve the chances of locating mobs of camels and improving their subsequent capture are financially beneficial. Because of their gregarious nature, the 'Judas' animal technique (Parkes *et al.* 1996), which uses radio-collared individuals, should prove a useful tool in locating herds of feral camels targeted for control or for the purpose of commercial utilisation. Satellite telemetry would be a cost-effective way to implement the 'Judas' animal technique, particularly in the more arid regions where camels move over very large areas.

Current management

NSW - Camels are not a major problem at the present time. It seems likely they will spread throughout the state's far west if their numbers continue to soar.

NT - Has recently completed another aerial survey of abundance of camels. Management efforts are largely ad hoc and appear to have little impact on populations. South of the Uluru-Kata Tjuta National Park, important waterholes have been fenced off to exclude camels. A small (<5000 animals p.a.) live-harvest industry also exists but populations are increasing despite this effort. Aerial culls are also undertaken at the behest of pastoralists to minimise browsing and fence-line damage.

QLD - No significant control for camels is currently undertaken

SA - Ground and aerial based shooting are used to periodically control camel populations in both National Parks and pastoral leases in the north of the state. A major aerial cull of several thousand is planned for the middle of 2005. This has received much opposition from animal rights campaigners claiming that shooting from helicopters is not accurate enough and therefore inhumane.

Camel management in Australian Rangelands

Managing a species like the feral camel in remote areas of Australia presents many challenges. Extensive aerial culling over large areas of the Rangelands, combined with some harvesting, appears to be the only management strategy. Control efforts will have to be intensified if camel numbers continue to rise at their present rate, otherwise adequate control will require significantly more investment as the population expands. Commercial harvesting should follow the COP for commercial mustering that was developed by the Standing Committee on Agriculture and Resource Management (Model Code of Practice for the Welfare of Animals: The Camel). Unfortunately there are likely to be large expanses of country where no management will occur due to a lack of resources. In these areas, local groups which are supportive and enthusiastic about management are required.

Summary of the effectiveness of feral camel control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Hunting and harvesting	Moderate	High	High	Low to moderate	Low	Sale of animals offsets costs of control Incentive for control	Not possible in inaccessible or remote locations Small impact on population
Aerial shooting	High	High	High	High	High	Allows broad-scale control over remote, difficult to access areas.	Particularly expensive at low feral camel densities.
Ground shooting and recreational hunting	Low	Unknown	High	Low	Low	Target specific control Income from recreational hunters	Difficult in remote areas Confined to easily accessible locations Low removal rate
Judas camel	High	Low	High	Low	Moderate	Allows targeted control of small residual populations of camels and the location of remote herds	Expensive and requires a high level of proficiency. Not applicable at high populations densities.
Fencing	High	Low	Unknown	Low	Moderate	Allows excellent protection of small areas of land	Requires continuing maintenance and cannot be applied across large remote areas
Biological control	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown, but possibly low cost implementation through self-dissemination.	Impact on commercial camel industry especially export market Yet to be developed

5.5 Management of feral cats

Historically, a range of techniques has been used in attempts to control feral cats, including shooting, trapping, poison baiting, fumigation and hunting. Available methods are generally expensive, labour intensive, require continuing management effort and can be effective only in very limited areas. Eradication with these techniques is currently not possible and research into more effective methods is required. The level of control pressure on feral cats is also generally lower than that on some other feral predators due to the fact they have little or no impact on agricultural production.

Commercial harvesting

Feral cats have been hunted in the past for their fur, which was mostly exported, but no skins or furs have been exported since 1988-89 (Ramsay 1994) and this practise has now ceased.

Shooting

Shooting, when carried out humanely, is an acceptable control technique, although it is labour intensive. Recently a code of practice for the humane destruction of feral cats was devloped (Sharp & Saunders 2004). In order to maximise the value of shooting, it needs to be applied for an extended period or timed to take advantage of opportunities that expose feral cats to such control actions, e.g. wet season flooding. Newsome *et al.* (1989) demonstrated that prey population numbers (in this case rabbits) can be increased significantly in areas where feral cats and foxes were systematically removed by spotlight shooting, highlightling the potential value of this control technique in managing endangered species in appropriate habitats. Recreational shooters also target feral cats; however the magnitude of the impact on feral cat or prey populations is unknown. The South Australian Department of Environment and Natural Resources uses recreational hunters to complement other methods of feral cat control in some areas.

Trapping

Trapping as a control method is labour intensive and is only recommended where eradication is the objective, such as on islands, isolated populations or small reserve areas. Historically, steel-jawed traps, neck snares and other trap types have been used to capture feral cats including. The inhumane nature of many of these traps has led to the cessation of their use. Instead, more humane soft-jawed traps are are used to capture live feral cats and represent a viable option for control. The likelihood of lighter non-target species being snared in these traps can be reduced by appropriately adjusting the pan that tensions the trap. Cage traps are also widely used, but are generally ineffective for trapping feral cats (Environment Australia 1999c). To successfully trap feral cats, the lure or attractant chosen is most important. Research on a number of lure types is currently being undertaken. Researchers within Australia are currently examining audio and visual attractants that will lure feral cats to baits. Bait additives that enhance smell and taste are also being evaluated.

Individual tracking

Tracking is a labour intensive technique but the time and expense may be offset by the benefit in being able to remove particular problem animals. By selectively removing a few individual cats, such as large, experienced males specialising in hunting particular rare species, the primary agents of damage may be eliminated allowing wildlife colonies to survive even though there are other feral cats around (Gibson *etal.* 1994). Tracking may prove an effective technique on Aboriginal lands where threatened species are present and where Indigenous people retain good tracking skills, provided funding can be provided (R. Paltridge pers. comm.)

Baiting

Baiting techniques for feral cats currently appear much less effective than techniques for dogs and foxes. Baiting feral cats is difficult as they are often found in low densities, can have large home ranges, are disinclined to feed on carrion except during drought or during food shortages, and are naturally wary. The timing of a baiting program is a critical element in the successful baiting of feral cats (Short et. al. 1997) and should utilise environmental extremes such as drought to increase bait uptake. Shea (1996) announced the development by the Western Australian Department of Conservation and Land Management of a bait which is attractive to cats, but this bait has yet to be widely evaluated. Development of an effective baiting technique, and the incorporation of a suitable toxin for feral cats, is a high priority as it is most likely to yield an operational and cost-effective method to reduce cat numbers in strategic areas. Currently no cat-specific toxin has been developed for large scale use. Cyanide has been used for cat control; however its use is currently illegal except under permit for research. Preliminary studies by the Victorian Institute of Animal Science (Department of Natural Resources and Environment) have identified a possible feline-specific toxin. Laboratory and field studies to investigate the feasibility of using this toxin are currently being conducted.

Fumigation

Feral cats are known to use rabbit warrens as dens or shelter. They are therefore vulnerable to techniques such as fumigation. Native wildlife such as goannas, other reptiles and small native mammals also use rabbit warrens and may be at risk of exposure to the fumigants. Any use of fumigants would have to take account of the risk to native species. There are strong concerns regarding animal welfare and the humaneness of this technique.

Biological control

The viral disease *Feline panleucopenia,* also known as feline parvovirus and feline enteritis, has been investigated as a potential biological control control agent for cats (van Rensburg *et al.* 1987, Copley 1991, Moodie 1995). This disease causes high mortality in non-immune populations, but confers immunity on survivors. Screening of blood samples in Australian feral cats indicates that there is widespread immunity to the disease (Moodie 1995). This suggests that the disease is already circulating through feral cat populations and any control effect base on the virus would be ineffective. Furthermore, it seems unlikely that there are any felid-specific pathogens that may be suitable as biological control agents (Moodie 1995).

Fertility control

Currently there are no effective chemical sterilants which produce permanent sterility in cats (Moodie 1995). At the present there is also no research being undertaken on immunocontraception for feral cats. A major benefit of the development of immunocontraceptive techniques is that they are humane. Broadscale control of cats using an immunocontraceptive vaccine, if one were developed, would be dependent upon the development of a suitable delivery mechanism for the vaccine and appropriate approvals to release the vaccine into the wild.

Barrier fencing

One of the most effective management techniques for feral cats is the creation of barriers limiting their access. In many cases these are natural barriers–stretches of water surrounding islands–but a number of small reserves have been enclosed with predator-proof fencing. Whilst most fences are a significant barrier to feral cats, even the most elaborate can be breached (Coman & McCutchan 1994). If breached, fences increase the vulnerability of endangered species by preventing their escape from the predator(s). To minimise this risk, fencing should be combined with an integrated baiting and trapping program to reduce the frequency of challenge to the fence by incoming predators (Environment Australia 1999c). The combination of fencing with a baiting and trapping program is an expensive option which is likely to be useful only for small areas or areas with specific characteristics, such as peninsulas. It may also affect movements of other wildlife, preventing their dispersal and interbreeding with other populations. Recent projects in Shark Bay, Western Australia, have sought to use a combination of conventional control methods, natural water barriers and fencing to create large predator-free reserves on peninsulas (Department of Conservation and Land Management 1994).

Habitat management

Components of the environment may be manipulated or managed in order to reduce the damage done by feral cats. Therefore, habitat management in itself represents a critical factor in feral cat control. Native animals may be more secure in structurally complex habitats (Dickman 1996) so management of habitat to reduce fragmentation (rehabilitation of fire trails, roads and clearings) and to increase the density of vegetation (perhaps by better managing fire and grazing) may be effective in reducing the level of feral cat predation.

Current management

NSW – Currently the lack of effective control options hampers efforts and they are waiting on the bait trial results from WA and VIC. A combination of trapping and shooting has been used in several conservation reserves considered to be of high conservation value and the use of audio lures to increase visitation rates to traps has been trialled.

NT – Currently little control is undertaken for cats in the NT except where isolated populations of IUCN listed species are threatened and trapping and shooting are used to remove cats from the area.

QLD – Little control is undertaken in QLD for cats, with the majority of investment involving shooting and trapping programs, especially in conservation areas.

SA – Currently cats are not widely controlled in SA due to a lack of suitable techniques. In some regions such as the Western Mining Roxby recovery area, vermin proof fencing has been erected to exclude cats from the rehabilitation and conservation area. Priority for efforts is currently given to areas of high conservation value such as the Gammon and Flinders Ranges. In these areas trapping and shooting are utilised. Baiting for cats is also being trialled.

WA – A new bait is being developed that is palatable to cats in most cases. Trials have shown a bait uptake of approximately 80% when rabbit densities are low. The toxin to be used has yet to be decided. Predator-proof fencing has been used to effectively keep feral cats out of several conservation reserves.

Management of feral cats in the Rangelands

Management of feral cats in the Rangelands with the current suite of available techniques is best targeted towards the protection of areas and species of high conservation value. An integrated approach using exclusion fencing surrounded by a buffer zone maintained through trapping, shooting and tracking of individuals should prove effective around conservation areas. Effective population control over large areas will only be possible with the development of a toxin or biocontrol for cats

Summary of the effectiveness of feral camel control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Exclusion fencing	Limited	Expensive	Moderate	Moderate	High	Useful for protection of threatened wildlife species and other valuable animals.	Expensive, therefore impractical for broad scale application
Baiting	Relatively ineffective	Cost-effective	Low.	High	High		Successful baiting of feral cats is difficult as they do not take baits readily Ingestion of 1080 can also kill non-target animals including native species, domestic cats, dogs and livestock. 1080 is toxic to humans; operators need to take precautions to safeguard against exposure.
Ground shooting	Limited effectiveness	Not cost - effective	High	Low	High	Best suited to smaller, isolated areas May be effective if applied for an extended period.	Labour intensive Difficult in remote or inaccessible areas
Cage traps	Relatively ineffective	Not cost - effective	High	Moderate	Moderate to high	May be useful in small areas where eradication is the objective and in semi-rural/urban areas for problem animals.	Labour intensive, therefore not suitable for broad-scale control
Soft net trap	Relatively ineffective	Not cost - effective	High	High	High	May be useful in small areas where eradication is the objective and in semi-rural/urban areas for problem animals.	Labour intensive, therefore not suitable for broad-scale control.
Padded-jaw traps	Relatively ineffective	Not cost - effective	Low	Low	Moderate	May be useful in small areas where eradication is the objective	Labour intensive. May be useful for problem animals Effectiveness depends on skill of operator Inefficient for general control

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Treadle snares	Relatively ineffective	Not cost - effective	Low	Low	Low	Can be used to target problem animals	Labour intensive. May be useful for problem animals but are inefficient for general control. Difficult to set. Need to be checked even more regularly than padded-jaw traps
Steel-jawed traps		Expensive	Low	Moderate	Unknown		Inhumane and should not be used Alternatives are available
Individual tracking	High	High	High	Low	Low	Target specific problem animals Employment for Indigenous communities	Only low numbers can be controlled Very labour intensive Not suitable for broad scale control
Fertility control	Unknown	Unknown	Variable	Unknown	Unknown	Reduce population recovery potential Cost-effective if self-disseminating	No suitable method is available
Biological control	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown, but possibly low cost implementation through self-dissemination.	Impact on domestic cats market Yet to be developed
Habitat management	Unknown	Unknown	Unknown	Unknown	Unknown, but probably low	Increased habitat for native species Ecosystem benefits to the environment	Could be expensive and only suitable for small areas of high conservation value

5.6 Management of feral deer

Management strategies for feral deer are still in their infancy due to only recent realisation by many resource managers that deer are becoming a substantial pest. This is evident by the lack of effective legislation governing the management of wild deer in Australia and the general lack of knowledge and understanding by land managers of deer ecology, impacts and management methods. One of the key priorities for feral deer management in Australia must be the addressing the issue of deer escaping from farms and forming new populations or bolstering those already in the wild. Moriarty (2004) suggests that many of the newly established deer populations are prime targets for eradication. If escapes from deer farms can be managed, immigration into these populations will most likely not occur and control efforts have a high probability of achieving eradication. Where populations are well established, containment through sustained control efforts may prove to be a better use of resources, unless the deer are causing socio-economic or environmental damage, in which case eradication should be the goal. From a survey of 268 government agency land managers across Australia, Moriarty (2004) reported that only 74% of respondents managed deer in their area. The main management methods utilised were ground shooting (28%), aerial shooting (21%), sustainable harvest using hunters (15%), trapping (6%), fencing (6%), mustering (2%) and repellents (1%). Furthermore, 65% of the respondents indicated that they believed current management techniques for deer were inadequate.

Recreational hunting

Recreational hunting is commonly associated with the presence of deer populations in Australia. Recreational hunters have been implicated in the deliberate release of deer into remote conservation parks in order to provide game for hunting. In fact, over half of the feral deer populations in Australia are thought to have been translocated illegally (Moriarty 2004). The ease with which live deer can be purchased and translocated assists this and tighter regulation of farmed deer stocks needs to occur. In some states, the hunting of deer is regulated by State conservation agencies, however in New South Wales the hunting of deer in national parks is specifically excluded in the *Game and Feral Control Act 2004*. Controlled recreation hunting of deer populations may significantly reduce control costs to land managers and potentially provide enough pressure to prevent the populations expanding. The activity may even be incorporated into an integrated eradication program. This management strategy may be a useful option in regions where resources to control feral animals are restricted. However, care must be taken with such an approach to ensure that the control pressure is adequate and that land managers ensure the hunting is for control purposes and not a supplementary source of income.

Ground shooting

Ground shooting has commonly been used to control deer populations along the east coast of Australia (NPWS NSW 2002). This humane technique is target specific, and appropriate for more remote or isolated areas where deer are having impacts. Shooting can help remove deer where they have the greatest negative impact on the environment and reduce the potential for future population growth. Unless, herds are small, shooting may not be effective for eradication due to dispersal and wary adults. All shooting should be undertaken in accordance with DEH Standard Operating Procedures.

Aerial shooting

Aerial shooting can be an effective method of controlling animals in remote and difficult to access areas; however the expense and nature of the terrain where deer often occur can preclude the use of this technique.

Trapping

Trapping has been utilised as a control technique for deer. It is an expensive and time consuming exercise, however part of the costs can be offset through the sale of the live deer. The effective location of traps is essential for this technique to be effective, and usually occurs in regions where animals tend to congregate, such as waterholes. The technique has been used for two years at two locations in the Royal National Park near Sydney; however in that time only 30 deer were removed (NPWS NSW 2002). In general, for the purpose of conservation, shooting is a more cost effective option unless large herds can easily be trapped and transported. It may prove useful for small, newly established herds, but is unlikely to be a suitable technique for long-term control of large deer populations.

Baiting

Poisoning with 1080 baits has been found to be an effective way of controlling deer in some location overseas. 1080 is currently not registered as a deer poison in Australia and the high likelihood in many areas of non-target species consuming poison grain bait is high. Until a more specific toxin or delivery mechanism can be found, baiting may prove to be too risky to be used as a broad-scale control method.

Fencing

Fencing has been used to exclude deer from small areas of high conservation value. The initial expense and high maintenance costs are rarely justifiable when the fencing is used to control deer alone, however there is scope to perhaps utilise or modify existing fences to assist in deer control.

Current management of deer

NSW - Deer are classified as a game species and a permit is required for control. The majority of control occurs within national parks outside of the Rangelands.

NT - Deer are not considered a major pest in the Rangelands and not controlled

QLD - Very little is done to control deer even though they have been assessed as having a high potential to become a serious pest. Currently they are not a declared pest species.

SA - Deer are an emerging problem however little control is undertaken apart from shooting. Their status as a pest or a resource to the hunting lobby is still being debated.

Management of deer in the Rangelands

In general for the purpose of conservation, shooting is the most cost effective option unless large herds can easily be trapped and transported. Trapping and mustering may prove useful for small, newly established herds, but are unlikely to be suitable techniques for long-term control of large deer populations. Eradication small, isolated populations before they become established should be attempted since immigration will be virtually zero. Tighter control and greater responsibility for escapes from deer farms is also needed to reduce the rate of new incursions.

Summary of the effectiveness of feral deer control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Fencing	High	Low	Unknown	Low	High	Allows excellent protection of small areas of land	Requires continuing maintenance and cannot be applied across large remote areas Expensive
Trapping	Moderate to high	Low	High	Moderate	Moderate to high	Effective where deer congregate	Expensive and time consuming. Difficult to apply in remote areas due to high labour requirements.
Aerial shooting	High	High	High	High	Moderate	Allows broad-scale control over remote, difficult to access areas.	Not applicable to all habitats Expensive, particularly at low feral deer densities Requires skilled shooters
Recreational hunting	Moderate	High	High	Moderate	Unknown	Reduces control costs to land manager Good for areas where there are no resources for control	Deliberate releases of feral deer Small impact on population sizes
Ground shooting	High	High	High	Low	Moderate to high	Target specific control Reduce deer where they have the most impact	Difficult in remote areas Difficult to locate deer Dispersal of herds makes eradication difficult
Baiting	Unknown	Unknown	Low	Moderate	Low	Low cost	Not currently registered for use with deer Non-target uptake
Biological control	Unknown	Unknown	Unknown	High	Unknown	Unknown, but possibly low cost implementation through self dissemination.	Impact on commercial deer industry.

5.7 Management of feral goats

The feral goat has not been eradicated from any extensive mainland environment in Australia, despite decades of control effort. Complete removal of feral goats from Australia is currently beyond the capacity of available techniques and resources, because the species is well established across a vast area. However, feral goats can be managed, and perhaps even eradicated from some local areas and regions, in cost-effective ways using presently available technology. That they are not so managed is usually because the local landowners either see goats as a resource or because they do not have the organisation necessary to implement a comprehensive management plan Techniques to manage feral goats in the Rangelands fall into two types depending on the fate of the goats. Mustering and trapping are used in cases where goats are intended for commercial slaughter, whereas shooting and other lethal techniques are used when carcasses are not commercially utilised. Commercial harvesters use three principal methods to capture feral goats - trapping at watering points, mustering with dogs and vehicles, or field shooting for game meat export (Ramsay 1994, Choquenot *et al.* 1995*)*. Little information is available regarding whether current levels of commercial feral goats harvesting is reducing environmental and agricultural damage in Australia. It appears that off-takes this large must mitigate damage by reducing the numbers of feral goats or at least curbing their rate of increase, however commercial harvesting is only retarding but not preventing the increase in feral goat numbers. More information on the links between commercial harvesting and damage control is needed.

Mustering

Although mustering feral goats for slaughter or live sale is labour-intensive and limited to relatively flat terrain (Harrington 1982), it is most efficient at high goat densities. The advantage of this technique in the context of harvesting is that the cost of control is either partly or fully offset by the sale of the goats. Two methods are used: aerial mustering, using helicopters or light aircraft to flush animals out of dense vegetation or inaccessible terrain, followed up by a ground team; and ground mustering on motor bikes or horseback usually with the help of dogs (Parkes *etal.* 1996). It has been estimated that on average only 30-40% of populations are removed in a muster, though this figure can be as high as 80% (Henzell 1984, Parkes *et al.* 1996). Mustering for commercial harvest becomes uneconomic once populations are reduced to densities below about one goat per square kilometre (Henzell 1984), and there is evidence that some populations have increased despite mustering, so other control methods must be used (Henzell 1992). Many landholders muster opportunistically when they notice a large group of goats on their land. Standard operating procedures and codes of practice have been developed and should be followed in these operations. In western NSW there is apparently a glut of feral goats at the moment, despite the drought and a high level of harvesting in recent years, and this is driving prices down. A recent muster removed 4000 and returned $70,000; a recent aerial shoot removed 1500 goats and cost $30,000 (Q. Hart pers.comm.). It is not hard to see why mustering is often the preferred option, but unless goats are removed to a density well below their 'maximum sustainable yield', they will continue to be a problem. The export value of goats (both live and meat) was worth a gross value of approximately $51 million in 2003-2004, and it is believed that around

80% of export was derived from feral goats resulting in an export value of approximately $41 million (Q. Hart pers.comm.).

Trapping

The reliance of goats on water during dry periods, particularly on artificial water supplies, is a critical weak-point in the feral goat's normal resilience to control. Trapping groups of goats around watering points can be an effective and efficient control technique (Harrington 1982). It involves the construction of goat proof fences around water points with a number of one way entrances or jump down ramps to allow the goats access to the water, but prevent their leaving (Henzell 1984, Diver 1991, Sullivan 1992, Parkes *et al.* 1996). This technique is most effective during dry times when goats are obliged to find water and there is limited access to alternative water sources. Once captured, the goats may be sold to offset the costs of capture or they may be humanely destroyed.

Some concerns have been expressed about the use of traps at water points and the potential deleterious impacts on non-target species and animal welfare. Some of these concerns can be addressed by providing larger traps to minimise stress and allow for more effective handling of stock. Non-target species may also be trapped and these animals must be drafted out as quickly as possible to avoid undue stress. Trap yards at natural water holes pose special problems as they may severely restrict access by native species. One option is to design fences that selectively exclude certain species from water points. Knowledge of other species that may be locally at risk from inappropriately designed traps could be used to identify the most suitable trap design and usage.

Machine vision technology is one option for reducing trapping rates of non-target species and increasing the effectiveness of trapping in the future. Electronic perception technology is a form of machine vision technology that gives a semiconductor or system the ability not only to record the image of an object, but to be able to distinguish the object from the background or from other objects in a scene. The technology uses an approach similar to radar, where waves of emitted energy are bounced off an object. Animals are identified before they enter a trap, allowing the potential for segregating goats and other feral animals from native species and stock. This could be achieved through a computer controlled swing gate directing animals into different caged zones, or by denying access into the traps to undesirable species.

Artificial watering points are so numerous in the arid and semi-arid Rangelands of Australia that their spacing is rarely more than 10 kilometres apart (James *etal.* 1997). Current efforts to cap the bores throughout the Great Artesian Basin are likely to contribute in time to more effective management of feral goats. In Western Australia it has been proposed that the installation of trap yards throughout the feral goat range in that State be required to ensure a level of control of both feral and domesticated goats.

Fencing

Fencing can be expensive to establish and maintain (Lim *et al.* 1992, Cash & Able 1994). There are several recommended designs for conventional and electric fences to constrain domestic goats for normal Australian conditions (Lund & May 1990, Markwick *et al.* 1992, McCutchan 1994, Long & Robley 2004). Feral goats have been found to respect electric fences, particularly once they have encountered them. Where total exclusion of goats is required, adequate fences are likely to remain unacceptably and prohinitively expensive. Since fences usually do not permanently stop the movement of all goats, they should only be used as a tactical technique in a management program (Parkes 1990). They may be useful for excluding goats from land containing flora of high conservation value when used in conjuction with a controlled buffer zone and continual monitoring.

Shooting

Aerial shooting has been successfully used to control goats (Mahood 1985, Naismith 1992, Maas & Choquenot 1995, Pople *et al.* 1996). In pastoral areas this method is mostly used to control inaccessible populations, manage low density populations or remove survivors from other control campaigns (Parkes *et al.* 1996). It may also be the only technique to achieve broad scale reductions when goat prices are low. It generally involves using helicopters as a shooting platform with light aircraft occasionally acting as 'spotters'. This method is costly, but allows difficult terrain to be covered quickly and gives culling rates far in excess of other control methods (Lim *et al.* 1992). The costs of this technique vary greatly, but tend to rise exponentially with decreasing goat density (Parkes 1993b, Maas & Choquenot 1995).
Ground based shooting is not commonly used as a control strategy for feral goats in the pastoral areas of Australia due to its labour intensity and variable efficiency dependent upon climatic conditions (Dodd & Hartwig 1992, Edwards *et al.* 1994). Shooting goats from the ground is mainly used in forested areas, and in such areas, ground hunters may also use trained dogs to indicate, track, or bail goats (Parkes 1990).

Volunteer shooters have been successfully used to conduct ground shooting as part of the control methods within Bounceback 2000. The success with volunteer shooters in this case has been achieved by having well defined objectives and an effective system of coordinating their activities to maximise the level of control achieved. In one example from the Gammon Ranges National Park (South Australia), 78 volunteer hunters killed over 3400 goats in about 1000 square kilometres of rugged country at a cost (excluding labour) of about $10 per square kilometre (Dodd & Hartwig 1992).

Judas goat

This technique involves attaching a radio collar to a feral goat and releasing it in the expectation that it will join up with other goats. The goat is then tracked down and the herd which it has joined is killed. Judas goats are generally used where there is a low density population; to locate survivors of other control campaigns (Parkes *et al.* 1996) and to monitor areas thought to be free of goats (Taylor & Katahira 1988). However, this technique is expensive as it requires costly equipment and skilled staff. It may be warranted only in areas where extremely low goat densities are identified as being necessary to protect conservation values or where eradication of goats is a feasible option. This technique has not been used to eradicate goats in flatter semi-arid pastoral areas. The use of helicopters to locate and shoot animals associating with the Judas goat has not been trialled in Australia, but is used with success in high altitude grassland/scrub habitats in New Zealand (Hondelink 1992).

Fertility control

The use of contraceptive control through hormone treatment is not considered a viable option for managing feral goat populations as there are no practical methods of ensuring effective treatment of unrestrained animals. Immunocontraception has the potential to provide a target specific form of fertility control which can be used on wild goat populations. If the immunocontraception can be made to work, it may provide a cheap, easily disseminated method for reducing fertility and populations of some pest species on a continental scale. Broad scale control of goats using an immunocontraceptive vaccine, if one were developed, would depend on developing a suitable delivery mechanism for the vaccine and obtaining appropriate approvals to release the vaccine into the wild. The development and initial employment of such a vaccine would initially be very expensive; however the long-term cost of a successful immunocontraception program would be low due to the low on-going costs. Currently no immunocontraceptive research for feral goats is being undertaken.

Poisoning and baiting

The only poison that has been trialled for feral goat control in Australia is 1080 (sodium monofluoroacetate). The main risk with this technique is consumption of baits by non-target species. Three baiting techniques have been reported: pelletised grain bait (Forsyth & Parkes, 1995); foliage baiting (Parkes 1983); and poisoning of a water supply (Norbury 1993). This last technique to kill feral goats by adding 1080 to water troughs, was trialled in Western Australia (Norbury 1993). The trial showed that goats could be killed with minimal non target risks by designing the troughs to exclude birds and providing them with alternative water, by excluding domestic stock, and by poisoning between 8.00am and noon to reduce the risk to macropods. Following a public environment review (Agriculture Protection Board 1993), the technique of adding 1080 to water troughs, under strict management conditions, is now being used in Western Australia. This technique is not registered in any other state. Goats free-fed on untreated bait material (such as grain) might be able to be immobilised with bait to which a sedative such as Valium has been added. Initial trials in South Australia have been promising, but further development is needed (R. Henzell, unpublished). If effective, this technique could avert many of the animal welfare concerns associated with poisoning or trapping at water.

Biological control

Control of feral goats using a pathogen may be theoretically possible, but currently none is known to be virulent, humane, specific to goats and not transferable to other species. The potential risks to both the domestic goat industry and other livestock industries from using a pathogen are too high to warrant any research on this approach. Another disadvantage is that animals are likely to develop resistance to the pathogen and such resistance will eventually spread through the species.

Feral goats do not generally occur where there are uncontrolled populations of dingoes (Parkes *et al.* 1996). One feral goat population on an offshore island was successfully controlled by releasing dingoes onto the island (Allen & Lee 1995). It is unlikely that dingoes would be acceptable as a 'biological control' in pastoral areas where most feral goats occur, as predation by dingoes is not a target specific control measure and other livestock would be at risk.

Bounties

Bounties on goats' ears have been paid in Western Australia to induce people mustering goats to kill unmarketable animals instead of releasing them. Over 120 000 bounties were paid between 1977 and 1985, but discontinued in 1985 as the scheme was considered of doubtful value (Parkes *et al.* 1996). A bounty scheme would be of no use in the sparsely populated Rangelands.

Current management

NSW - In NSW the majority of goat control efforts are focussed on live removal for commercial use with mustering (56.8%) and trapping (20.9%) the most utilised techniques. These efforts are supported with ground shooting (13.4%), aerial shooting (4.5%), exclusion fencing (2.1%) and the use of Judas goats (0.4%). In areas around National Parks, mustering followed by aerial culling is used to reduce the impacts of feral goats.

NT – In the arid southern regions where dingos are prevalent, feral goats are not a problem and no control is undertaken. In the northern regions no feral goat control occurs, although safari hunting is popular on private lands.

QLD - In QLD limited pest control of feral goats occurs due to their value as an economic resource to many farmers. In fact, in some cases, farmers are thought to breed goats to increase herd sizes (Strong pers. comm). Most control is associated with commercial exploitation of the goats, and thus mustering and trapping are the predominant control measures. In National Parks aerial shooting is often implemented to control goat densities in more difficult to access terrain.

SA - Commercial mustering occurs at high goat densities, particularly on agricultural lands. Other methods used include trapping near water points and both aerial and ground shooting. Large scale integrated control programs in high value conservation areas of the Flinders, Gammon and Olary Ranges appear to have been successful in reducing feral goat numbers. The use of Judas goats with ground and aerial shooting at low goat population densities is proving to be effective. Volunteer recreational hunters are sometimes used to target feral goats where localised eradication is the target

WA - The value of goats to agriculturalists is proving to be a great hindrance to the effective management of goats in WA. Despite this, there is a feral goat management plan that involves trapping and mustering goats for commercial sale to achieve an initial population reduction, followed by aerial and ground shooting to remove the rest. The installation of fencing has been tried; however the persistent nature of the goats resulted in the fences frequently being breaches. More secure fences were deemed to be too expensive for large areas. The capping or control of access to artificial watering points in more arid regions has helped restrict goat densities to areas surrounding available water, and increased the efficiency of trapping

Management of feral goats in the Rangelands

Most feral goats in Australia live on land managed by pastoral farmers of sheep. How these pastoralists perceive the risks and costs or benefits of managing goats will be the crucial factor, both in the short and long term, in determining the fate of the feral goats. Eradication is the most efficient way of dealing with small colonies of feral goats which have the potential to expand their range into unoccupied territory. Management strategies including both aerial shooting and mustering will achieve the highest population reductions for the minimum net cost. In inaccessible terrain, aerial shooting is really the only successful control technique. Mustering does not reduce goat populations to the same extent as helicopter shooting, however, this is offset by the lower cost, with cost effectiveness depending on the price of goats at the time. Trapping, should only be used during dry times in places where access to water can be controlled. The Judas goat technique is expensive and is only appropriate where protection of native species and ecological communities can only be achieved with extremely low goat densities.

Summary of the effectiveness of feral goat control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Fencing	Moderate	High	Moderate	Low	High	Very effective short-term barriers	Expensive, therefore impractical for large scale application. Will no permanently stop goats Requires continuing maintenance
Aerial shooting	High	High	High	High	High	Used for control at both high and low densities especially in rugged or inaccessible terrain. Effective for eradicating small numbers of goats remaining after the use of other control methods. Useful for achieving broad scale reductions when goat prices are low.	Can be expensive at lower goat densities
Ground shooting	Low	Low	High	Low	Low	Can be cost-effective when densities are high.	Labour intensive, only suitable for smaller scale operations Difficult in remote areas
Judas goat	High	High	High	Low	Moderate	Can be a useful adjunct to other control methods. Effective if local eradication is the aim.	Requires expensive equipment and skilled operators Not applicable at high populations densities.
Trapping	Moderate	Moderate	Low	Moderate	Moderate to high	Most effective during dry times. Cost-efficient when prices for goats are high	Generally requires road access. Difficult to apply in remote areas.
Mustering	High	Moderate	Target specific	Moderate	Unknown	Efficient and cost–effective where goats are present in high densities, the terrain is relatively flat and goat prices are high.	Welfare concerns associated with capture and transport of goats. Difficult in remote/inaccessible areas
Biological control	Unknown			High	Unknown	Unknown, but possibly low cost implementation through self dissemination.	Impact on commercial goat industry.

5.8 Management of feral pigs

The past focus on feral pig control in Australia has been on reducing feral pig population numbers. Feral pig management is attempting to change from this ideology, to one involving strategic, integrated and co-ordinated control campaigns focused on optimising the efficiency of reducing the impacts of feral pigs (Lapidge & Cowled 2004). The application of combined methods of feral pig control in an integrated approach has been advocated as a means of improving the effectiveness of control programs. However, the order of application, intensity of application and the most effective combinations of control methods are unknown.

Eradication of feral pigs from mainland Australia is not possible using current technologies and resources. However, the effective reduction of feral pig impacts on biodiversity may require the targeting of feral pig control efforts to areas of overlap between feral pigs and threatened species, the application of effective broad-scale control methods and localised eradications. The impact of feral pigs on conservation outcomes needs to be quantified in order to justify the application of feral pig control methods in environmentally sensitive areas and to allow the auditing of these control methods for effectiveness. The use of cost-minimisation and benefit-maximisation approaches and interactive models to strategically manage feral pig control are useful in conservation situations.

Poisoning

Poisoning is one of the main methods used to control pig numbers. Poisoning campaigns are one of the most efficient, effective and widespread control tools for managing feral pig impacts. It is a widely accepted practice in rural communities, can provide fast and efficient knockdown of feral pig populations over a large area and be utilised in remote regions (O'Brien *et al.* 1986, Choquenot *et al.* 1996, McIlroy 2004). Feral pig baits usually consist of grain, fruit, vegetables, pellets and meat, although the compositions vary in different areas of Australia. Pre-baiting, using non-toxic baits is generally used to increase the uptake of the poisoned baits. The efficacy of baiting efforts can be reduced by a variety of factors ranging from plentiful food supplies in the treated area to unseasonably wet conditions. Ground baiting is widely practised to reduce feral pig populations across large areas in a cost effective manner. One major drawback is that it is generally limited to areas with reasonable road access. Aerial baiting is becoming an increasingly utilised tool in the management of feral pigs in large, remote areas. Aerial baiting is potentially a cost effective and efficacious means of controlling widespread and remote feral pig populations, but is currently only permitted in Queensland. However, research to investigate non-target impacts and improve the efficacy of the method is required. Currently monofluoroacetate (1080) and yellow phosphorous (CSSP) are the only registered toxins for feral pig control, with limited use of warfarin under special permit in restricted areas.

1080 (Sodium monofluoroacetate)

The main toxin used for baiting is compound 1080. The relatively large dose of 1080 required in feral pig baits means that these baits can be lethal to smaller non-target species and is one of the biggest drawbacks of this management technique, particularly in environmentally sensitive areas or those containing threatened animals. In parts of the Rangelands, native animals exhibit greater tolerance to 1080 than feral animals due in part to its natural occurrence in some locally endemic plant species (Twigg & King 1991). This enhances the target specificity of 1080 baiting campaigns in these areas, resulting in reduced potential for non-target impacts on native wildlife. 1080 ground baiting can be highly effective at reducing feral pig populations in the field.

CSSP (yellow Phosphorous)

CSSP is also sometimes used in pig baiting, however the efficacy of CSSP in the field and its potential impact on non-target species are somewhat unclear. CSSP is generally used in an ad-hoc manner rather than in a coordinated campaigns since it is available as a restricted 'take home' poison. It is the only take home feral pig poison registered in Australia, and as such, it is valuable to individual land managers, probably extending the area over which feral pigs are controlled. However, because of this, the use of CSSP is often not coordinated and non-target impacts on scavenging and carnivorous animals are probably high since no baiting strategy is used to reduce this impact. The logistics of using CSSP are relatively low compared with other ground based toxins since no free feeding is carried out with this method and the toxin is relatively inexpensive. The major drawback to CSSP is that it compromises the welfare of poisoned animals. A recent review by Lapidge & Cowled (2005) on welfare issues in feral pig control concluded that CSSP caused feral pigs considerable pain and in their opinion its use should be discontinued due to major animal welfare concerns.

Warfarin

Warfarin is an anticoagulant to which feral pigs are reasonably sensitive. The effectiveness of warfarin in controlling feral pig populations has been demonstrated when used in grain over a number of consecutive days (Hone 1987, McIlroy 1989, Saunders *et al.* 1990, Clarke 1993). Large decreases in feral pig numbers have occurred in field trials, resulting in reduced environmental damage. Warfarin is however, a toxin not supported for feral pig use by animal welfare societies, due to the long time it takes for feral pigs to succumb to its effects. The use of warfarin in grain can be labour intensive and impractical due to the requirement for repeat dosing and the lack of an aerial delivery method. The effects of warfarin on non-target animals and native communities are unclear. The control method efficiency of warfarin baiting campaigns is high, and the qualities of the toxin and the baiting strategies employed probably reduce the potential risks to non-target populations. The logistics of warfarin baiting campaigns are relatively high compared with other ground baiting methods because several consecutive doses of warfarin must occur for baiting to be lethal. A 'one shot' warfarin bait may improve the logistics of warfarin baiting campaigns, but may increase the potential non-target impacts.

Trapping

Aside from poison baiting, trapping is one of the most widely used methods of feral pig management. Although labour intensive, the technique can be profitable and incorporated into daily land management practices. The ability of this method to control widespread feral pig populations is largely unknown. Trapping can produced large decreases in feral pig populations, especially in small localised areas. The effectiveness of trapping is determined by the attractiveness of the trap bait material, and the rate at which feral pigs encounter traps. No assessment of the efficacy of trapping as a broad-scale method of feral pig control has occurred. Trapping is generally an expensive and time consuming means of feral pig control, with logistical practicalities meaning that it is best applied to small areas of high agricultural or conservation value rather than larger, remote areas. However, once feral pig trapping materials are purchased and traps are established, the costs and time taken for subsequent trapping campaigns are reduced significantly. New technology, such as shape recognition trapping may improve the applicability of this method. Research is required to assess the applicability of trapping to broad-scale feral pig control. The practice has the advantage of being highly target specific and providing a means of off-setting the cost of the control efforts.

Commercial harvesting

In total since 1998, between 140 000 and 332 000 feral pigs have been inspected annually at game meat processing plants in Australia (Lapidge & Cowled 2004 unpublished). These rates of commercially harvested pigs, although significant when applied to some local areas are small in comparison to the total numbers of feral pigs in Australia. Commercially harvested pigs are sourced from accredited field harvesters who utilise dogging, ground shooting and trapping to source the pigs

Ground shooting

Hunting by non-commercial hunters and commercial harvesters using ground shooting, dogging and trapping can have a significant localised reduction on feral pig numbers. Generally, the benefits of hunting and harvesting feral pigs are unquantified. A criticism of hunting as a control method is that non-commercial and commercial hunting may hold feral pig numbers at a point where the benefits of hunting exceeds the cost of hunting. The ability of hunting and harvesting to reduce feral pig impacts on conservation outcomes is unknown. In some areas the methods have markedly reduced feral pig populations, however, the efficacy of the method is reduced by deliberate introductions and decreasing returns in hunted areas. The method is generally inexpensive to apply since hunters and harvesters will often volunteer their time. The method may be difficult to apply in remote areas and can result in feral pig translocations. The non-target effects of hunting and harvesting have not been researched (escape of hunting dogs, feral pig translocations), but if conducted responsibly they should be low.

Aerial shooting

Aerial shooting is a method which can deliver rapid and large reductions (up to 80%) in feral pig numbers across extensive areas in appropriate habitats, including remote locations. However, the technique can be expensive, generally is undertaken in isolation, and the effect can be short-lived. It is highly target specific and can be cost effective. The main disadvantages are that the method is not applicable to all habitats and is expensive when feral pigs are in low densities. Aerial shooting is especially useful to extend feral pig control to remote or inaccessible areas and is one of the efficacious techniques available for use over broad areas in many areas of Australia. However, aerial shooting is not effective in all habitats, such as mountainous or heavily forested areas. The target specificity of aerial shooting is extremely high and the logistical practicalities are relatively easily met.

Fencing

Fencing can be a useful method of feral pig management through reducing or eliminating impacts on small, valuable areas. Its use is however expensive and time consuming and is generally limited to small areas or islands to allow eradication and exclusion. Ongoing maintenance requirements can be high. Fencing will potentially reduce the ease of movement by some terrestrial vertebrates but the non-target impacts of fencing have not been quantified. Fencing can improve the efficacy of other methods of control since it can prevent reinvasion and re-establishment of feral pig populations.

Judas pig

The Judas pig technique can aid in the detection of small isolated populations, and to improve the overall planning and effectiveness of control operations. The Judas pig method can improve the effectiveness of other control methods by allowing the targeting of control procedures to areas where feral pigs are present. However, it is expensive, can have some difficult logistical requirements, and is generally not applicable to reducing feral pig populations in high densities. It is also likely to reduce the non-target impacts of the other method of control which is utilised with the Judas pig technique.

Neck snaring

Neck snaring has been a useful means of managing feral pigs overseas, but would not be applicable to Australia, due to animal welfare concerns, non-target issues and the inefficiency of the method. The method requires many worker hours per pig removed from the population (Lapidge & Cowled 2004) and also requires workers 'on the ground' in all pig habitats, meaning it is not feasible for large land areas in remote places such as the Rangelands. It is likely to have extremely high non-target impacts.

Habitat modification

Habitat modification includes active management of feral pig food, water and shelter sources. Removal of water sources through the capping of bore drains is currently occurring on some properties in the Australian Rangelands. However, generally habitat modification would not have wide-spread value due to potential undesirable impacts associated with vegetation clearing.

Biological control

Biological control could be an effective means of controlling feral pig populations in Australia. Biological control of feral pigs in Australia could theoretically be attempted using African swine fever and classical swine fever. Both viruses are passed on by direct contact and fomites and are highly contagious, with porcines being the only natural vertebrate hosts (Geering *et al*. 1995). Rates of mortality from acute infections of both diseases can be in excess of 90%, generally significantly greater than other feral pig control methods discussed herein (Hone *et al.* 1992). However, Choquenot *et al*. (1996) cast doubts over the usefulness of CSF due to the disease remaining in low prevalence in areas that have previously had outbreaks of the disease. The potential impacts on the commercial pig industry will most likely make this control method unacceptable and currently no biocontrol research is being undertaken in Australia for feral pigs.

Current management efforts

NSW - The main investments in control efforts in NSW are poison baiting with 1080 (21%) and CSSP (14%), recreational hunting (21%), ground shooting (13%), trapping (15%) and commercial harvesting (11%). Aerial shooting (4%) and exclusion fencing are also used at times (1%). NSW NPWS are spending a lot of effort on the control of feral pigs, however they are having a problem from not dealing effectively with immigration, and thus the control efforts are typically not effective in the long-term. Feral pigs are controlled in National Parks and Conservation Reserves with integrated programs using some or all of aerial and ground shooting, poisoning (1080, warfarin), and trapping. Aerial shooting is often much more effective than shooting from the ground, provided that it is used frequently enough and on a scale sufficient to prevent immigration or recovery through breeding. Trapping can be effective but results are variable. It is used most often as a follow up after an initial knockdown of a population, or when poisoning is impractical or in conjunction with poisoning. Ground shooting and dogging are not used by NPWS due to ineffectiveness, although in some jurisdictions they are used opportunistically to follow up after initial knock down has occurred.

NT – Limited control is undertaken in conservation reserves and National Parks using 1080 ground baiting. The Judas pig technique has been used to eradicate small isolated feral pig populations in the past (McIllroy & Gifford 1997). Off-reserve, there are no formalised control programs and many landholders invest little in control other than opportunistic shooting and sport hunting. Some baiting of carcasses with CSSP in cropping areas is also undertaken by land managers.

QLD - The control methods used for feral pigs are strongly determined by the market price for feral pig meat. When prices are high, hunting, harvesting and trapping for commercial sale are the predominant techniques used. In 2001, approximately 240 000 feral pig carcasses were processed. This is supported by extensive 1080 ground baiting. Queensland is also the only state in Australia where it is legal to aerially bait for pigs and proves to be an effective measure for broad-scale control. The non-target impacts are still somewhat unclear. When market prices are low, efforts are increased in baiting and hunting.

SA - Feral pigs are not overly abundant in the Rangelands of SA, occurring mainly in the far north of the state. The majority of control undertaken is via aerial shooting in order to cover the vast and remote landscape.

WA – Ground baiting with 1080 laced grain is the most common form of feral pig control used in WA. Trapping is also frequently used, and has been the primary control method in several cooperative control projects (Higgs 2002). Aerial shooting is used in more remote areas with sparse vegetation and in the north-west of the state and Fitzroy river regions, recreational hunters have worked with land managers to reduce local feral pig numbers though annual shooting.

Management of feral pigs in the Rangelands

Like other feral animals that have a market value, the level of feral pig control varies with community attitudes and market prices. The most effective management techniques for the Rangelands are aerial shooting and aerial baiting. These techniques allow cost effective control of feral pigs over the vast and remote landscape. In more urban regions, trapping can be a useful additional control tool that also allows for some control-cost off-setting. Control efforts should seek to maximise the benefit from environmental conditions as much as possible. Control will be easier and more effective during times of drought when feral pigs are forced to congregate around a small number of water sources and when food is scarce. Conversely, baiting campaigns following rain may be ineffective due to the new-growth (‘green stick’) available to the pigs, and shooting may be more effective.

Summary of the effectiveness of feral pig control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Ground baiting with 1080 and warfarin	High	High	Variable	Moderate	High	Relatively target specific control applicable across broad areas of land in a cost effective manner.	Potential non-target impacts. Road access required.
Aerial baiting with 1080 and biomarkers	Moderate,	High	Unknown	High	High	Broad-scale control over remote and inaccessible areas.	Potential non-target impacts and efficacy needs research and refining with baiting strategies.
Fencing	High	Low	Unknown	Low	High	Allows excellent protection of small areas of land	Requires continuing maintenance and cannot be applied across large remote areas
Trapping	Moderate to high	Low	High	Moderate	Moderate to high	Allow targeted control of feral pig populations in localised areas	Generally requires road access. Difficult to apply in remote areas due to high labour requirements.
Aerial shooting	High	High	High	High	High	Allows broad-scale control over remote, difficult to access areas.	Not applicable to all habitats and particularly expensive at low feral pig densities.
Judas pig	High	Low	High	Low	Moderate	Allows targeted control of small residual populations of feral pigs.	Expensive and requires a high level of proficiency. Not applicable at high populations densities.
Snaring	Moderate to high	Low	Low but variable	Low	Low	Not recommended in Australia	Non-target impacts high. Labour costs prohibitive.
Hunting and harvesting	Moderate	High	High	Moderate	Unknown	Generally free for land manager	Deliberate releases of feral pigs, not practiced in all remote areas, unknown benefit.
Ground shooting	Low	Unknown	High	Low	Low	Target specific control	Difficult in remote areas, difficult to locate feral pigs
Biological control	Unknown	Unknown	Unknown	High	Unknown	Unknown, but possibly low cost implementation through self dissemination.	Impact on commercial pork industry.

5.9 Management of foxes

Eradication of foxes is not currently considered a viable proposition for mainland Australia due to their population size and expansive range. A variety of fox control techniques are used including trapping, shooting, poisoning, den fumigation, exclusion fencing and changed farming practices. The most effective measures for conservation and protection of endangered species are poison baiting and exclusion fencing. The effectiveness of these can be greatly enhanced by developing buffer zones of up to 20 kilometres where foxes are held at a low density to decrease the risk of inward migration rapidly replacing foxes killed (Saunders *et al.* 1995).

Bounty systems

The payment of a bounty or bonus upon presenting proof of the destruction of a pest animal has been frequently used against foxes (Rolls 1969, Whitehouse 1977, Lloyd 1980). These bounty systems have been shown to be an ineffective form of control and provide no long-term relief from fox impacts (Smith 1990, Braysher 1993, Saunders *et al.* 1995). Where private land adjoins or contains important wildlife habitat, assistance or encouragement to landholders and the development of incentives to promote fox control on private land may be appropriate, especially if the property forms part of a buffer zone to protect threatened species populations. This should be achieved through incentives such as resources to assist with control, rather than provision of bounties.

Poison baiting

In most situations, poison baiting is the most effective method of reducing fox numbers and impact, although a major drawback is that it may affect native carnivores and scavengers and also domestic pets. The benefits of this control method are confined to the baited area and, unless some barrier prevents reinvasion, last only for as long as baiting is regularly applied. A variety of toxins and bait types have been used, however only 1080 and strychnine are registered for fox control in Australia. 1080 is now the only widely recommended poison for fox control and the use of strychnine is being phased out. A variety of baits are used to deliver poison to foxes, including injected eggs, dried meat baits, fresh meat, and commercial products (eg Foxoff baits). However meat is the primary bait used to deliver poisons to foxes. It is very palatable to foxes, easily obtained and handled, and is relatively target-specific, being attractive only to a limited number of carnivores and omnivores. Target-specificity can be further enhanced by the manipulation of size and by drying. Tests have shown that smaller carnivorous marsupials and scavenging birds such as ravens, cannot consume dried meat baits as they are too tough and stringy (Calver *et al.* 1989). However, the assumption that dried baits maintain their consistency in the field, and hence their target-specificity, has not been demonstrated in the higher rainfall areas of south-eastern Australia. Surface application of manufactured or fresh meat baits, which are equally or more attractive than dried meat baits, may put non-targets at risk because they can be readily ingested. Dried meat is the preferred bait material in Western Australia especially for aerial application where native fauna have a tolerance to 1080. Manufactured baits, such as Foxoff, are now used extensively throughout south-eastern Australia. They can be easily distributed, stored on the shelf until required, have accurate amounts of poison and the potential to include attractants, such as Feralmone, to increase bait uptake. The disadvantage of manufactured baits is that they tend to be deployed in a less coordinated manner due to the ease of deployment and storage.

Establishing area specific baiting protocols for foxes can minimise impacts on non-target species. Saunders *etal*. (1995) discuss methods for minimising the risk to non-target species including: making the bait too big for smaller animals to swallow and too tough for them to tear apart; burying baits to make them inaccessible; minimising the dose of poison in each bait; and conducting surveys to detect animals which may be at high risk and avoiding baiting near them. These increase the labour costs, but these extra costs can be offset to some extent by using fewer baits and ensuring greater target-specificity (Allen *et al.* 1989). Baits should be prepared and deployed in accordance with the Standard Operating Procedures and Codes of Practice recently developed by DEH (Sharp & Saunders 2004).

1080

Poisoning using 1080 is the most suitable lethal technique for foxes. It can be readily applied to a wide variety of baits by authorised personnel and has the potential for minimal non-target poisoning (Section 4.1.1) in certain areas, allowing for its use in aerially delivered baits. In Western Australia, dried 1080 meat baits have been shown to be very effective for fox control over large areas. In New South Wales the number of 1080 baits distributed for fox control rose dramatically from approximately 2000 in 1980 to over 300 000 in 1994. Similarly, in Queensland the use of 1080 baits has also increased tenfold from 1999 to 2004 (K. Strong, QDNR&M pers. comm.).

Cyanide

Cyanide was once commonly used to kill foxes for the fur trade in Australia. The rapid action of cyanide ensured that the carcass was found close to the bait point for easy retrieval of the pelt (Lugton 1987). The use of cyanide baits is now illegal in Australia and can only be used as a research or management tool by government agencies. Cyanide capsules are currently being re-evaluated for use as a toxin in new delivery systems; however the work is still at the experimental stage.

New poisons

Research is being undertaken to identify and register new, more target-specific and humane toxins for foxes. Australian Wool Innovation Ltd, Pestat Ltd and the Pest Animal Control Cooperative Research Centre are working together to develop additional chemical agents for use in lethal baiting of foxes. One of the chemicals under investigation is faster acting and more selective in its toxicity than 1080. Availability and adoption of the new chemical is expected to increase the efficiency with which fox control can be implemented in Australia and decrease non-target impacts.

Aerial baiting

Aerial baiting of foxes with 1080 has been demonstrated to be an effective method of control for covering large areas provided the risk of non-target bait uptake is minimal. Currently Western Australia is the only state that uses aircraft to lay bait for fox control. In Western Australia, fox-baiting programs over large areas (up to three million hectares) have been shown to dramatically reduce fox numbers, to allow populations of rare species to increase and have minimal impact on non-target species (Saunders *et al.* 1995). This is largely due to the native fauna having a higher resistance to the naturally occurring 1080 poison found in native plants. Aircraft follow transect lines, one kilometre apart, across the site to be baited, deploying baits at prescribed intervals.

Frequency and intensity of baiting
The frequency with which baits need to be laid depends on the size of the area to be protected, with small areas requiring more frequent baiting due to rapid recolonisation by foxes (Kinnear *et al.* 1988, Saunders *et al.* 1995). In Western Australia, small area baiting has been restricted mainly to nature reserves surrounded by farmland. These have been routinely baited once per month. Baits are laid from a moving vehicle travelling along the perimeter firebreaks by tossing baits under shrubbery at intervals of 100–200 metres. Any internal tracks are baited as well. This baiting regime has been used for ten years at different sites. In each case, low density populations of marsupials have increased markedly, but it is expensive.

Hunting

The hunting of foxes either for their pelts, a bounty, or merely as a sport has long been seen by the agricultural community as a useful and economic way of regulating fox numbers. With the falling value of fox pelts, and in the absence of bounties, this is now left to the more enthusiastic amateurs and a few remaining professionals. Hunting of foxes is time-consuming and few landholders carry out this control technique, except opportunistically. While hunting may have some effect on overall fox densities, it is generally agreed that reductions will be minimal. This has been observed throughout the fox's natural range where hunting has been used to reduce predation, to prevent the spread of rabies, or for commercial harvesting (Harris 1977, Macdonald 1980, Hewson 1986, Voigt 1987, Wandeler 1988, Saunders *et al.* 1995). Most hunting is performed with guns; however dogs and traps are still used in some areas.

Shooting
Shooting is usually done at night from a vehicle and with the aid of spotlights. The method is not suitable where there is dense cover for foxes. In Yathong Nature Reserve, Newsome *et al.* (1989) removed foxes and cats from by shooting and observed significant increases in rabbits compared to control areas with no fox or cat shooting. The effort was considerable, one week in every two or three. It is not known if this level of effort would have been sufficient to allow native prey species to increase or if the cost was justified. Replacement of shot foxes was high, particularly during the period when young foxes were dispersing. Shooting may prove to be a useful technique for small scale control to account for gaps in regional control programs, such as on properties that refuse to use 1080 baits.

Fox drives
Fox drives still occur in some rural communities. Groups drive foxes into a waiting line of guns using dogs and beaters. Usually only small areas of prime fox cover are treated, however significant numbers of foxes can be taken, with the advantage that this method takes all foxes in an area. This approach may be effective for populations of wary foxes but the human resource requirements are generally prohibitive.

Dogging
Another technique of fox hunting still used in some parts of Australia is the use of small terrier dogs to flush foxes from dens. Dislodged animals are either killed with shotguns or coursed with larger dogs. As with fox drives, this technique produces

little more than a temporary and localised reduction in fox damage and also cannot be condoned on animal welfare grounds.

Traps
Steel-jawed traps can be used in Northern Territory, Queensland and Western Australia, but are banned in South Australia due to the injuries inflicted upon trapped animals. Steel-jawed traps have considerable non-target catches that are usually fatal or cause serious injury. Soft-jaw traps and treadle snare traps (leg snares) are now occasionally used for the capture of foxes in areas where conventional control methods are unsuitable. These traps are more humane alternatives to the steel-jawed trap, however are difficult to set and unsuitable for use by the general public. Trapping is a labour intensive and a somewhat non-target specific technique which makes it impractical for large-scale operations and of limited use within the Rangelands for conservation purposes.

Den destruction and fumigation

Den destruction and fumigation can be an effective technique to reduce fox numbers at the time when cubs are born. Only one fumigant is specifically registered for foxes (Denco-fume). Phosphine and chloropicrin which are recommended fumigants for rabbit warrens are commonly used, but phosphine is the preferred fumigant in terms of relative humaneness. Den destruction and fumigation can also affect non-target species. The major disadvantage of this strategy is that fox dens are not easily located. They only have a small number of entrances which are usually discretely hidden under tree roots or rocky outcrops.

Exclusion fencing

A large range of fence designs have been used to exclude foxes from particular areas but there is little information on the effectiveness of particular designs. A review of predator-proof fencing in Australia (Coman & McCutchan 1994) found that although fences can be a significant barrier to foxes, even the most elaborate can be breached. Frequent monitoring for the presence of foxes inside the fence is an essential precaution as considerable damage can be caused by a single fox breaching the fence. The high cost of establishing predator-proof fencing, and the ongoing maintenance costs involved, means that it is likely to be useful only for small areas (Aviss & Roberts 1994). However, studies at Shark Bay, Western Australia have integrated fencing with baiting and trapping to reduce the frequency of challenge to the fence by incoming predators. These studies have focused on using a combination of natural water barriers, fencing and baiting to create large predator-free reserves on peninsulas (Department of Conservation and Land Management 1994).

Habitat modification

Habitat modification may have a role in protecting wildlife from fox predation. In environments with dense vegetation, steep topography, rocky crevices or extensive wetlands, prey are less likely to be caught by foxes (Saunders *et al.* 1995). The foraging efficiency of foxes seems to be maximal in open habitats where they are able to range widely and freely. They readily use roads, tracks and other cleared access ways through denser vegetation or complex topography. One option to minimise fox impacts on endangered species, is to reduce such access points to a minimum and to maintain bait stations along those access paths which are retained. Kinnear *et al.* (1988) concluded that fauna subject to fox predation can only survive in sites that act as a refuge from predators. Removal of predators allows prey to utilise less protected sites. Conversely, not changing habitat where susceptible species are present or recreating necessary habitat may also prevent fox predation. Logging activities and the establishment of roads through undisturbed habitat for example, may allow foxes to colonise new areas which contain endangered or vulnerable species (Mansergh & Marks 1993).

Fertility control

Targeting fox fertility may yield an effective long-term approach to reducing their numbers and hence lower the need to use poison baits. Lethal control will be needed to achieve a rapid reduction in fox numbers. Fertility control could then be used strategically to maintain reduced fox numbers to provide long-term protection for threatened species. Fertility control is still at an experimental stage of development. Hormone treatment is not considered a viable option for managing populations of wild foxes as there are no practical methods of ensuring effective treatment of unrestrained animals. Research has, however, indicated that Cabergoline may have the potential to control fox fertility in areas where poison baiting cannot be undertaken (Marks *et al.* 1995a, 1995b). Immunocontraception has the potential to provide a target specific form of fertility control which can be used on wild populations, but has yet to be developed.

The Pest Animal Control CRC has been exploring the possibility of reducing the fox population by anti-fertility vaccination. The canine herpesvirus has been identified as potentially the most suitable virus carrier for the vaccine. Work on genetically altering this virus in such a way as to cause an immune repsonse in foxes that supresses reproduction has been conducted. A successful recombinant virus has yet to be discovered and the research will be downsized and a briefing watch maintained.

Biocontrol

Some form of pathogen could conceivably affect foxes on a continental scale, but currently none is known to be virulent, humane, specific to foxes and not transferable to other species, especially domestic dogs. Research to develop an effective biocontrol agent to manage foxes continues, however it has to address difficult scientific, technical and biological problems.

Current management

NSW - Ground baiting with 1080 is by far the most commonly used technique in NSW. In fact 78% of control efforts use this technique. Ground shooting is the only other commonly used control technique (15%), although trapping, exclusion fencing and den fumigation are used to a small degree. The most widely used technique by NPWS is broad-scale baiting (both ground and aerial) with 1080, which is the most effective and target-specific method of fox control currently available. Other less frequently used methods are trapping, shooting, den fumigation and exclusion fencing. They are expensive, labour intensive, requiring continuing management effort and can be effective in only limited areas. Aerial baiting is used in western NSW to increase the cost-efficiency of fox control over a very large area, with the aim of protecting endangered mallee fowl populations. Aerial baiting of these reserves is complemented by an extensive ground baiting program on surrounding properties and state forests.

Broad-scale cooperative programs involving several National Parks, RLPBs and local landholders in western NSW have lowered fox numbers in these locations.

NT – Very little fox control is undertaken due to the difficulties imposed by the protection of dingoes in the Territory. This prevents the use of poisoned baits and other such control techniques. The Parks and Wildlife Comission is currently developing a fox-specific bait delivery system that will prevent bait consumption by wild dogs and other predatory scavengers.

QLD – The majority of fox control is by 1080 ground baiting, supported by trapping and opportunistic shooting. The Dingo Barrier Fence runs across the south of the state and is also believed to assist in controlling the spread of foxes.

SA – 1080 baiting is the most commonly used control technique in SA. Priority is given to managing foxes in high-value conservation areas and large-scale baiting programs, such as those carried out as part of Operation Bounceback, have resulted in a decline of foxes in the Flinders and Gammon Ranges and an increase in several native species such as the yellow-footed rock wallaby..

WA - Only place in Australia where aerial baiting with 1080 occurs. This is because of the native species natural tolerance to the poison. Allows efficient and cost-effective baiting on a very broad-scale. In conservation reserves, 1080 fox baits are also laid out from the back of moving vehicles along fire trails and access tracks.

Management of foxes in the Rangelands

Aerial baiting of foxes has been demonstrated to be an effective method of control for covering large areas provided the risk of non-target bait uptake is minimal. This method is the most effective when using 1080 baits in areas where native species have developed a natural tolerence to the poison and is suited to broad-scale control in the western parts of the Rangelands. It has the advantage of being cost-effective and applicable to remote or inaccessible country. Where native species do not exhibit greater 1080 tolerance, integrated ground-baiting programs using buried baits can prove to be very effective although more labour intensive. All baiting campaigns require sustained efforts and should utilise environmental conditions, such as droughts or floods, for maximum effectiveness. If research into new fox specific toxins is fruitful, and a bait is developed that can be aerially delivered, it will allow for effective fox control throughout the rangelands and create the potential for population control over extremely vast areas. In areas of high conservation value, although high cost, exclusion fencing can be effective in protecting the enclosed biodiversity, especially when combined with a baited buffer zone. Problem animals can be trapped or shot, but this will only be effective for for short-term control in small areas.

Summary of the effectiveness of fox control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Ground baiting with 1080	High	High	Variable	Low to moderate	High	Relatively target specific control applicable across broad areas of land in a cost effective manner. Baits can be made more target specific by burying and placement	Potential non-target impacts. Road access required.
Aerial baiting with 1080	Moderate	High	Unknown	Low to moderate	High	Broad-scale control over remote and inaccessible areas.	Potential non-target impacts and efficacy needs research and refining with baiting strategies.
Bounties	Low	Low	High	Low	Low	Incentive for control	Fraudulent claims Efforts only targeted where fox densities are high Small impact on population
Fencing	Moderate	Moderate	High	Moderate	Moderate to high	Very effective in small conservation areas	Risk of breaching Expensive to erect and maintain Not suitable for broad-scale application
Trapping	Low	Low	Low	Low	Low	Target specific trouble animals	Inhumane and not recommended High labour costs
Hunting	Moderate	High	High	Moderate	Unknown	Generally free for land manager	Deliberate releases of foxes
Ground shooting	Low	Low	High	Low	Low	Target specific	Difficult in remote areas Labour intensive
Den destruction and fumigation	Low	Low	Variable			Useful for localised fox problems where baiting and shooting is not an option	Not effective for broad scale control Potential health risks for operators Labour intensive
Fertility control	Unknown	Unknown	Variable	Unknown	Unknown		No suitable method is available
Biological control	Unknown	Unknown	Unknown	High	Unknown	Cost effective if self-disseminating	No suitable biocontrol is available

5.10 Management of rabbits

Rabbit control was first attempted in the 1880s in south-eastern Australia (Meyers *et al.* 1994). Early methods of control included extensive rabbit-proof fencing, mass poisoning campaigns and rabbit drives. Control was only achieved on some individual properties through labour intensive efforts including fencing, removal of harbour, manually digging out warrens and the persistent hunting of remnant rabbits (Edwards & Dobbie 1999). Athough control technology has improved since then, the complete removal of rabbits from Australia is still well beyond the capacity of available techniques and resources. Recently, the eradication of rabbits from localised, newly established populations has been accomplished and is feasible (McManus 1979, Martin & Sobey 1983) provided a sufficiently rapid, well-funded and persistent campaign could be mounted. Most rabbit control programs now aim to achieve the long-term suppression of rabbit populations, to reduce the damage that rabbits cause to production and the environment in the most cost-efficient manner (Williams *et al.* 1995).

Fencing

Fences have often been used to exclude rabbits from an area. Rabbit-proof fencing deters immigration and is particularly useful where control methods are to be applied only on one side of the fence, or for sequential control operations over large areas. Long-term exclusion requires the use of wire-netting fences (McKillop & Wilson 1987). Electrified wire-netting fences can be very effective if properly maintained. Where the rabbit's normal food source is some distance from the warren, temporary electric fencing can be used to prevent access to the food and to make baiting near warrens more effective. The entire length of fencing, including gates, must always be maintained in good repair, requiring regular patrols and repairs and potentially high ongoing costs (Korn & Hosie 1988, Williams *et al.* 1995). Breaches of the fence resulting from burrowing animals, fire damage, tree falls stock or rabbits climbing into the exclusion zone will quickly make it ineffective (Williams *et al.* 1995). The high cost ($1700 - $3500 per kilometre, Korn & Hosie 1988, Williams *et al.* 1995) and need for ongoing maintenance generally limits the use of such fences to small regions and those of high conservation value. Fencing can be used on perimeters of properties, or internally to protect high-value assets such as tree plantations, or to contain rabbits in areas where control is difficult. Internal fences may enable a sequential control program through a property with minimum recolonisation of paddocks already treated. The movements and dynamics of native fauna populations should be considered in the planning and construction of rabbit-proof fences to ensure non-target impacts are minimised.

Rabbit-proof fences in Australia

Australia has a long history with using barrier-fencing for control of feral animals. In 1896, Arthur Gregory Mason recommended the WA government build a rabbit proof fence to stop the westward encroachment of rabbits into Western Australia. After much debate and a Royal Commission, the government eventually adopted the idea of a barrier fence and began construction in late 1901. Seven years of hard work followed - gangs of men, teams of horses, mules, camels, wagons, carts, picks and shovels, and a lot of sweat and tired muscles. When the fence was completed it was the longest fence in the world, stretching from Starvation Boat Harbour, just west of Esperance in the south, to Wallal on the 80 Mile Beach in the north-west. However, even before completion, the rabbits were past the fence and work had begun on Fences No.2 and 3. By 1908 the three fences were complete, over 3,000km of fence line in total. Despite the best efforts to stop the rabbits at the barrier fence, all was to fail. Erosion under the fences, holes in the wire and gates left open allowed rabbits to continue their movement west into the fertile agricultural areas. Queensland also attempted barrier fencing along the NSW border, however this also proved unsuccessful for similar reasons.

The following extract from an article by Mike Sydell (2004) provides an insight into the costs, effectiveness and the design requirements of rabbit-proof fencing for conservation areas.

"After enclosing 60 square kilometres of land with what was labelled rabbit-proof fencing, volunteers of the Arid Recovery project from the local Roxby Downs community set about eradicating the feral animals contained within it. Rabbits proved the most elusive, although thousands were eliminated and warrens destroyed. Eventually the rabbits were confined to discrete pockets of land, and were exterminated one by one. Finally, one last rabbit – nicknamed Bunston – was left. The capture of this barren female rabbit led to major celebrations. But a month later, more rabbit tracks were found. How could this be, with the fencing seemingly secure? One day, John Read and a colleague found a kitten rabbit on its own within the fence. They took it to the rabbit-proof fence, and it slipped right through and back, performing the trick several times. A few days later a much larger young rabbit, of about 450 grams, performed the same casual exercise, this time caught on video. The 40-millimetre mesh fence, erected at a cost of $200,000 by volunteer fencers, was not rabbit-proof after all. The only solution was a specially made 30-millimetre mesh fence. After it was erected, the rabbits were finally exterminated."

Whilst fences have proved unsuccessful in the west, some success has been achieved in the east. When rabbits first reached Queensland in the 1880s from the southern states, a fence was quickly constructed along the border in an attempt to keep them out. Unfortunately, the rabbits had already invaded some districts before the fence was completeand some of the invaded districts had inadequate financial and technical resources to cope with the problem. In 1964 the last remaining rabbit boards merged to form the Darling Downs-Moreton Rabbit Board which now manages the fence. The fence is now 555 km long and stretches from Lamington National Park in the east, to Goombi in the south-west where it connects to the Wild Dog Barrier Fence. It protects about 28 000 km^2 within southern Queensland and is patrolled and maitained weekly to keep it in rabbit-proof condition. The local governments in the Board area fund its activities to the value of $0.8 million per annum. As well as maintaining the physical barrier the staff of the Board also provides control activities within the board area. This area is the only sizeable suitable habitat on mainland Australia where rabbits have never established. The returns from this exclusion zone have not been calculated, but they are likely to be significant given the enormous impacts on rabbits on pastures, cropping lands and market gardens (up to 50% biomass loss at medium rabbit densities) and the biodiversity losses, described as "identical to chainsaws and bulldozers" (Williams *et al.* 1995).

Warren ripping

Where rabbits use warrens, ripping is the most cost-effective and enduring of the available single techniques (Cooke 1981, Williams & Moore 1995). Ripping is also the most suitable method for treating large areas (Myers *et al.* 1976, Martin & Eveleigh 1979, Wood 1985, Lord 1991, Tatnell 1991, Williams *et al.* 1995). Rabbits living in severe climatic regions, such as the semi-arid and arid zones, depend on warrens for protection from climatic extremes and predators (Hall & Myers 1978, Parer & Libke 1985). Ripping warrens removes their principal shelter. Rabbits do not dig new warrens readily and the destruction of warrens greatly inhibits resurgence and recolonisation of treated areas, especially if surface harbour is removed beforehand and follow-on control by re-ripping or fumigation is undertaken. (Williams & Moore 1995, Williams *et al.* 1995). The success of the technique depends on efficient destruction of the entire burrow system (Mutze 1995), adequate follow-up control (Williams & Moore 1995) and using appropriate control measures on adjacent lands (Parer & Parker 1986, Parer & Milkovits 1994). Erosion after ripping is a potential problem but can be reduced by ripping along rather than down slope contours, seeding ripped areas with vegetation, and refraining from ripping when heavy rain is likely. Warrens in relatively inaccessible places such as between trees and in narrow gullies can be ripped using a drag-arm ripper (Williams *et al.* 1995). This is a ripper mounted on a hydraulic arm, allowing more flexibility in its placement and resulting in little disturbance to the surrounding soil and vegetation. Recent innovations for large-scale ripping operations, mainly on inland Rangelands, have increased efficiency and reduced costs markedly. Warrens are identified prior to the commencement of ripping and the most efficient course between them is calculated. The effectiveness of ripping is greatly enhanced when followed with other control techniques, or with repeated ripping (Cooke 1981, Williams & Moore 1995). The efficiency of ripping is also enhanced by ripping warrens when the rabbit population is low and the potential level of rabbits surviving and recolonising is depleted. Dogs or trained dog packs, which send surface rabbits underground, improve the efficiency of ripping. They reduce the likelihood of surface-living rabbits surviving to re-open ripped warrens or dig new ones (Williams *et al.* 1995).

Explosives

Explosives can be used to destroy warrens in rocky areas, along rivers and in steep sandbanks where ripping and other techniques are not possible. If used correctly, explosives will completely destroy the tunnel system (Barnes 1983). The use of explosives is expensive and requires qualified personnel if the method is to be safe and effective. If excessive explosive is used, the blast may create a crater and pulverise surface soil or stone, which rabbits may dig easily, leaving the deeper warren structure amenable to recolonisation. On the other hand, skilled operators may destroy deep warrens effectively.

Surface refugia destruction

Rabbits in some parts of Australia prefer surface refugia even when warrens are present (Wheeler *et al.* 1981, Williams *et al.* 1995). Habitat destruction in these situations may require the removal of the shrub layer, of exotic weeds such as blackberry and debris such as logs, and can greatly enhance the efficiency and effectiveness of control programs and slow recolonisation. This may be undesirable as such refugia also provide important habitat for amphibians, reptiles, small mammals, and ground dwelling or ground feeding birds. The relative benefits of this action for enhancing the recovery of endangered or vulnerable species would need to be carefully assessed against the risks to other native species if such action is proposed in areas being managed for conservation purposes.

Shooting

Shooting can be a humane way of destroying rabbits but is rarely an effective means of reducing populations. Shooting may be used by land managers as a method for maintaining control once populations have been substantially reduced by other methods. Small numbers of survivors in difficult country can also be hunted with dogs and guns. Although not highly regarded as a game animal, wild rabbits are probably the largest hunting resource in southern Australia. There are no published reports on the size and value of sport hunting of rabbits. The commercial rabbit industry depends largely on the supply of field-shot rabbits to processing works, however harvesting efforts have no significant impact rabbit populations (Ramsay 1994). To maximise returns, commercial hunters move to areas where rabbits are more abundant rather than continuing to shoot rabbits in a lower density population. Many of the areas now subject to commercial harvesting, mainly in the Rangelands, are those where wide-scale effective management with conventional control techniques such as poisoning, fumigation and ripping are difficult to achieve in the short term, either economically or logistically (Williams *et al.* 1995)

Trapping

Leg-hold traps have been used to catch feral rabbits for many years. The use of the traditional steel-jawed leg-hold trap for the control of rabbits is not advocated as they subject animals to unnecessary pain and suffering and this technique does not reduce rabbit numbers significantly to be an effective control technique (Gibb *et al.*1969, Williams & Robson 1985). Exceptions to this are where small isolated populations are targeted, in which case barrel traps or soft catch traps should be used (Korn & Hosie 1988).

Fumigation

There are two fumigation methods; pressure fumigation and diffusion fumigation (Cooke 1981, Williams & Moore 1995). Toxins used for fumigation include chloropicrin, carbon monoxide, carbon dioxide, calcium cyanide, and phosphine (Hayward & Lisson, 1978, Williams *et al.* 1995). Pressure fumigation requires the use of a pump to generate and force the fumigant throughout the warren. The fumigant usually comprises a mixture of thick smoke, carbon monoxide and chloropicrin (Parer & Milkovits 1994). During fumigation all warren entrances are sealed. Entrances hidden in rocks or vegetation may be revealed by emerging smoke. Pressure fumigation is a slow and cumbersome process and is suitable only for small areas (Williams *et al.* 1995). In addition, the use of chloropicrin in pressure fumigation is both dangerous to operators and perceived to be inhumane (Oliver & Blackshaw 1979). Diffusion fumigation can use chloropicrin liquid, or aluminium-phosphide pellets, which give off phosphine gas (Korn & Hosie 1988). Pellets are placed in absorbent paper towel or newspaper, then moistened with water and sealed as far into the burrow as possible. Diffusion fumigation is useful for impromptu treatment of isolated warrens or re-openings detected by chance during normal property practices. Little equipment is required and it can be carried readily in a vehicle, on a motorbike, or by an operator walking in difficult terrain. The technique also allows for the use of an alternate toxin such as phosphine which is possibly more humane (Williams & Moore 1995; Williams *et al.* 1995). Both methods are labour-intensive and only small areas can be treated because of cost, the time required, and the intensity of the operation. The methods are useful where warrens cannot be ripped and for follow-up maintenance after large-scale programs such as warren ripping or baiting (Korn & Hosie 1988, Williams & Moore 1995). The efficiency of fumigation can be greatly increased by using dogs to drive rabbits into the warren. Fumigated warrens remain intact and therefore prone to recolonisation by rabbits. Once fumigated, warrens should be rendered unusable by securely blocking entrances. This is likely to be more cost-effective than repeated fumigation

Poisoning

Poisoning is another commonly used rabbit management technique. If used alone, it is an expensive method of controlling rabbits because the treated areas are rapidly recolonised (Rowley 1968, Martin & Atkinson 1978, Foran *et al.* 1985, Williams & Moore 1995). Resources per rabbit are increased leading to increased survival and breeding, and the warren, the rabbit's main form of shelter, remains intact and available for recolonisation. Frequent and ineffective poison baiting can lead to neophobia in rabbit populations that can reduce the effectiveness of baiting. Changing poisons does not overcome the problem (Williams *et al.* 1985). When used in conjunction with ripping or fumigation and follow-on control however, poisoning can be a cheap and effective component of integrated rabbit management. It is also an important management tool where rabbits are mainly surface dwelling, a common situation in several parts of Australia. Baits commonly used for rabbits include pieces of carrot, oat grains, or pellets manufactured from bran or pollard. Poison baits can be delivered from aircraft or from baitlayers towed by vehicles including four-wheeled motorcycles. Aerial bait laying is useful for broad-scale application but is less accurate. It should not be used where non-target animals occupy habitat close to the proposed treatment area. Vehicle-drawn baitlayers can broadcast the bait in a swathe or lay it in a shallow ploughed furrow. The choice of method depends primarily on the scale of the operation, the terrain, and the cost and availability of equipment. The selectivity of poisoning is enhanced by:

(1) Pre-baiting with non-poisoned bait and ensuring that only rabbits are taking the bait
(2) Using baits that are most attractive to rabbits
(3) Using the minimal concentration of poison sufficient to kill rabbits
(4) Placing the bait in the prime feeding areas of rabbits
(5) Collecting carcasses of poisoned rabbits to minimise secondary poisoning.

Poisons

Traditionally, strychnine, phosphorous and arsenic were used for poisoning rabbits. 1080 has generally replaced the use of these chemicals in most parts of Australia. 1080 is cheap and is used where there is little risk of poisoning dogs, sheep or cattle. 1080 is rapidly eliminated from animals that consume a non-lethal dose, presenting a negligible risk to people who consume meat from stock from areas treated with 1080 poisoned baits (Eason 1992). Concerns about sublethal ingestion leading to bait shyness and non-target impacts have led to the study of alternative poisons such as pindone and second generation coagulants (Oliver *et al.* 1982, Crosbie *et al.* 1986, Mead *et al.* 1991, Eason & Jolly 1993). Pindone is a chronic anticoagulant poison which requires several consecutive doses, but does have an effective antidote. Pindone is relatively expensive and is used in areas close to human settlement where there is significant risk of poisoning dogs or people. In Western Australia the use of pindone is carefully controlled, and specific prescriptions require its careful use in the presence of certain native species, especially large macropods. Experience has shown that marsupials are very sensitive to this toxin (Martin *et al.* 1991, Martin *et al.* 1994). Second generation coagulants are comparatively expensive and will continue to receive little use whilst 1080 is cheap and effective to use.

One-shot baiting

Conventional poisoning methods rely on pre-feeding with non-poisoned bait prior to laying poisoned bait. The one-shot oats technique requires no pre-baiting, relying on rabbits becoming accustomed to eating the oat bait while consuming the non-poisoned grains, before encountering the ‘one in a hundred’ oat grain containing more than sufficient 1080 poison to kill it. The two techniques were equally effective when tested under similar conditions in South Australia during summer/autumn, but not during the winter/spring breeding season (Cooke 1968). One-shot oats also proved less effective than conventional poisoning during the rabbit breeding season in other trials (Gooding 1968). Where rabbits are not bait shy, the one-shot oat technique may achieve kills as high as those achieved in eastern Australia by conventional 1080 poisoning. One-shot oats poisoning was used for three years in South Australia. Its use was discontinued because of severe non-target losses (Williams *et al.* 1995).

Tarbaby

The ‘tarbaby’ technique is a possible alternative to baiting. This uses a toxin mixed with grease, which is placed down the entrance of the burrow. Rabbits which pass through the grease will attempt to groom themselves by licking the grease from their fur and will thereby ingest the toxin. The high concentration of 1080 required precludes its use with this technique. Combining second generation anticoagulants with tarbaby may overcome this obstacle. The technique could have a useful but very specific role as a follow-up technique to destroy rabbits in rocky areas. Trials have shown that this technique performs poorly in light sandy soils, such as those found in Western Australia (Williams *et al.* 1995).

Myxomatosis

Myxomatosis, a disease specific to leporids, is caused by myxoma pox virus which was released into Australian wild rabbit populations in 1950. Initially it caused extremely high mortality, but the virus quickly attenuated (weakened) and rabbits with a genetic resistance to the disease became more common. Rabbits that survive myxomatosis acquire lifelong immunity. Since myxomatosis established in Australian rabbit populations, highly virulent strains, have been introduced many times on the premise that they would kill a high proportion of rabbits and thus control their populations. This has generally proven unsuccessful so far. The European rabbit flea (*Spilopsyllus cuniculi*) was introduced into some Australian wild rabbit populations in 1968 as a vector for the myxoma virus (Sobey & Conolly 1971). However the flea is unable to cope with arid conditions and does not occur permanently with populations in arid regions (Cooke 1984). To overcome this, the Spanish flea was introduced into Australia as a vector in the more arid zones (Williams *et al.* 1995) and its distribution will complement that of the European rabbit flea. Highest flea infestation levels occur in summer/autumn (Abreu 1980), the time when myxomatosis is most prevalent in inland Australia (Parer & Korn 1989). Despite a decrease in the effectiveness of the myxoma virus since its initial release in the 1950s, it continues to have an important role in rabbit control. Like most effective biocontrols, despite initial high research and implementation costs, it has remained an extremely cost effective form of rabbit management due to little or no on-going costs. Parer *et al.* (1985) demonstrated that in the absence of myxomatosis, rabbit populations can again increase rapidly.

Rabbit haemorrhagic disease

Rabbit haemorrhagic disease (RHD, formerly known as Calicivirus) is an acute and fatal infectious disease of rabbits. The virus escaped onto the mainland in 1995 during field investigations on Wardang Island, South Australia, possibly as a result of windborne vectors (Cooke 1996). In September 1996 RHD was accepted as a biological control agent under the Commonwealth *Biological Control Act 1984* and later also accepted by the States and Northern Territory. The virus is transmitted through direct contact between infected and susceptible rabbits and by contact with the secretions or excretions of infective rabbits, or items such as food and water that have been contaminated (Xu & Chen 1989). Rabbits, which survive an RHD epizootic, may persist as carriers for up to a month (Gregg *et al.* 1991). Mortality rates in excess of 90 percent have been observed in some South Australian populations (Mutze *et al.* 1998) where naturally recurring outbreaks have kept the population at an average population level only 17 percent of the long-term pre-RHD average (Mutze *et al.* 1998b). More humid sites do not always fare as well with some sites observing little change in rabbit numbers following the arrival of the virus (Anon 1997).

The impact of RHD on rabbits in the higher rainfall areas of south-eastern Australia has been highly variable. The Invasive Animal CRC will investigate methods of increasing the effectiveness of RHD in these areas. One avenue of research will focus on the development of a virus that can be released on bait in susceptible populations in these areas. This would provide a cheap and simple tool to aid rabbit control.

Immunocontraception

Current research in molecular biotechnology aims to insert into the myxoma virus genetic information coding for specific antigens derived from surface proteins of rabbit sperm and egg. It is hoped that infection of rabbits by this modified virus will cause an immune response, blocking fertilisation or embryo implantation in females that survive the disease (Tyndale-Biscoe 1991, Tyndale-Biscoe & Jackson 1991). The intended strategy is for such a genetically modified myxoma virus to infect wild rabbit populations and induce sterility in sufficient proportions to cause rabbit populations to decline. If both sperm and egg antigens are inserted into the virus the proportion of infected and sterilised rabbits required for population decline is much lower than if only one antigen were used. No species other than the rabbit would be at risk, because the system would possess double species-specificity, the species-specific virus and the species-specific reproductive antigens. The concept is a humane method of rabbit control in that it reduces rabbit numbers without increasing the incidence of myxoma infection. It is a long-term project that will require years of research and development. An effective virus would need to be approved for release by the Office of the Gene Technology Regulator (OGTR) after exhaustive investigations into its stability, species-specificity and safety. For such an immunocontraceptive virus to be effective it must produce a long-lasting immune response. Initially it would be advantageous if the virus could provoke an adequate immune response in a second infection in rabbits that have had myxomatosis previously. Effective dissemination of the virus into the field in Australia will be a formidable challenge, because it will need to be able to spread and infect a high proportion (more than 80 percent) of rabbits in competition with existing field strains of myxoma virus (Parer *et al.* 1985). Breeding by the European rabbit flea, a major vector of myxoma virus is linked intimately with the breeding of rabbits (Mead-Briggs 1977). Therefore, flea populations may decline after the introduction of an immunocontraceptive virus. Intensive annual introductions of the immunocontraceptive virus may be needed, and this would add significantly to the cost. A substantial reduction in fertility may eliminate rabbits from marginal habitats, such as subalpine areas, where females produce only 15 young per year (Gilbert *et al.* 1987). In environments more favourable to rabbits, an effective immunocontraceptive virus would make the rabbit problem more amenable to solution by conventional techniques. The rate at which wild rabbits would be selected for genetic resistance to the modified virus is not known.

Research by the Pest Animal Control CRC has discovered encouraging results with the achievement of temporary anti-fertility in up to 70 percent of female rabbits. However, permanent infertility has proved elusive and the investment into this research will be scaled down and not carried forward into the new Invasive Animals CRC.

Integrated control

It is clear from the information provided above that when any one technique of rabbit control is used in isolation it is less effective than when two or more techniques are carefully combined (Cooke 1993). When reliance is placed on only one technique and follow-up control is not implemented, the initial gains made in controlling rabbits are soon lost; as rabbits will readily recolonise an area in the absence of any further control (Parer & Milkovits 1994, Williams & Moore 1995). Integrated rabbit control in Australia normally involves a significant reduction of the population, followed by harbour destruction and subsequent follow-up control. The initial population reduction may be brought about by an effective outbreak of myxomatosis or RCD, poisoning, or even a drought. Techniques such as harbour destruction, poisoning, warren ripping, and fumigation may be effective in keeping rabbit populations low (Williams *et al.* 1995).

Cooke (1993) demonstrated the value in following up an effective myxomatosis epidemic with ripping in South Australia. A property where warrens were ripped following a large decline in rabbit numbers remained almost rabbit free many years later, but a nearby property that was not ripped, experienced high rabbit numbers again soon after, even though myxomatosis re-occurred at both sites in the following year. Similar results were obtained from a study in central Australia that assessed the impacts of ripping warrens on rabbit persistence (Dobbie 1998).

Williams *et al.* (1995) proposed the following hypothetical integrated control scenario based on biocontrol and current techniques. If an effective immunosterilising virus can be produced and approved for release, and if permission is given to release RCD, simultaneous and intensive release of both viruses over very large areas would seem to be an effective strategy for the following reasons: often high proportions of adult rabbits have antibodies to myxoma virus; RCD could kill them within a few days; the immunosterilising myxoma virus then could kill or sterilise young rabbits. An intensive maintenance warren ripping program could take maximum advantage of epizootics of myxomatosis, RCD or both. A follow-up warren ripping program, or a tactical poisoning program for areas of dense rabbit-infested scrub, is an essential component of such a strategy of integrated biological control.

Bulloo Downs warren ripping

In his report on making the most of RCD, Cooke (2003) provided an economic example of rabbit control utilising warren ripping after a RCD epizootic. His account of the Bulloo Station control results was based on data provided by David Berman (2001) from the Queensland Department of Natural resources and Mines. It highlights how integrated strategic management can be the most effective form of control in the long-term. An extract of the report states:

"Many landholders in the rangelands do not rip their warrens because they either can't afford the up-front costs or believe ripping to be uneconomic. However, at Bulloo Downs in south-west Queensland, they are showing that the cost:benefit of warren ripping can be greatly improved by focussing on key rabbit refuge areas rather than treating the whole property. Over 30,000 warrens were ripped in an area of about 95 square kilometres over 18 months at a cost of $1,462 per square kilometre. The aim is to knock out the rabbits' drought refuge warrens by ripping all areas within one kilometre of permanent water. If all drought refuge areas can be ripped, rabbit numbers may be pushed low enough that they will not recover well after drought, with dingoes, myxomatosis and RHD potentially keeping numbers low. If this proves to be the case, $240,000 in ripping costs will have removed the impact of rabbits from 2,500 square kilometres with an estimated cattle production benefit of over $500,000 per year. In marked contrast, the cost of ripping all warrens on Bulloo Downs would be over $6 million! There also seem to be clear environmental benefits from ripping rather than just relying on myxomatosis and RHD. An experimental warren ripping trial showed that native animals were still reduced by the presence of rabbits, even though myxomatosis and RHD were active. Ripping stopped the impact of rabbits almost immediately, with the numbers of some small native mammals doubling within two months."

Strategies

Resources will never be sufficient to deal with all rabbit management problems so strategic allocation of resources to give the best outcome for threatened species conservation must occur. Localised rabbit control in specific areas of high conservation concern, particularly around populations of threatened species, should be of high priority. Buffer zones may be a necessary component of managing small areas, to reduce the threat from continual reinvasion from surrounding areas. Local eradication is an option only in areas where the chances of reinvasion are minimal; all animals are accessible and at risk during the control operations and animals can killed at a rate higher than their ability to replace losses through breeding. Maintaining an area free from rabbits will require a sustained control operation to prevent reinvasion from surrounding rabbit infested areas, or the use of rabbit exclusion fences. Local eradication in the Rangelands is really only applicable to small isolated populations or small sites surrounded by rabbit exclusion fences.

Where local eradication of rabbits is not feasible, sustained management, where control is implemented on a continuing regular basis, and intermittent management, which seeks to apply control at critical periods of the year when damage is greatest and short-term control will reduce impacts to acceptable levels. Intermittent control may be useful as a temporary seasonal measure at sites where competition is a seasonal threat (for example with annual plants) or where the threat is most pronounced during adverse seasonal conditions such as drought.

Treating rabbit populations when density is low greatly improves effectiveness, economy and humaneness of control. Controlling rabbits in drought refuge areas should be given high priority. Between droughts, high priority may be given to protecting vulnerable plant associations such as regenerating trees, crops, or endangered plant species or native wildlife habitat. The relative contributions to population resurgence of rabbits in survival–refuge areas and of individuals dispersed widely at very low density are not known. If survival areas contribute most to rabbit population resurgence, where practicable, warrens in these areas should be treated first, although all warrens need to be treated eventually to prevent future recolonisation.

Current management

NSW – In NSW the greatest investment in rabbit control is warren ripping (24%) and poison baiting with 1080 (19%). Other commonly utilised control methods include poison baiting with pindone (10%), warren fumigation (8%), ground shooting (5%) and habitat modification such a clearing ground harbour (5%). To increase the natural effectiveness biocontrols, efforts are also made to enhance both the calicivirus (12%) and the myxoma virus (5%).NSW Agriculture has been testing carrot and oat baits as a way to introduce the virus into a rabbit population quickly and cheaply. In conservation areas, follow-up control after epizootics using extensive warren destruction and fumigation, as well as 1080 baiting are used.

NT - There are currently no co-ordinated and integrated management efforts for rabbits it the NT. The effectiveness of RCD has been very high and landholders do not feel the need for other control measures. Warren ripping could significantly enhance the effectiveness of RCD by further lowering rabbit numbers.

QLD - Rabbits are controlled using a wide range of techniques. Rabbit populations are being suppressed by about 70% by RHD in the southern part of Queensland. RHD, myxomatosis, drought and warren ripping have combined to push rabbit numbers to very low levels in south-west of the state. Ripping of warrens and the destruction of harbour (especially blackberry bushes) are the most common techniques. These are augmented with occasional introductions of RCD and myomatosis into new populations, shooting, fumigation, and the maintenance of a rabbit-proof fence in the south of the state.

SA – RHDV and myxomatosis still control a large number of rabbits each year. This is supplemented by ripping of warrens and the laying of 1080 baits.

WA - RHDV has been particularly effective in the arid and semi-arid rangelands where epizootics have occurred frequently. Along with myxomatosis and conventional control techniques, such as warren ripping and 1080 baiting (including one-shot oats), RHDV has been effective in helping to lower rabbit numbers throughout much of the rangelands. Surface dwelling rabbits, which are prevalent in some areas, have been controlled with harbour destruction and 1080 poison baiting.

Management of feral rabbits in the Rangelands

Rabbits can be present at very low numbers and still have significant environmental impacts.The lack of understanding on the relationship between rabbit density and damage, is still a major hindrance to effection control for conservation purposes. Until densities resulting in acceptable damage are identified, management will aim for the lowest rabbit densities that control can realistically provide. In the arid and semi-arid Rangelands, broadscale mechanical and chemical control of rabbits presents many challenges. Properties are vast, human resources are few and productivity returns are low. Broadscale ripping programs are the recommended follow-up method for disease outbreak control where rabbits live in warrens. Ripping is generally the most cost effective non-biocontrol method of rabbit control and also the most long lasting because it destroys the harbour. In areas which are difficult to rip or where rabbits do not live in warrens, fumigation and or strategic poisoning are recommended. In these areas effective biocontrol offers the most cost-effective control technique, especially when followed up with mechanical and chemical control techniques. Opportunities presented by environmental conditions, such as drought, should be capitalised upon, to further increase the effectiveness of control and minimise the cost. Efforts should be targeted towards periods when rabbit numbers are lowest so as to minimise control costs and maximise benefits.

Summary of the effectiveness of rabbit control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Poisoning with 1080	Moderate	Moderate	Low	Low	Moderate	Effective for quick population reduction Easy implementation Inexpensive	Non-target poisoning Development of bait shyness Short-term effect
Poisoning with pindone	Moderate	Moderate	Low	Low	Moderate	Effective for quick population reduction Antidote available so is suitable for use near urban areas	Non-target poisoning Development of bait shyness Expensive Should only be used in areas where it is impractical or unsuitable to use 1080 eg. urban/residential and semi-rural areas.
Fencing	Moderate	High	High	Low	Moderate	Useful for small conservation areas	Expensive establishment and maintenance costs Not suitable for broad-scale use May still be penetrated
Trapping	Low	Low	Low	Low	Low	Easy to apply in small areas	Occasionally used in areas with small isolated rabbit populations but are inefficient for general control.
Explosives	High	High	Moderate	High	Moderate	Provides long term management of rabbit populations. Effective in inaccessible and rocky where ripping cannot be done	Requires trained and licensed operators and adherence to strict OH&S requirements. Expensive compared to ripping
Warren ripping	High	High	Moderate	Moderate	High	Kills animals and destroys warrens preventing recolonisation and reproduction Long-lasting Relatively inexpensive Most effective control technique	Make kill native animals using warren Not suitable for all terrains or where rabbits are surface dwellers

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Warren fumigation	High	Moderate	Moderate	Moderate	Moderate	Kills both adult and young rabbits	Labour intensive. Warren is not destroyed therefore it can be easily recolonised. Unsuitable for large areas. May be inhumane
Surface habitat destruction or removal	Moderate	High	Low	Moderate	Moderate	Retards recolonisation Can be labour intensive in difficult to access areas	May impact upon native species
Hunting and Harvesting	Low	Low	High	Low	Low	Useful only in isolated populations Low control costs	Little impact on population size
Ground shooting	Low	Low	High	Low	Low	Only suitable for small scale operations at very low rabbit densities.	Time consuming and labour intensive Not suitable in certain situations e.g. where dense cover is available, inaccessible or rough terrain, near human habitation Little impact on overall population size
Fertility control	Unknown	Unknown	Probably low	Unknown	Unknown	Potential for low ongoing control costs Cost-effective broad-scale application	No products currently registered
Biological control	High	High	High	Low	High	Controls rabbit numbers for low on-going cost Self-disseminating Most successful long-term technique Target specific	Immunity gradually develops reducing effectiveness Risk of escape overseas Effectiveness varies with climate

5.11 Management of wild horses and donkeys

The eradication of wild horses and donkeys using current techniques is not feasible. Instead, the aim of management is to reduce the damage these species cause to an acceptable level. The common practice is to muster and harvest around key points such as feeding areas and water points. Harvested animals can then be sold. Where feral horses cannot be caught (or where no viable market exists), shooting is the only available control alternative. Population reductions in arid Australia are usually obtained through helicopter-based shooting using highly skilled, trained shooters, particularly in inaccessible areas. On a smaller scale, ground shooting can have a role. No single method is likely to control feral horse and donkey damage. Combinations of methods are required for effective management of the impacts of these species.

Commercial harvesting and pet food production

Captured feral horses and donkeys may be sold for domestification or slaughter, or humanely destroyed at the point of capture. Transportation of captured animals over distances is usually necessary and may limit the usefulness of live harvesting from more remote locations. Some captured feral horses can be sold as riding horses; however there is little demand for domestification (Dobbie *et al.* 1993). Most captured horses and donkeys are killed and their carcasses used for meat products such as pet food. The economics of harvesting equines for pet meat can be tenuous due to the rugged country with limited access to freezer facilities and processing plants, and high transportation costs (McCoot *et al.* 1981).

Trapping

Feral equines can be caught in trapping yards at water points or by using feed or mares as an enticement McCoot *et al.* 1981, Dobbie *et al.* 1993). Portable yards with one-way gates erected around watering points are probably the most effective technique. However, trapping at water sources can have variable results, and cannot be used in some areas because there are too many watering places. Trapping costs are generally low, involving only the erection and maintenance of the yards, and the sale of several animals may be enough to cover the labour costs if existing yards are utilised.

Mustering

Feral horses can be mustered by helicopter, motorbike or horseback. The effectiveness of mustering campaigns can be improved substantially by using helicopters or light aircraft to spot horses and through the use of coacher horses. Donkeys can be difficult to muster because of their habit of breaking away when driven. Helicopters are ideal for mustering because they can cover large expanse of rough terrain and are highly manoeuvrable. Once the feral animals are brought out of the rough terrain onto flatter, more open ground, riders on horse and motorbike can be used to then direct the mobs into the yards.

Pet-meat shooting

Field slaughter of feral horses and donkeys for pet meat currently occurs in Western Australia and the Northern Territory. Pet meat shooters typically work on private land with the encouragement of the landholders and set up portable chillers and processing plants. The animals are then hunted and shot, along with other large animals such as camels, goats and buffaloes. The animals are either boned on the spot or are quartered and taken to the processing plant for boning. The meat is placed in the chillers until the operation is complete, before being transported to processing plants for packing and sale (Dobbie *et al.* 1993)

Fencing

Standard cattle fencing can be used to exclude feral horses and donkeys from high value conservation areas. This style of fencing has the advantage that most native fauna can readily pass through, and only larger herbivores such as stock, horses or donkeys are denied access. Natural waterholes can be fenced off using lightweight solar-powered electric fencing to either assist with trapping, or to prevent degradation from hoofed feet.

Ground shooting

Ground shooting can be effective on islands or in areas where horses are forced to visit water points. However it is labour intensive and impractical in rugged habitats where large-scale control is required. Ground shooting is not recommended where mobs larger than two horses are concerned because of animal welfare considerations. Shooting from the ground can be difficult because of the rough terrain. In more open land, it becomes a more viable technique. With horses, when a mob is located, the stallion is normally shot first which confuses the remaining horses (Dobbie *et al.* 1993). This slows their retreat and allows more animals to be taken. This technique is usually used opportunistically, but can cause mobs to scatter and make taking high numbers difficult. When used concertedly, the technique has the capability to lead to local eradication (Dobbie *et al.* 1993).

Aerial shooting

Aerial shooting is the only practical method for quick, large-scale and humane culling of horses and donkeys in inaccessible locations (SSCAW 1991). Shooters can get close to their targets and any wounded animals can be quickly followed up and dispatched. When equines occur in high densities the technique can also be extremely cost-effective, however at low densities, the cost may become prohibitive. Shooting from helicopters has made a valuable contribution to the control programs for feral donkeys in the Kimberley. Between 1980 and 1988 the population in the East Kimberley has been reduced by 87 per cent using this method (Dobbie *et al.* 1993). In 2002, the New South Wales Government banned aerial shooting of feral horses in National parks on the basis of public opinions. Ground based culling and mustering is now used for control instead.

Judas donkey

The 'Judas' technique utilises radio tracking equipment and donkeys to locate other feral donkeys for eradication. A Judas animal is fitted with a collar to which a radio transmitter is attached and is then released in the area where feral donkeys are to be controlled. The Judas animal soon joins a feral group, which is then located by radio tracking. The uncollared animals are then destroyed. This technique was first employed on a trial basis in the Kimberley in 1994 and since 1995 it has become the primary means of control. Since this time over 25,000 feral donkeys have been culled in 'Judas' operations, over an area of 150 000 km^2 mostly below the Leopold Ranges. More than 270 radio collars have now been fitted across the southern Kimberley. The technique can allow for cost-effective location of small mobs or donkeys occurring at low-densities, which are then usually culled by aerial shooting.

Recreational hunting

Recreational hunting can be used to help control feral mobs on private land. Many hunting lodges and safari operators bring clients out to remote areas to hunt horses and donkeys. For example, 'Hunt Australia Safaris' runs feral animal culls on a large remote property south of Darwin (http://www.huntaust.com.au/home.html). Their description of a cull is as follows:

> "We shoot every feral animal we see right from the Toyota, or within a short walk. It makes very productive hunting with two shooters in one Toyota. We also hunt surrounding properties at the same time. In this combined area there are 50,000 feral donkeys, horses, camels, dingoes, etc. Although we have taken just over 13,000 donkeys from this property so far, it is not making too much of an impression. We still need to reduce the remaining numbers dramatically. There is no bag limit, except on camels where a trophy fee applies. We like to hunt two hunters to each guide and Toyota as when we come across a big mob of donkeys (20 or 30, or up to 60 in a bunch) one shooter simply cannot shoot them all. We let none get away. We always shoot every donkey we see so that there are no escapees."

As the excerpt above attests, the small off-take of recreational hunting rarely has an impact on feral donkey or horse population numbers.

Victoria River District feral donkey control program

In 2002-2003, to provide environmental benefits the Indigenous Land Corporation and the NT Government conducted a feral horse and donkey eradication program in the Victoria River District (VRD). Surveys in 1996 and 2001 by the then NT Department for Lands, Planning and Environment indicated that feral donkeys and horses were in plague proportions across most properties in the VRD. Among the environmental problems feral horses and donkeys caused were:

- Gully erosion caused and exacerbated by their hard hooves.
- Competition with native animals for food increases and habitat is destroyed.
- Waterholes are fouled and weeds are introduced to an area through seeds carried in their dung or manes and tails.
- The large areas of vegetation needed to sustain both native wildlife and commercial herds of livestock are adversely affected.

Thirty-nine properties in the VRD region undertook feral horse and donkey control. Negotiations with the landholders from most of these properties indicated support for reducing the feral population across the whole region. The NT Government reported at the end of 2002 that control works had resulted in the removal of 103,999 feral horses and donkeys. The results of control are an improvement in biodiversity, ecological integrity and land capability, which also improves prospects for sustainable land-based enterprises. A major emphasis of the project was on increasing awareness and capacity to prevent a recurrence of the plague. The VRD Conservation Association managed a significant grant from the Natural Heritage Trust to assist in reducing feral population size.

Fertility control

Fertility control has also been suggested but has limited application for widespread populations because of the difficulty in delivering the fertility agent, which usually has to be administered on a regular basis to ensure ongoing control of the population.

Current management

NT - In the southern regions of the NT horses and donkeys have been effectively managed for the last 15 years. Although some mustering does occur, horse and donkey populations are usually maintained at low numbers through aerial culling in National Parks and some privately managed lands. In the northern regions, feral horse and donkey control only occurs in the Victoria River District. Large numbers have been aerially culled in recent years, however the population appears to still be increasing, although at a significantly lower rate.

WA - Little integrated feral horse management occurs. They are only abundant in the Kimberley, but their numbers appear to be restricted by the widespread occurrence of toxic plants (Dobbie *et al.* 1993). Low numbers of feral horses are opportunistically shot or captured for use as stock horses by local station managers. Donkeys are more of a problem and a more strategic management approach is taken. Trapping at water sources, a limited pet meat industry and aerial shooting are all used to control the donkey populations in WA. A concerted effort made in the Kimberly region using aerial shooting, reduced the donkey population in the East Kimberlys by 87% between 1980 and 1988. Judas donkeys have also been successfully used and it has been estimated that 25 000 were aerially culled between 1995 and 2000 using this technique.

QLD – Ground shooting is the most commonly used control technique and has been reported to be successful on a number of smaller leases in northern Queensland (Dobbie *et al.* 1993). A small number of horses are mustered and used for the pet meat industry.

SA – Little feral horse management occurs in SA. In the north ground shooting is the main form of control used, and limited mustering for sale occurs. During the BTEC operations in the 1980s shooting from helicopters was used to cull large numbers of horses.

NSW – Limited control for feral horses occurs. In national parks and nature reserves, limited success has been had with mustering and trapping. Aerial culling was the alternative method, but this has recently been stopped due to public outcry by animal liberationists.

Management of feral horses and donkeys in the Rangelands

The most cost effective operations with the least financial risk, such as trapping on the flats, should be conducted first so that they can provide funds for more risky or expensive operations such as helicopter mustering or aerial shooting. Aerial shooting is the most effective control method in many areas due to the inaccessible terrain.

Summary of the effectiveness of feral horse and donkey control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Fencing	High	Low	Unknown	Low	Moderate	Allows excellent protection of small areas of land	Requires continuing maintenance and cannot be applied across large remote areas
Mustering	High	Moderate	High	Moderate	Moderate to high	Efficient and cost-effective where horses are present in high densities, terrain is relatively flat and horse prices are high.	Welfare concerns associated with capture and transport or horses. More costly than trapping due to high labour cost
Trapping	Moderate to high	Low	High	Moderate	Moderate to high	Most effective when conditions are dry and there are few waterholes around where horses can drink. Cost-efficient method of capture	Difficult to apply in remote areas Transport may be costly or stress animals
Aerial shooting	High	High	High	High	High	Suitable for extensive areas and inaccessible country. Most effective way of achieving quick, large scale culling.	Can be expensive at low feral horse densities
Ground shooting	Low	Unknown	High	Low	Low	Most useful during drought and where horses cannot be captured by trapping or mustering.	Labour intensive, only suitable for smaller scale operations. Impractical in good seasons when there is lots of water around and in rugged country where large scale control is required.
Judas donkey	High	Low	High	Low	Moderate	Allows targeted control of small residual populations of camels and the location of remote herds	Expensive and requires a high level of proficiency. Not applicable at high populations densities.
Recreational hunting	Low	Unknown	High	Low	Low	Target specific control Income from recreational hunters	Difficult in remote areas Confined to easily accessible locations Low removal rate
Biological control	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown, but possibly low cost implementation through self-dissemination.	Impact on commercial camel industry especially export market Yet to be developed

5.12 Management of wild dogs

The management of wild dogs for biodiversity conservation will only be briefly discussed here as the majority of control is undertaken by agriculturalists to protect their livestock. A variety of control techniques are available to manage the impact of wild dogs. These include the famous 'dog fences' which aim to physically exclude dogs from the livestock grazing areas, the laying of poison baits, as well as specific techniques such as trapping and shooting to remove individual animals.

In the past, management of wild dogs relied heavily on labour-intensive techniques, such as trapping, shooting, and ground baiting, with bounty payments being offered as an incentive to kill dogs. Much of the control work was reactive, dealing with problems as they arose. Nevertheless, some strategic, preventative control was carried out including the construction of district-wide exclusion fences.

Current management strategies focus on the objective of minimising the impact of wild dog predation, not just on killing wild dogs. Aerial baiting with 1080 baits forms a major part of most management programs and is primarily targeted at limited zones adjacent to livestock grazing areas. Large coordinated campaigns have generally been adopted, being more efficient and effective than small localised efforts. Bounty payments have not been successful in reducing predation by wild dogs and are subject to abuse.

5.13 Management of carp

Until recently there has been no co-ordinated management of carp in Australia and carp control has been undertaken predominantly by State Fisheries agencies. Several national bodies (including the National Carp Taskforce and Carp Control Coordinating Group) have now been established and the Murray-Darling Basin Commission champions carp control through its Native Fish Strategy. Carp are a declared noxious fish in New South Wales, South Australia, and Queensland with supporting regulations for possession, transport or release. Management has been minimal in most cases, except for some new invasions where eradication has been attempted.

Carp management has become an increasingly important issue in New South Wales as knowledge and understanding of carp impacts slowly improve and public pressure is applied. In 1998, a three year, $1 million Carp Assessment and Reduction Program was implemented. This program aimed to develop the recreational and commercial fisheries, research carp impacts and biology, and educate the general community about carp issues. In the program, incentives were paid to commercial carp fishers for their catch to offset costs associated with establishing the fishery. In 1998, a state-wide carp fish-off was organised to increase recreational take of the species. This project succeeded in removing 34 tonnes of carp across the state. Such projects as mentioned above will not control carp numbers in the long-term, however they have helped develop a positive community attitude towards carp control and can be utilised in an integrated control approach.

In South Australia, between 30 and 120 small populations of carp have been successfully eradicated, but these mostly have occurred outside the Rangelands (Hall 1988). A high priority has been given to the eradication of carp when they are detected in new areas, such as the Cooper Basin in the north of the State. Wetland management frequently includes measures to control carp and is often undertaken by non-government agencies such as community groups.

General control techniques

Carp are presently controlled mainly with chemical agents, commercial harvesting, recreational fishing, electro fishing, nets and traps and exclusion devices. Whilst theses options may reduce carp numbers, and may even eradicate them from isolated areas, other options are needed and being explored for more widespread control.

Environmental rehabilitation

Environmental rehabilitation is being seen as one way of improving habitat quality to favour native fish. By potentially increasing native fish numbers, particularly large predators, predation pressure on carp will be increased.

Biocontrol

The use of viral agents for biocontrol has also been considered, however a suitable, species-specific lethal virus has yet to be identified for carp. If such a virus were found, it would have to undergo intense scrutiny and overcome potential public outcry before being released. Biocontrol has one major advantage in that it can be the most cost-effective management technique if successful. A self-disseminating biocontrol agent can require only minimal ongoing investment once successfully established in the carp population. A classic example of this is the myxoma virus in rabbits, discussed elsewhere in this report. One potential virus that has recently been discovered is the Koi Herpes Virus. This virus has decimated both wild and cultured stock of carp in areas ranging from the middle-east to Europe. The new Invasive Animals CRC plans to conduct trials into the suitability of this virus as a biocontrol agent.

Genetic manipulation

Another potential approach to carp control is the use of genetic manipulation. Genetic technology offers potential opportunities to succeed where traditional approaches have failed. One potential genetic technique is the ‘daughterless technology’. Daughterless technology works by altering population sex ratio towards males whilst maintaining the fitness of individuals. The technology is hereditary and passed on to the male only offspring, thus disseminating through the carp population. As the trait spreads through the population, fewer breeding females exist and population recruitment declines. The population then steadily declines before eventually crashing. The research is currently being undertaken by the Pest Animal Control Cooperative Research Centre in conjunction with CSIRO and is funded by the Murray-Darling Basin Commission as part of their 50 year Native Fish Strategy. Long-term support for this type of project is essential as it may take 30-50 years or more for the technique to work, once a viable genetic construct is released into the environment.

Community fish-outs

Carp have only relatively recently expanded their range significantly into Queensland. Since carp are now widespread, particularly through the Murray-Darling Basin, eradication is not currently being attempted. Recreational carp fishing competitions are becoming more popular in Queensland and can provide targeted carp extraction as well as educate the community about carp.

Current management

NSW – Current management efforts in NSW are targeted towards the collection of life history traits and movement patterns to enable more effective management. Traps have been designed and implemented in fishways around Locks and Weirs in the Murray River and many recreational fishing competitions now have a category for carp.

QLD – Little control is undertaken in Queensland. The waters of the Darling River are surveyed annually to determine fish assemblage structures, but little investment goes into carp control. Outside of the Rangelands, community-based fishing competitions targeting carp are held, however the long-term effectiveness of these events is still unclear.

SA – Much of the carp control effort is focused on the restoration of semi-isolated lakes along the Murray River. Lakes are either drained, electrofished or poisoned to remove the carp and then screens are set up on the inlets to the lakes to prevent reinvasion. Commercial fishing of carp also occurs.

Management of carp in the Rangelands

Much of the debate about carp management centres on population control rather than impact reduction. This focus may hinder setting priorities for carp management, directing resources away more susceptible and inherently valuable areas (e.g. areas with threatened species or pristine areas recently invaded) where the return may be greater. Focus on impact reduction will prove to be more effective and economical in the long-term. Current control methods are expensive and only effective over smaller areas. The most likely solutions to reducing carp impacts on biodiversity are viral biocontrol or the ‘daughterless technology’.

Summary of the effectiveness of carp control methods

Method of control	Efficacy	Control method efficiency	Target specificity	Logistical practicalities	Overall effectiveness	Advantages of method	Disadvantages of method
Netting and trapping	High	Low	Low to moderate	Low	Moderate	Cost effective at high densities	Locating fish can be difficult Non-target issues Does not remove all carp
Environmental manipulation	Unknown	Unknown	High	High	Unknown	May reduce carp whilst improving river ecosystems and native fish assemblages	Very expensive and labour intensive Effectiveness unknown
Electrofishing	Moderate to high	Low	High	High	Moderate	Effective for catching larger specimens Target specific	Difficult to apply in remote areas Does not get all carp present Expensive Suitable only for smaller waterways
Exclusion screens	High	High	Low	High	Low	Useful for preventing reinvasion	Only suitable to semi-enclosed waterways and lakes All carp need to be removed first Can clog with debris May be circumvented during flooding.
Poisoning	Moderate	Moderate	Low	High	Low	Most useful for small isolated waters	Lack of target specificity Cannot be effectively applied in flowing waters
Commercial fishing	High	Low	Moderate	Moderate	Moderate	Allows targeted control of small residual populations	Only viable at high populations densities. Low market value of catch
Recreational fishing	Low	Unknown	High	Low	Unknown	Target specific control	Difficult in remote areas Confined to easily accessible locations Low removal rate
Biological control	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown, but possibly low cost implementation through self-dissemination.	Public acceptance Clean-up of dead fish Market status

Section 6 Stakeholder survey

General survey results

A total of 42 people responded to our stakeholder survey on feral animal management in the Australian Rangelands. We had responses from private land managers, community groups, land protection boards, aboriginal land managers, state agencies, Rangeland consultancy firms, and catchment management authorities (Table 13). Respondents were evenly spread around the Australian Rangelands although the response from Queensland was low (Table 14).

Table 13 Capacity of survey respondents

Group	% of respondents
Private land managers	33%
Community group	21%
Land protection boards	12%
Aboriginal land managers	12%
State agencies	10%
Rangeland consultants	7%
Catchment management authorities	5%

Table 14 Distribution of respondents

State or Territory	% of respondents
Western Australia	31%
South Australia	26%
Northern Territory	24%
New South Wales	14%
Queensland	5%

In general, the survey responses varied with the respondents backgrounds and capacity more than with their geographical location. In particular, private land managers and consultants were typically dissatisfied with government efforts in feral animal management in arid regions and their management efforts were under-appreciated and under-valued.

The feral animals most commonly reported to have a detrimental impact on Rangeland biodiversity were cats, house mice, wild dogs, rabbits, foxes, goats and horses (Figure 2). Cats were also reported the most frequently to have a high detrimental environmental impact, followed by wild dogs, foxes, goats, rabbits and donkeys.

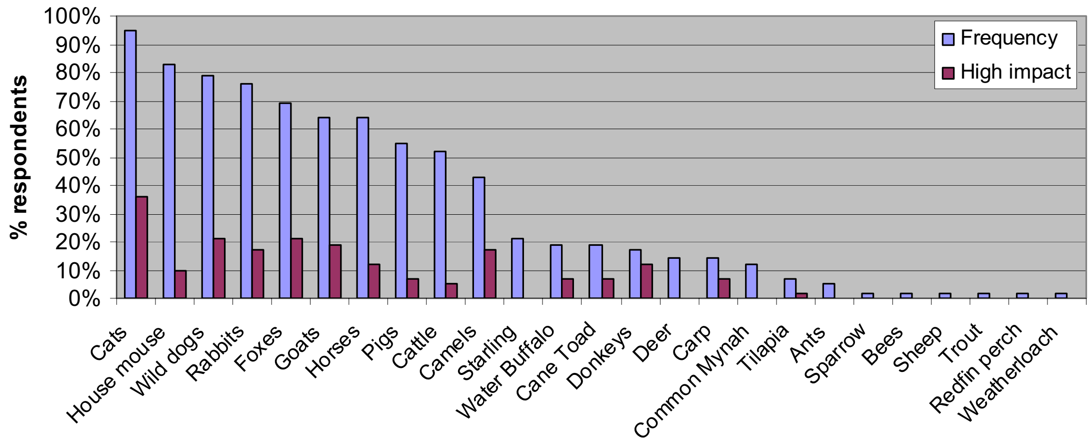

Figure 2 Frequency of feral animals reported as a having a negative biodiversity impact and reported to have a high impact.

The type of impact each species have is summarised in the Table 15. The values given indicate the percentage of survey respondents who recorded that type of impact in their region. More details can be seen under each species description.

Table 15 Impacts of feral animals in Australian Rangelands

	Predation	Habitat destruction	Resource competition	Displacement	Disease spread
Feral pig	33%	52%	43%	29%	36%
Wild dog	76%	5%	19%	29%	17%
Feral cat	81%	7%	26%	52%	19%
Foxes	69%	7%	21%	31%	26%
Rabbit	7%	64%	60%	31%	14%
House mouse	5%	17%	31%	33%	33%
Feral camel	0%	38%	35%	17%	2%
Feral goat	5%	60%	50%	36%	12%
Feral horse	0%	52%	43%	31%	0%
Feral cattle	0%	38%	40%	24%	10%
Water buffalo	0%	17%	17%	12%	5%
Deer	0%	10%	5%	0%	5%
Cane toad	0%	0%	17%	14%	2%
Common starling	0%	5%	14%	14%	2%
Indian Mynah	0%	0%	5%	7%	0%
Carp	7%	14%	14%	14%	5%
Tilapia	**5%**	2%	2%	2%	2%

Many of the individual respondents did not know or did not include information on the threatened flora and fauna in their region. State agencies or NRM specialists typically included the numbers of threatened species in the region and either provided a list of species threatened by feral animals in the area, or a link to a reference covering the issue. Species that were reported as threatened by feral animals included:

Plants

Thryptomene wittweri	*Conospermum toddii*	*Eriocaulon carsonii*
Marieana rhorlachii	*Acacia carnei*	*Acacia rhigiopylla*
Codonocarpus pyramidalis	*Hemichroa mesembryanthea*	*Acacia spilleriana*
Acacia wattsiana		

Animals

Bilby	Brush tailed phascogale	Thick billed grass-wren
Marsupial mole	Carpentarian antechinus	Painted snipe
Northern hopping mouse	Mulgara	Plains wanderer
Golden backed tree rat	Carpet python.	Night parrot
Sandhill dunnart	Woma python	Australian bustard
Kowari	Pigmy blue-tongue	Crested shrike-tit
Brush-tailed rabbit-rat	Great Desert skink,	Red goshawk
Spectacled hare-wallaby	Bronzeback snake-lizard	Striated grass-wren
Golden bandicoot	Leichhardt's grasshopper	Black-eared miner
Northern quoll	Malleefowl	Chestnut quail-thrush
Chuditch	Yellow chat	Emu
Black-footed rock wallaby	Carpentarian grass-wren	

The common denominator in answers regarding the impact of feral animals on regional biodiversity hotspots was that water courses sustain the greatest impact. Nearly all those who responded to the question commented on damage to waterholes or the associated riparian vegetation, particularly by feral pigs, feral camels and other large herbivores.

Most of the land managers and regional community groups indicated that they were aware of the main legislation governing feral animal management (e.g. EPBC Act), however most did not list and were presumably unawares of the other associated legislation (e.g. Wild dog Act in Queensland). Many respondents were happy with the present legislation but want to see it more stringently enforced. It was suggested that the political will was not there because stricter enforcement would require greater investment. Several private land managers were quite scathing of current legislative requirements for feral animal management on crown lands. They believed that regulations should be implemented to enforce higher levels of control on these lands by government departments. The issue of inconsistent status for pest species was also raised. For example, in Western Australia, goats are classified as a declared pest and domestic species at the same time, hindering their control. Whilst some are trying to rid them from their property, others are encouraging their numbers to increase or bringing them into the region for stock, sometimes without the infrastructure to prevent their escape (S. Clarke CALM, pers. comm.)

The most commonly used management techniques were baiting and poisoning, commercial harvesting and mustering and shooting (both ground and aerial). Of the available techniques, baiting and poisoning were rated as the most successful by far, followed in a distant second, by shooting (Figure 3). Many respondents indicated they would like to see biocontrols developed for a greater range of species and more effective control techniques for large herbivores.

a)

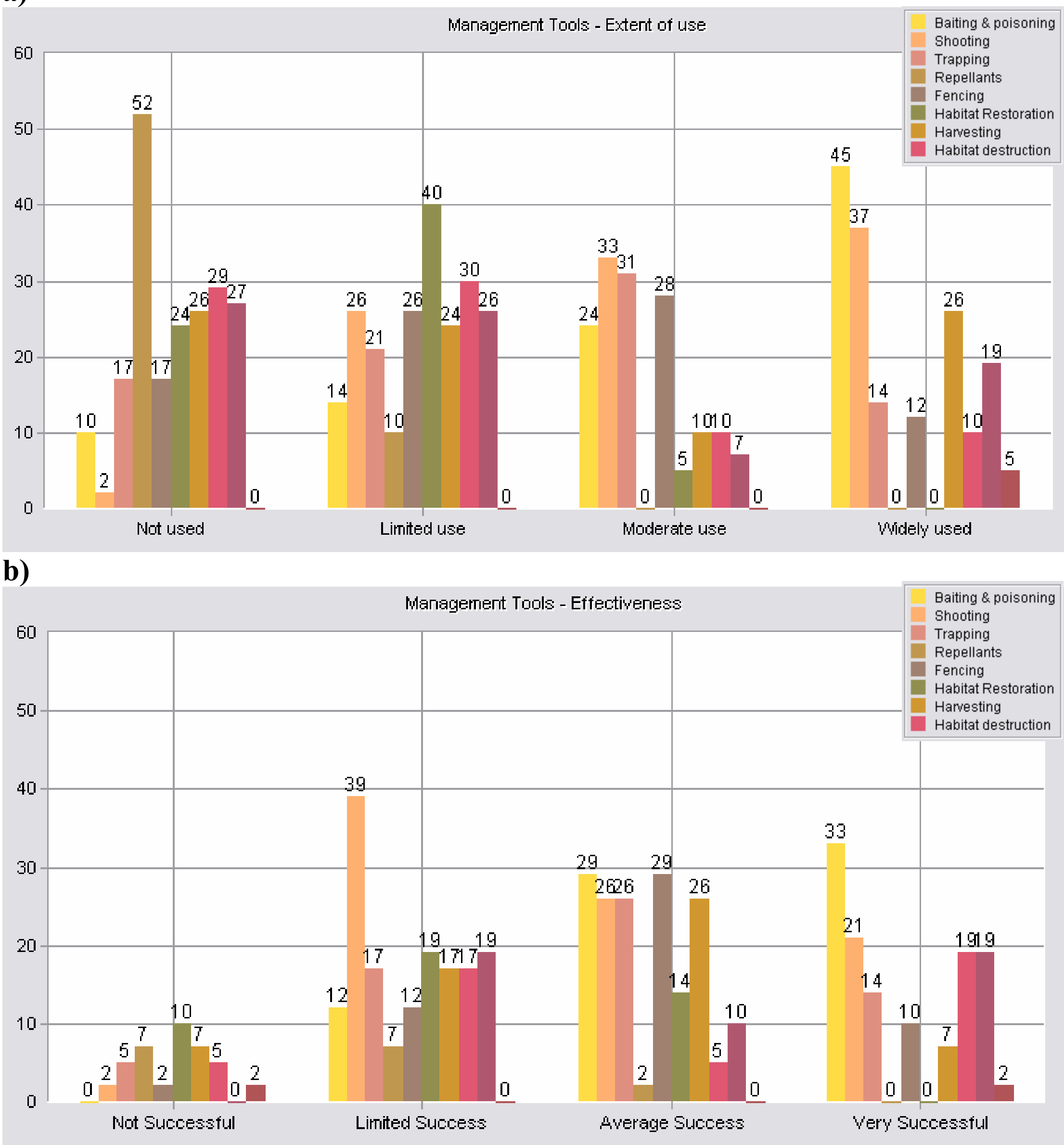

Figure 3. a) Extent of feral animal management tool usage; b) general effectiveness of feral animal management tools

The greatest barrier to effective feral animal management in the Rangelands was considered to be inadequate funding. Seventy-nine percent believed that increasing management funding levels would result in better management and reduced feral animal impacts on biodiversity. Landholder incentive was considered the second greatest impediment, followed by political support and ownership of the problem (Table 16).

Table 16 Barriers to effective management of feral animal impacts on biodiversity

	Insignificant	Somewhat significant	Significant	Very significant
Knowledge of biodiversity	10%	21%	31%	36%
Knowledge of feral animal impacts	0%	7%	45%	48%
Funding	0%	5%	17%	79%
Strategies and BPM plans	0%	14%	43%	43%
Community support	0%	10%	38%	52%
Political support	0%	12%	19%	69%
Legislation	7%	19%	10%	31%
Significance of biodiversity	7%	17%	45%	31%
Conservation reserves	14%	35%	33%	12%
Appreciation of common habitat	10%	24%	40%	17%
Management tools	0%	7%	43%	48%
Ownership of the problem	0%	2%	36%	60%
Landholder incentive	2%	5%	19%	71%

The majority of respondents indicated that they would like to see a more co-ordinated and strategic approach to feral animal management and that more effort is required in the area of legislation implementation and enforcement. One group suggested that a fund be set up to allow prompt response to new incursions to prevent establishment.

Sixty-four percent of those surveyed were involved in regionally co-ordinated feral animal management programs, although most believed that not as many land managers were involved in these programs as there should be. The number of groups involved in coordinated management action varied depending upon the species being targeted and the regions involved. In areas where the property sizes were immense, generally only a few neighbouring properties would co-ordinate a feral animal management effort. However, the vast size of the properties ensured that large amounts of land were managed in a coordinated manner. As property sizes decreased the number of land managers participating in coordinated control generally increased, with up to several hundred involved in more urban regions. Most co-ordinated control was conducted on feral animals that were negatively impacting pastoral activities. Thus, co-ordinated control for foxes, wild dogs, feral pigs, rabbits and goats were the most common. In several regions, specialty community groups have been formed to target the impacts of particular pest species.

The majority of respondents followed some form of best practice management. These were usually local district of catchment management plans, or those developed by state agencies such as RLPBs (New South Wales) or Soil Boards (South Australia). Best practice management plans were reported for a wide range of species.

Survey respondents believed that although new incursions by feral animals will occur through a variety of means, unassisted dispersal is the most likely avenue. The most unlikely of the listed incursion routes was deemed to be malicious release, such as the introduction of animals by the game hunting fraternity.

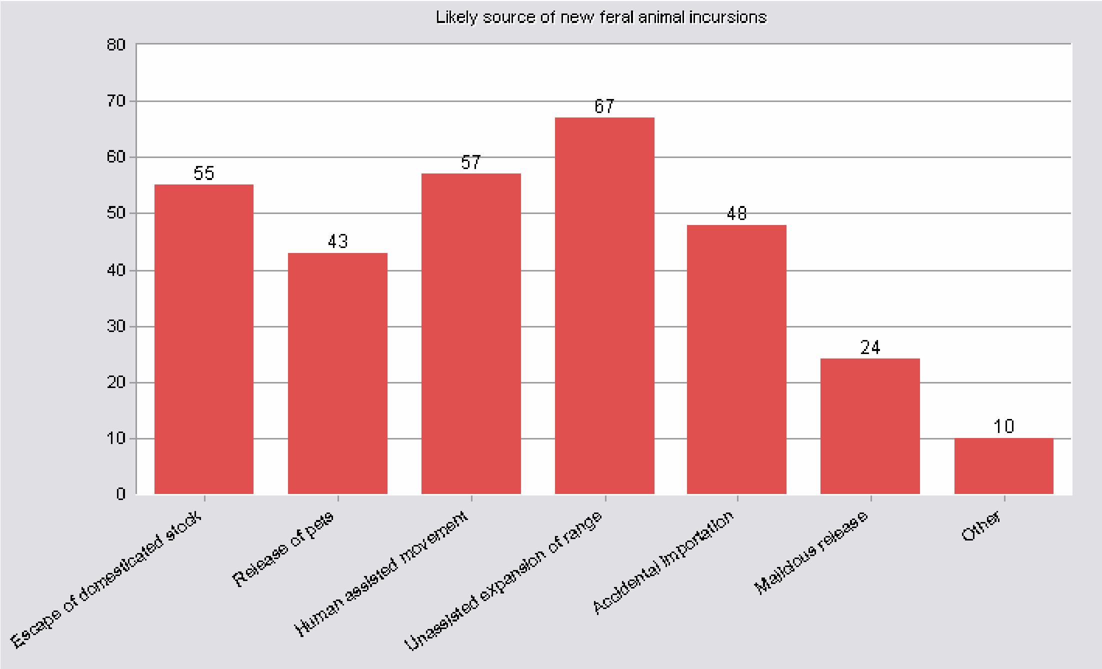

Figure 4 Response frequency for likely new feral animal incursion pathways.

One of the most frequent general comments was that currently there is too much talk and not enough action. Many respondents believed that bureaucracy and excess research were delaying on-ground actions. Several respondents complained that they are frequently asked to participate in surveys, but find these tend to result in little change or no action.

Survey results for individual species

Feral camels

Forty-two percent of respondents thought that camels were having a deleterious impact on the rangeland environment. 17% believed that the impact was high, 10% that it was moderate and another 17% that it was quite minimal. Habitat destruction and competition for resources were strongly reported as the main impacts, although several also listed the displacement of natives. Opinion was divided on the nature of camel impacts, but no-one believed that the situation was improving. More people thought that the problem was stable than those who reported it to be worsening.

Foxes

Sixty-nine percent of respondents believed that foxes were having a detrimental impact on the biodiversity in their area. The scale of the impact was evenly divided between low medium and high, with just under half the respondents reporting the severity of the impact to be stable. Encouragingly, more respondents believed that the situation was improving than those who believed it was declining. All of the respondents highlighted predation on native species as one of the major biodiversity impacts foxes have. Respondents also thought that foxes played a role in the displacement of native species (31%), spread disease (26%) and competed with natives for resources (21%).

Feral cats

Every single person who responded to the survey believed that feral cats were having detrimental impacts on the biodiversity of their area. Thirty-seven percent of people thought that the impacts were severe, 33% that they were moderate in scale, and 30% that they were only small. The level of the impact was reported to be static by 78% of people surveyed, whilst the rest (22%) indicated that the situation was worsening. Predation on native species was by far the most frequently (81%) reported impact feral cats had on biodiversity. Displacement of native species (52%) was also commonly mentioned, whilst resource competition (26%) and spreading disease (19%) were reported to a lesser degree.

Feral cattle

Slightly more than half (55%) of those surveyed believed that feral cattle were having a detrimental impact on biodiversity in their area. The majority of these people (42%) indicated that the impact was low, with on a few people indicating either moderate of high impacts. Nearly all (93%) of those in areas where feral cattle were causing problems believed the problem had not changed much in recent times. Resource competition (40%) and habitat destruction (38%) were the most frequently reported impacts, followed by the displacement of native species (24%) and spreading of disease (10%).

Feral deer

Only 14% of people reported feral deer as a problem in their area. These people all suggested that the biodiversity impacts were low, primarily habitat destruction (10%), resource competition (5%) and the spread of disease (5%), and at a relatively constant level.

Feral goats

The level of impact on biodiversity reported for feral goats varied greatly amongst respondents. Thirty-three percent reported no significant impacts, 22% only minor impacts, 25% moderate impacts and 20% high levels of environmental damage. The majority of people (59%) believed that the level of impact was steady, however 32% reported the situation as worsening and only 9% reported improvements. Habitat destruction (60%), resource competition (50%) and the displacement of native species (36%) were the most commonly reported environmental impacts.

Feral horses

Sixty-seven percent of people reported that feral horses were having detrimental impacts on biodiversity in their region. The majority of these people believed the impacts to be low (27%) or moderate (27%), with only 13% indicating high impacts. All respondents believed that biodiversity problems caused by feral horses were either at a constant level (75%) or increasing (25%). Habitat destruction was the most commonly reported impact (52%), followed by resource competition (43%) and the displacement of native species (31%).

Feral pigs

Only respondents from the margins of arid and semi-arid regions reported feral pigs to be having a negative impact on biodiversity in their area. This was consistent with the distribution of feral pigs reported in Section 3. Of those who indicated feral pigs to be a problem, only 7% indicated that the scale of the impact was high. The majority reported low (33%) to moderate (18%) levels of impact only. A significant number (36%) of people indicated that the feral pig problem was worsening in their area with most of the remainder reporting the situation static (58%). Only two land managers reported reductions in feral pig impacts on biodiversity in recent times. Feral pigs were frequently reported as having a wide range of impacts. Habitat destruction (52%) was the most common, followed by resource competition (43%), spread of disease (36%), predation (33) and the displacement of native species (29%).

Wild dogs

The majority of people survey believed that wild dogs were having an impact on biodiversity. These people were relatively evenly divided over the scale of impact the dogs were having with 23% believing the impact was high, 31% reporting the impacts be moderate and the same indicating only low impact levels. Only one respondent indicated that the situation was improving. 53% of people reported the impact level as remaining constant, whilst 44% believed the impact wild dogs were having on biodiversity were getting worse. As expected, predation of natives was the most frequently reported impact (76%), however displacement of natives (29%), resource competition (19%) and the spread of disease (17%) were also frequently reported. It should be noted that the definition for wild dogs included dingoes and crossbreeds.

House mouse

A surprisingly high number (92%) of people reported the house mouse to be having an impact on biodiversity in their area. Most believed that the scale of mouse impacts was low (58%); with only a few reporting high damage levels to the environment (10%). House mice were described as competing with native species for resources (31%), spreading disease (33%) and displacing native species (33%). Habitat destruction was only indicated by 17% of those in areas where mice had an impact. 83% of people believed that the scale of the problem was quite stable, whilst 14% reported it to be getting worse.

Indian mynah

The majority of respondents indicated that Indian mynahs were not a biodiversity issue in their area. Only 14% of respondents reported Indian mynahs as a low (8%) to medium (6%) level threat to biodiversity. The impacts reported involved resource competition with, and displacement of native species. Most believed that the scale of the problem was stable, but two respondents thought that it was becoming worse.

Common starling

No one surveyed believed that starlings were having a high impact on Rangeland biodiversity; however 21% believed they had either a low or moderate effect. The majority of people also believed that the nature of the problem was relatively stable, although a few believed the impacts had worsened. Resource competition and the displacement of native species were believed to be the greatest impacts the starlings were having on biodiversity.

Rabbits

Eighty-two percent of survey respondents reported rabbits to have a negative environmental impact in their area. Approximately half (48%) believed that these impacts were small, whilst the remainder were concerned that the impact was either moderate (15%) or high (18%). Just over half (56%) of those surveyed that had rabbit impacts thought that the nature of the problem was stable, whilst 23% believed that the situation was worsening and 21% believed it was improving. Interestingly, those who tended to believe that rabbits were having little impact or that the problem was improving, lived in the central arid zones where myxomatosis and particularly the Rabbit Calicivirus Disease have had the greatest effect. Rabbits were reported by many to primarily be having environmental impacts through habitat destruction (64%) and resource competition (61%). They were also thought to be displacing natives (31%) and to a lesser degree involved in the spread of disease (14%).

Water buffalo

Only three of the survey respondents reported water buffalo to be having a negative environmental impact in their region. This was hardly surprising considering the buffalo's restricted distribution. These people reported habitat destruction, resource competition and the displacement of native species to be the significant impacts on biodiversity. Two of the respondents believed that the nature and scale of the impact was not changing, however the third respondent reported the damage to be getting worse.

Cane toads

Nineteen percent of respondents believed that cane toads were having a medium to high impact on biodiversity in their region. These respondents were from the tropical margins of the Rangelands in Queensland and the Northern Territory. People were evenly divided as to whether cane toad impacts were staying the same or worsening. This probably reflects the location of people relative to the cane toad's distribution. Those who were in areas that have long been populated by the toads tended to respond that there was now little change to nature of the problem, whilst those who were nearer the edge of the toad distribution reported the situation as worsening. The primary impacts observed on biodiversity were predation, displacement of native species and resource competition.

Carp

Fourteen percent of respondents thought that carp were having a significant impact on biodiversity in their region. Of these, habitat destruction, displacement of natives and resource competition were listed as the most common impacts. Most people believed that the impact on biodiversity was not really changing, although a few respondents believed that the situation had either improved or worsened.

Tilapia

The majority of respondents indicated that tilapia were not a biodiversity issue in their area. Only three respondents highlighted tilapia as a threat to biodiversity. These were not surprisingly from Western Australia and Queensland. Predation was believed to be the most common impact on native species, whilst a broad range of other impacts were also suggested. The nature of the problem was indicated as being stable in most areas; however one region reported the problem as worsening.

Section 7 Key problems and opportunities for investment

This chapter identifies gaps and opportunities where further investment by the Australian Government would improve biodiversity conservation. The potential to identify gaps was limited by a lack of information about the impacts pests are having on biodiversity. The distribution of pests is well known, and general comments about their impacts can be made, but far more research is needed on the precise nature of those impacts. For example, foxes and cats are known to prey on a wide range of native animals, including various rare species, but it is often not known if the predation is substantial enough to pose a serious threat. Large assumptions are often made from small-scale studies. In a very significant study completed in 2005, foxes, pigs and dingoes were identified as posing a very serious threat to three endangered freshwater turtles in southern Queensland. But nothing is known about the impacts of these same pests on other rare freshwater turtles elsewhere in Australia, for example the endangered Gulf snapping turtle (*Elusor lavarackorum*). Funding bodies prefer to spend money on management rather than research, but without research to guide the management, funds are likely to be wasted on the wrong management actions. 'Lack of research' is a recurring complaint made by pest managers trying to save biodiversity in the Rangelands.

This chapter has two sections: one that identifies pest animals which warrant more attention in certain regions; and another that identifies social and industry issues that require more government attention'.

7.1 Emerging and growing problems

This study found that many feral species are expanding their range within the Rangelands (see Table 15). Some of the range expansions are very limited in extent (for example black rats into Kakadu, pigs into the Arafura Swamp and new catchments) and some are of little consequence to biodiversity (house gecko, flowerpot snake). Range expansions of the listed invertebrates are significant but they fall outside the scope of this study so they are no considered further. The range expansions identified as significant for this study are as follows:

- One-humped camel – Spreading widely in the arid zone
- Buffalo – spreading in east Arnhem Land and the Victoria River Basin, NT
- Feral cow – penetrating remote regions in the Kimberly, NT
- Fallow deer – new feral populations appearing in NSW & QLD
- Chital deer – new feral populations appearing in NSW & QLD
- Red deer – new feral populations appearing in NSW & QLD
- Rusa deer – new feral populations appearing in NSW & QLD
- Cane toad – spreading in the NT and soon into WA
- Tilapia – colonising new rivers in QLD
- Blue acara – newly naturalised in north QLD
- Midas cichlid – newly naturalised in north QLD
- Burton's haplochromus – newly naturalised in north QLD

Table 17 Feral animals that are expanding their range in the Rangelands.

Spreading within the Rangelands	Where	Scale of problem
Black Rat	NT (Kakadu)	Low (?)
Pig	NT (Top End)	Locally high
One-humped Camel	WA, NT	High
Swamp Buffalo	NT (Arnhem Land)	Locally high
Feral Cow	WA (Kimberley)	High
Fallow Deer	NSW, Qld	Medium
Chital Deer	NSW, Qld	High
Spotted Turtle-dove	Alice Springs	Low
Nutmeg Mannikin	Cape York Peninsula	Low (?)
Common Myna	NSW	Medium
House Gecko	QLD, NT	Low
Flowerpot Snake	QLD, NT	Low
Cane Toad	NT	High
Tilapia	QLD	High
Honeybee	NT (Top End)	Medium
Big-headed Ant	NT (Kakadu, Alice Springs)	Medium
New to the Rangelands	**Where**	**Scale of problem**
Red Deer	NSW, QLD	High
Rusa Deer	NSW, QLD	High
Barbary Dove	Alice Springs	Low
Blue Acara	QLD	Unknown
Midas Cichlid	QLD	Unknown
Burton’s Haplochromus	QLD	Unknown
Guppy	QLD	Unknown
Insufficient information	**Where**	**Scale of problem**
Blackbuck	Spreading in QLD?	Unknown

Some experts reported anecdotal evidence to suggest that foxes are spreading north (see Section 3), but the evidence for this is unconvincing, and was rejected by most experts. Occasional foxes do wander north, and have done so in the past, but there is no compelling evidence of populations spreading north.

The list of species spreading north is dominated by deer and fish. Camels and buffalo are both expanding their range and increasing in population density, and they are also considered in detail. The spread of cane toads across northern Australia is a very serious issue, but there appears to be virtually no available management techniques to prevent or mitigate their spread (see Section 5), and they are not considered here further, since they do not represent an opportunity for government investment.

Apart from those pests which are expanding in range, there are several well-entrenched species which require further attention. These are:

- Rabbits preventing Mulga regeneration in South Australia

- Goats degrading temperate woodlands
- Banteng at high densities degrading Garig Gunak Barlu National Park
- Donkeys in high densities degrading Indigenous lands in the Northern Territory
- Foxes, dingoes, pigs and cats preying on the eggs of two freshwater turtles in Queensland
- Pigs preying on turtle eggs in north Queensland
- Dingoes and dogs preying on turtle eggs in the Northern Territory.

7.1.1 Deer

Deer have suddenly emerged as a serious pest issue for Australia. Many new populations have appeared across the Rangelands as stock from deer farms are released or escape. But deer provide a unique opportunity for cost-effective action as most of the new populations can be eradicated if action is taken soon.

Deer were released at many sites in the nineteenth century, but usually they failed to survive, and those that did survive rarely prospered, usually remaining near their site of introduction (Wilson *et al.* 1992). Deer are attractive, and the convenient perception has arisen that unlike other feral animals, they do not multiply or cause harm. In his ground-breaking book about pests, *They All Ran Wild*, Eric Rolls claimed that 'Deer have done no noticeable damage in Australia' (Rolls 1969). The Bureau of Rural Resources book, *Pest Animals in Australia* (Wilson *et al.* 1992) also remains silent about deer damage to the environment.

But deer are harmful and their numbers in Australia are exploding. Recently published and authoritative books (Strahan 1995, Harrison 1998) assert that Australia has only one population of chital deer, found near Charters Towers, when in truth there are at least 28 populations spread across four states, many within the Rangelands. This information comes from Moriarty (2004), who recently surveyed government land managers. He documented 65 red deer populations in place of the four mentioned in recent books (including Strahan 1995), contradicting the claim by Wilson *et al.* (1992) that 'There is evidence that the range of … red deer has contracted due to clearing of suitable habitat and hunting.' Moriarty concluded that 'Wild deer in Australia have moved from a minor component of the Australian biota to one that is now widespread.' Moriarty underestimated the deer population, overlooking several populations recorded during a Queensland survey (Jesser 2005). Small deer herds in thick vegetation are easily overlooked (Jesser pers. comm.)

Evidence is also mounting to show that deer cause serious ecological and environmental harm. The Scientific Committee of the New South Wales National Parks and Wildlife Service supports a proposal to list feral deer damage as a key threatening process impacting upon vulnerable or endangered species, populations of ecological communities (Jesser 2005). The red deer appears on the IUCN list of 100 of the World's Worst Invasive Alien Species, largely because of the harm it does in New Zealand.

The explosion in deer numbers is largely a consequence of deer farming (Section 3), an industry that grew rapidly during the 1980s (Jesser 2005). Deer were trapped from feral populations and used as breeding stock. According to the Rural Industries Research and Development Corporation (2000), the number of farmed deer rose annually by about 25 percent up until the early 1990s. Deer periodically escape through inadequate fences (Moriarty 2004). The market for their products crashed in the early 1990s and many deer were liberated when the cost of feeding them rose above their value. The Standing Committee on Agriculture (1980) expressed the view that escapes from deer farms would be of little consequence and would not result in deer expanding their range (Jesser 2005). But according to Moriarty (2004), deer farms account for 77 of the feral herds found today.

Hunting has also contributed to the problem (see Section 7.4). Deer have been released into national parks, state forests, catchment lands and other secluded places (Moriarty 2004). Sales of live deer to stock new lands have become and important source of revenue for deer farmers (Jesser pers. comm.). For a couple of thousand dollars a farmer can establish a herd on his or her land. Changes to the firearm laws in the wake of the Port Arthur Massacre oblige gun owners to show some reason for owning a gun, a requirement met by joining the Sporting Shooters Association. New members receiving the journal learn about the joys of deer hunting, which is thought to be growing in popularity (Jesser 2005). According to Moriarty (2004), 127 of Australia's 218 feral deer populations have arisen because of hunting.

Australia is now estimated to have 200,000 feral deer and 200,000 deer in captivity (Moriarty 2004). Within the Rangelands they occur in widely scattered herds in Queensland and New South Wales, but not in Western Australia or the Northern Territory. Within the South Australian Rangelands only feral red deer and fallow deer are present, and only around Port Augusta.

As is true for most feral animals, the environmental impacts of deer in Australia have not been adequately documented. Those members of the community who know most about deer are those who like them, and they disinclined to document all the harm done. Despite the inadequate information base, enough is known to show that deer, in sufficient numbers, can be as harmful as any other hoofed animal. The only studies of their impact in Australia have been undertaken in Royal National Park, Sydney, where rusa deer have long been recognised as a destructive feral pest (Mahood 1981). There they are blamed for 'overgrazing, browsing, trampling, ring-barking, dispersal of weeds… creation of trails, concentration of nutrients, exposing soils to erosion/accelerating erosion, and the subsequent degradation of water quality in creek and river systems' (Jesser 2005, and Section 3).

Other information about deer harm is more anecdotal. Jesser (2005), in a pest review undertaken by the Queensland government, recorded that chital in the Charters Towers area are 'causing significant environmental damage, with vegetation grazed to bare ground. Pest plants such as rubber vine (*Cryptostegia grandiflora*), chinee apple (*Zizyphus mauritiana*) and parthenium (*Parthenium hysterophorus*) are also flourishing in areas where chital are not adequately controlled.' Rubber vine and parthenium are two of Australia's 20 worst weeds (officially listed as Weeds of National Significance).

When Moriarty (2004) conducted his survey, he asked about damage caused by deer:

> 'Land managers reported the following deer-related problems: browsing of native plant species and agricultural crops (81% of respondents), fence damage (61%), garden damage (43%), competition with native animals and/or stock (40%), vehicle accidents (25%), weed dispersal (17%), water-quality degradation (11%), spread of stock disease (9%), erosion (5%).'

Other anecdotal evidence of deer damage is documented in Section 3. Overseas, damage by deer is well documented. Abundant native deer are causing major conservation problems in Europe and North America, and feral deer are highly destructive in New Zealand

Economic damage caused by deer is serious and includes severe damage to grape vines and other crops and sapling trees in forestry plots. Deer also act as hosts for screw worms, brucellosis and bovine tuberculosis, and these would become significant concerns if large herds developed in northern Australia. Deer in Australia have often become troublesome enough to require culling, with culls of fallow deer dating back to the 19th century.

Moriarty (2004) did bioclimatic modelling and found that all of Australia's deer species could greatly increase their range. They can easily leap over fences designed for cattle, and when they are not properly fed they can surmount deer fences as well. Chital could occupy most of the Rangelands, and sambar and hog deer could invade a broad swathe across northern Australia. Although many of the areas likely to be invaded by deer would be of low environmental value, others could be very significant. Habitats utilised by deer include rainforest, mangroves, freshwater wetlands, open forests, woodlands and grasslands. Deer contribute to the impacts created by other feral animals and by livestock including total grazing pressure.

Many of the feral deer populations within the Rangelands should be and could be eradicated. The maps created by Moriarty from his surveys show that some deer populations are small and highly isolated from others. Rusa deer are represented by just three widely separated populations in the Rangelands, one near Townsville (containing fewer than a hundred deer), one west of Mackay, and one near Rockhampton. The nearest rusa to these occur near Brisbane. Chital in Queensland are represented by two populations in the Gulf, and by others west of Rockhampton that are far removed from the main Charters Towers population, which is largely kept in check by hunting (P. Jesser pers. comm.).

In a Queensland Government report, Jesser (2005) proposed that all deer colonies found outside their historic range in Queensland be declared class one pests, which would oblige landholders to eradicate them. If his recommendation is adopted in Queensland, more than 23 populations of deer within the Queensland Rangelands would be eradicated, and only one population would remain – the chital colony near Charters Towers, which dates back to 1886. Hunting associations support the idea of eradicating new deer colonies (P. Jesser, pers. comm.). The peak grazier organisation, Agforce, presumably supports eradication as well, because they have called upon the Queensland Government to declare deer as pest species. In 2003, Agforce Cattle president Peter Kenny described them as a major threat to beef cattle production because they hosted cattle ticks and damaged vegetation.

7.1.2 Camels

Various experts spoken to for this report nominated camels as a major emerging concern (P. Copley, K. Saalfield, P. Mason, P. Kendrick, G. Edwards, P. Latz pers. comm.). Camels were also nominated as a worsening problem by several land managers surveyed in Western Australia and the Northern Territory. Camels are reported to be increasing in numbers and expanding their range almost everywhere they occur (Section 3). Increases were reported from Western Australia, South Australia, Queensland and the Northern Territory. Some experts contend that these changes are only a response to drought or, alternatively, a run of good years (D. Rolands, M. Lapwood pers. comm.) but the reports of multiplying camels are so numerous and so consistent it must be concluded that a major increase is underway. Camels have not yet reached their potential population size in Australia, which appears to be very large, probably many times the current population. Camels are not controlled by any predator, and often they evade droughts by travelling vast distances.

The impacts of camels upon the landscape have long been discounted, for a range of reasons:

- Camels always seemed to be scarce
- Because they can go for long periods without water they do not concentrate around waterholes as much as other feral livestock
- They are nomadic, which implies that their impacts must be spread widely
- They are soft-footed, unlike cattle and other hoofed beasts
- They occur in very remote regions where impacts are seldom noted or thought about.

Dörges and Heucke (1995), in Australia's leading mammal book, stated that 'The camel does not seem to degrade the Australian desert environment'. Recently they amended their views, and they are now saying that camels will feed on endangered plants and 'even have the potential to contribute to their extinction' (Dörges & Heucke 2003). Opinions about camels are changing out of recognition that camels may keep multiplying indefinitely and reach very destructive levels. Past assessments of their impacts were based upon the belief that they would always remain sparse within the Rangelands, but recent counts suggest a massive multiplication. In 1995 there were thought to be 'up to 100,000' camels (Dörges & Heucke 1995); now there are estimated to be 740,000 (Edwards *et al.* 2003). The Northern Territory population more than doubled between 1993 and 2001 and, if not controlled, will double again in about eight years (Edwards *et al.* 2003). Camel control has become an urgent necessity.

The impacts of camels are considered in Section 3. There have been no studies to assess camel impacts on biodiversity, although a study by Dörges and Heucke (2003) provides very useful information about dietary preferences. Camels have the potential to threaten rare plants and to change vegetation structure over wide areas, much as rabbits and goats do. They seriously deplete and degrade desert water supplies, and there are suggestions that uncommon birds (princess parrots, scarlet-chested parrots, Major Mitchell cockatoos) may be suffering. Camels may have contributed to the extinction from the mainland of the endangered Rufous hare-wallaby (Lundie-Jenkins *et al.* 1993). The Northern Territory Government has recently listed the desert quandong as a vulnerable plant, and the camel is the main threat to its survival.

Camel numbers should be reduced over large areas by aerial shooting programs. But attempts to control camels have been confounded by claims that they are a valuable resource. A decade ago Dörges and Heucke (1995) were claiming that:

> 'Until a few years ago it [the camel] was considered to be a pest and often shot on sight. Recently this attitude has changed and the species is now looked upon as a valuable asset.'

This comment is not entirely correct. Camels have long been considered a pest because they foul waterholes and knock over fences, water tanks and windmills, and they are still considered a pest for these reasons. What has changed is that some people who are trying to establish industries based around Camels are promoting the message that camels are a valuable resource. Dörges and Heucke are working with that industry.

Industries based around feral animals are often small and unstable, and this situation applies to camels. The camel industry in the Northern Territory is heavily supported by government, and its main source of income is live export, which is a high value but low volume market. Edwards *et al.* (2003) note that the current offtake (about 5,000 per year) is 'unable to contain population growth even within the Northern Territory'. The live export market may close in future under pressure from animal welfare groups. The industry does not want see the mass harvesting of camels for pet meat or skins because the value per animal will plummet.

The harvesting of camels will not solve the camel problem for a range of reasons:

- Most camels occur in extremely remote areas and they cannot profitably be harvested because their habitat is too distant from roads, and transportation costs from remote sites are too high (Robinson *et al.* 2003, Edwards *et al.* 2003)
- Wild camels cannot readily be moved in trucks because they are unruly and destructive, especially large bulls
- Markets for camel products are very limited and may prove difficult to maintain and expand.

The website of the peak organisation, Camels Australia Export, (at http://www.camelsaust.com.au/chemergency.htm) specifies that only camels weighing 400-600 kilograms can be processed in abattoirs, yet adult camels weigh 600-1000 kilograms (Dörges & Heucke 1995), implying that only the smaller animals are harvestable. At present there is only one export abattoir that can process camel meat, in Caboolture in southern Queensland, far from any camels (G. Edwards pers. comm.).

The belief that harvesting can solve the camel problem is promoted partly by those wanting to assist remote Aboriginal communities. Birgit Dörges and Jürgen Heucke recently gained Natural Heritage Trust funding to produce a report titled: *Demonstration of ecologically sustainable management of camels on aboriginal and pastoral land'* (2003). They claim that:

> 'Long term significant and economical [sic] viable reduction in feral camel numbers can only be achieved by creating the prerequisites for a permanent supply to the industry. Therefore Aboriginal and pastoral land managers have to be educated to harvest and manage camels from the wild and at the same time guarantee a regular supply to the camel industry.'

By framing the camel problem in this way they are encouraging Aboriginal and other landholders to conserve camels for sale rather than control them as pests. In the Rudall River National Park in Western Australia, regular culls of camels for biodiversity were stopped by the Aboriginal community after they were told that camels have economic value (P. Kendrick, pers. comm.). Rock holes in this area have been converted by camels into putrid cesspits. Unrealistic claims about the money to be made from camels do not benefit biodiversity and do not benefit the communities they are addressed to. Fortunately there are some Indigenous communities that recognise Camels as a pest, and the Watarru Community Inc. obtained NHT funding (under Envirofund) to 'restore local rock holes under threat from overuse and fouling by camels'. According to a summary of the project:

> 'Camels will be extensively culled and the native rock holes re-established by digging and cleaning. This will restore the delicate balance that existed before the explosion in camel numbers.'

In April 2005 a camel workshop was held in Alice Springs to address the growing camel problem. Several issues were addressed:

- The need to foster a national approach towards camel control and exploitation
- The need to protect key natural assets and farm infrastructure
- The need to determine an environmentally acceptable density of wild camels
- Clarification of the role of the camel industry in control.

The last question was not answered. Some industry players oppose any culling, arguing that the camel industry can solve the feral problem, but others are more realistic and accept that immediate action is needed, and that camel harvesting across the entire range of the camel will never be practical. Government representatives at the meeting have agreed to the first co-ordinated interstate cull of camels. More investment is needed in culling in Western Australia, the Northern Territory and South Australia. Harvesting of camels for pet meat or blood and bone may assist in camel control in some regions, but culling of camels should not be delayed by claims that lucrative markets for camel products lie just around the corner. Aboriginal communities should not be deceived into believing that their wild camel stocks represent a valuable resource (Section 7.2.1).

7.1.3 Buffalo

Buffalo numbers were greatly reduced in the Northern Territory for the Brucellosis and Tuberculosis Eradication Campaign. Prior to this campaign buffalo were causing enormous landscape damage, including the destruction of vast wetlands from buffalo swimways which promoted drainage of freshwater and subsequent saltwater intrusion, caused deaths of many paperbark forests. Since the campaign ended, the general perception is that buffalo are now in low numbers and having minimal impact. This perception is incorrect. It may have some validity for Kakadu National Park and other floodplain habitats near Darwin, but in remote eastern Arnhem Land, visited by few outsiders, buffalo are multiplying and serious degradation is underway. The Brucellosis and Tuberculosis Eradication Campaign focused on western Arnhem Land because the smaller buffalo population further east was found to be disease-free and was thus left alone to multiply. This latter population has now reached very high densities, is spreading into new catchments, and serious environmental degradation is underway. An environmental management report produced for Aboriginal lands in the Top End reports ample evidence of serious damage caused by growing numbers of buffalo (Northern Lands Council 2004). The following quotes come from that report, and refer to Arnhem Land catchments.

In the Buckingham River Basin:

> 'There are large numbers of buffalo on the Buckingham River itself. Considerable damage to floodplain, monsoon rainforest and riparian habitats is evident. Buffalo make channels and wallows, damaging wetlands and floodplains and causing salt water intrusion. They are in fact damaging important food sources for Yolgnu [people] all along the major floodplains, even down to Blue Mud Bay. Around the townships of Nhulinbuy and Yirrkala, buffalo are a threat to people.'

In the Koolatong River Basin:

> 'Buffalo are the most significant feral animal issue in the basin. The numbers in the southern sections are increasing and they are spreading into pristine wetlands…Saltwater intrusion is currently being observed in some wetlands which could effectively ruin their natural and cultural value. An urgent assessment, consultation and implementation of control actions need to be undertaken.'

In the Liverpool River Basin:

> 'Latest official estimates for the upper Mann and Liverpool basins are 10,000 animals…Buffalo numbers are on the increase as can be seen by the aerial monitoring that has been going on over the past decade.'

In the Goyder River Basin:

> 'Buffalo are steadily growing into large numbers through most of the basin with a rough estimate of over 1000. The area around Gatji and Galidjapin homelands support high densities of animals, and wetlands have been severely impacted. Control work in this area will be necessary to ensure the long-term protection of the basin.'

In the Goomadeer River Basin:

> 'A range of habitats in the sandstone plateau is being degraded by feral water buffalo… Continued management of buffalo populations in the plateau should be considered a priority.'

Buffalo numbers are also reported to be increasing in the Blyth River Basin.

As well, buffalo are now spreading west to reclaim former habitat, including Kakadu National Park, where numbers are presently low, but management problems are expected in future (A. Fitzgerald pers. comm.). And according to the Land Council report, buffalo are expanding their current distribution in the Victoria River Basin south-west of Katherine, and control may be possible 'while it remains economically feasible to do so'. As Edwards *et al.* (2003) observe about Top End buffalo, 'Obviously the population has enormous growth potential'.

Large scale culling of buffalo on Indigenous lands should become a high priority. This can only be undertaken with the consent of traditional landholders. Aboriginal landholders are well aware of the damage buffalo do to wetlands, and there is support for population reductions, although often an unwillingness to see animals killed and not used. Unfortunately, there is only limited demand for wild buffalo products. The largest numbers of buffalo occur in remote regions far from abattoirs. The demand for trophy animals by hunters is very limited. Indigenous attitudes towards buffalo are discussed further in Section 7.2.1 below.

7.1.4 Banteng

Banteng occur in Australia only on Coburg Peninsula, Northern Territory, inside Garig Gunak Barlu National Park (previously Gurig National Park). Banteng have long been a cause of land degradation on the Coburg Peninsula, and a Board of Inquiry that studied feral animal problems in the Northern Territory recommended in 1979 that banteng be removed from the reserve, with perhaps a 'small herd of say 100 head' retained for historical reasons within a small fenced area (Letts *et al.* 1979).

That advice was not followed, and instead the whole peninsula was fenced in, so that the banteng population was free to multiply within the reserve but could not spread. The population has multiplied dramatically since then, from 1070 in 1978, to 1500-3500 in 1985, to 7000-9000 today, resulting in a population density of perhaps 10 banteng per square kilometre (see Section 3).

The banteng have perhaps reached the maximum density that the fenced area can support. The head ranger, Peter Fitzgerald, said that sick and dying banteng are often noted at the end of the dry season. In one season, 28 were so sick they were shot. The banteng appeared to have eaten poisonous plants for want of better feed. They were dragging their legs and sometimes falling over.

The degradation in the national park caused by banteng includes loss of sedge vegetation, browse lines on trees, trampling of wetlands, damage to coastal dunes, and cattle pads passing through forests (Section 3). Panton (1993) found a 'highly significant difference' between plots that were fenced to exclude banteng and unfenced plots.

In March 2005 Cyclone Ingrid struck Coburg Peninsula. It was a category five cyclone with winds at 300 kilometres an hour. Almost every tree on the peninsula that was not blown over lost its crown. The ground within the national park is now strewn with fallen timber. Fitzgerald (pers. comm.), said it took rangers two days to remove fallen timber from a four kilometre road to the airstrip. A team of four men took almost two weeks to clear the three kilometre track to the old Victoria settlement.

The cyclone damage will impact upon the banteng in various ways:

- Fallen timber has covered grass and other groundcover plants
- Banteng tracks through the forest are now covered in timber, preventing access
- Fierce fires will rage through the park during the dry season and destroy vegetation.

Fitzgerald says that fires will inevitably be lit by the traditional owners of the park. Garig Gunak Barlu is co-managed by the local Aboriginal community and they burn fires each year. Park rangers have lit some fires recently, during the wet season, to reduce the dry season fire risk, and these have burnt with unexpected ferocity, destroying pipes and other infrastructure.

Banteng should be culled for two reasons:

- To reduce their numbers to a more ecologically acceptable level. Letts *et al.* (1979) were recommending a herd of 100 but there are about 8,000 in the park today;
- As a humanitarian act to prevent mass starvation during the dry season.

A cull of banteng may be resisted for two reasons:

- The Aboriginal community regards banteng as a resource because trophy hunters pay a fee to kill bull banteng within the park;
- Banteng are an endangered species in South-East Asia and the Australian population is (incorrectly) seen as having high conservation value.

Fitzgerald believes that the Indigenous community could be convinced about culling if they could be shown the damage that banteng do to bush tucker plants. Other indigenous communities have supported culling when the damage from feral animals was demonstrated. There is some local recognition that banteng 'have caused environmental degradation' (Northern Lands Council 2004), but this has been accepted because of their supposed conservation value. Keith Saalfield (pers. comm.) has proposed a major cull of females, which have no value because hunters only target the large bulls, which constitute about five per cent of the population. No effort has been made to document the damage done by banteng to bush tucker plants but Fitzgerald believes it is considerable, especially around wetlands. The banteng would also be competing with agile wallabies which the community uses as food. Fitzgerald says that a study of banteng impact in the park would need to be followed by negotiation with the community to obtain permission for a cull. The persons arguing for the cull would need to be skilled at negotiating with Indigenous communities. Fitzgerald says that feral pigs are damaging wetlands in the park and these should be culled at the same time. The park supports feral horses and deer but these are uncommon and do not need culling.

Much has been made of the supposed high conservation value of Australia's banteng herd (Corbett 1995, Bowman 1992, Northern Land Council 2004). In South East Asia the wild banteng is endangered, and Coburg has larger banteng herds than any Asian national park. However, Australia's banteng are descended from domesticated stock brought from Bali or Timor in 1849 (Corbett 1995, Long 2003). Within Bali, banteng are the dominant domestic cow and the population is vast. Domesticated banteng are also present on Java, Sumatra, Borneo, Sulawesi, Lombok and Timor (Long 2003). If these livestock were included in total population assessments the banteng would not qualify under IUCN criteria as endangered.

Corey Bradshaw has suggested (pers. comm.) that Australia's banteng are descended from wild-caught animals rather than domestic livestock. But this is certainly untrue. Alfred Russell Wallace visited Bali in 1856, 11 years after Australia's banteng where imported, and in *The Malay Archipelago* he described the Bali landscape (p 150-1):

> "We saw plenty of the fine race of domestic cattle descended from the *Bos sondaicus* of Java, driven by half-naked boys, or tethered in pasture-grounds. They are large and handsome animals, of a light brown colour, with white legs, and a conspicuous oval patch behind of the same colour. Wild cattle of the same race are said to be still found in the mountains. In so well-cultivated a country it was not to be expected that I could do much in natural history…"

It is inconceivable that the small ship that brought banteng to Australia in 1849 would have brought wild unruly banteng when tame banteng were so readily available. The animals were imported as domestic livestock. It is most unlikely that Victoria settlement had adequate fencing to graze all their herds and they would only have wanted tame livestock.

A cull can thus be justified on the following grounds. The goal would be to remove females and inferior males with no trophy value. The Aboriginal community would not lose any income. Hunters cannot operate in the park at the moment because fallen timber has obliterated trails through the forest (P. Fitzgerald pers. comm.). Large numbers of banteng are likely to die slowly of starvation in coming months anyway. A cull would be an act of kindness to avert mass starvation. The banteng are domesticated livestock gone wild not an endangered species of high conservation value. Banteng have been culled in the park in the past, during the 1970s, when their environmental impacts first became a cause of concern. The goal of national parks is to conserve natural ecosystems, not foreign animals.

7.1.5 Feral cattle in the Kimberley

Feral cattle are the most damaging feral animal in the Kimberley, where they pose a serious threat to the survival of monsoon rainforest remnants (McKenzie *et al.* 1991, T. Start, pers. comm.). Strays from pastoral leases are wandering along watercourses deep into national parks where they breed up and trample fragile riparian habitats and vine thickets (rainforests). The vine thickets are a rare and highly significant habitat, representing the rainforests that once occurred widely in the region when the climate was wetter. Cattle camp inside the thickets and damage them by browsing and trampling (P. Mason pers. comm.). By removing all the foliage within reach, feral cattle increase light levels and thereby facilitate invasion of rainforest edges and cattle trackways by exotic buffel grass (*Cenchrus ciliaris*), other weeds, or native grasses, which fuel very hot fires that kill rainforest trees. In surveys conducted during the 1980s, feral cattle were found in only one of 20 vine thicket sites, but all of the sites now have feral Cattle (P. Mason pers. comm.) The early surveys recorded small mammals in 30-40 per cent of traps; that rate has now dropped to one or two per cent. Feral cattle also pose a threat to endemic rainforest snails, insects and other fauna. Cattle and inappropriate fire regimes are together destroying this rare habitat type.

There is no effective management of feral Cattle within most of the Kimberley region. Further investment is needed.

7.1.6 Donkeys near Katherine

Donkeys occur in very large numbers to the north and east of Katherine, on Jawoyn Aboriginal lands. Donkey densities are especially high in the Beswick Land Trust area (397,000 ha) and the Eva Valley Land Trust area (= Manyalluk, 174,000 ha). Here they are known to be damaging hundreds of Aboriginal art sites when they shelter under overhangs (R. Whear pers. comm.), and they are undoubtedly causing habitat degradation as well. Donkey numbers are also high in the Victoria River Basin, despite a history of extensive culling, and land degradation by donkeys and horses are identified by the Northern Lands Council (2004) as the 'major environmental issue' for this basin. Further investment is needed to control donkey numbers in these areas. That investment should consider the Indigenous issues described below in Section 7.2.1.

7.1.7 Goats in New South Wales and Western Australia

Goats are seriously degrading vast areas within the Rangelands, especially in Western Australia and western New South Wales. Damon Oliver of the NSW National Parks and Wildlife Service fears looming 'ecosystem collapse' over a large proportion of western New South Wales. Peter Mason of CALM talks of landscapes in Western Australia 'absolutely flogged' by goats. Goat numbers have risen, dramatically in some places, because landholders now view them as an economic resource.

In degraded areas sheep-producers are turning to goats to gain more income from the land. John Blyth of CALM, Western Australia, describes goat farming as an industry that operates by degrading the land. Sheep damage the softer country, then goats 'devastate' the harder areas of hillsides and stony rises. Damon Oliver describes goat farming as 'the last fate before desertification'. Sheep country is well-suited for goats because dingo and dog numbers are heavily controlled. Dingoes are very effective predators of newborn goats, and goats do not do well where dingoes are common.

Goats are preventing regeneration of many woody plants in New South Wales. On MacCullochs Range, west of Cobar, New South Wales, large areas of mulga woodlands are failing to regenerate (Hugh McNee, pers. comm.) Areas west of Engonnia are also heavily impacted. When the larger trees die the habitat will disappear over substantial areas in New South Wales and Western Australia. Goats pose a particular threat to threatened malleefowl, eating the same foods as well as threatening their habitat (J. Benshemesh, D. Olivers pers. comm.). Malleefowl are rarely seen in goat country.

Management of goats on private lands is very variable. Some landholders are neglecting their land and unwittingly allowing goat numbers to rise. Others are deliberately encouraging goats to multiply. Oliver (pers. comm.) described absentee landholders who make good profits from their land by driving up from Sydney every six months to harvest wild goats, but whose land is suffering irrevocable damage. At the other end of the spectrum are property owners who are fencing off water supplies and setting in place traps to capture goats and restrict their numbers.

Goat management on private lands is a major concern for national park managers, because goats regularly invade reserves from adjoining lands. This is a serious problem in Western Australia, New South Wales, Queensland, and to a lesser extent South Australia. When large numbers of goats are removed from national parks by culling or mustering (in Currawinya National Park in Queensland, for example), they are quickly replaced by goats wandering in from adjoining properties. In western New South Wales grey kangaroos are contributing to the problems caused by goats (T. Auld pers. comm.).

Support should be given to landholders who manage their lands to reduce goat numbers by fencing off water supplies and install traps. Where kangaroo numbers are high they too should be reduced by restricting access to water.

7.1.8 Rabbits in South Australia

Rabbit Haemorrhagic Disease (RHD) has proved very successful in reducing rabbit numbers in the Rangelands, but this has not always led to the high levels of plant regeneration expected. Mass germination of seedlings has occurred in response to large rainfall events, but in some habitats the few surviving rabbits are preventing regeneration by removing all the seeds.

This problem is very acute in mulga woodlands monitored in the Flinders Ranges and Gammon Ranges in South Australia. Mulga (*Acacia aneura*) is a slow-growing long-lived tree with leaves that are highly palatable to browsing animals, including rabbits. The age structure of mulga woodlands in South Australia suggests there has been very little recruitment of mulga since rabbits invaded the state in the 1890s (G. Mutze pers. comm.). Most stands of trees are more than a hundred years old, or can be dated to the 1950s, when myxomatosis first struck and greatly depleted rabbit numbers. In studies underway in the Gammon Ranges, rabbits occurring at very low densities are found to be removing all the seedlings.

Mulga seedlings in South Australia grow so slowly that they remain vulnerable to rabbit damage for many years (G. Mutze pers. comm.). A seedling less than six months old will die if it is chewed by a rabbit, and even a two year old seedling may not survive. Young mulga plants in South Australia remain vulnerable to rabbit destruction for the first five or ten years, perhaps surviving one attack from a rabbit, but not surviving repeated browsing. Study plots in the Gammon Ranges are showing that rabbits in very low densities, perhaps one per square kilometre, are completely preventing mulga regeneration. Other tree and shrub species in South Australia suffer as well, for example *Eremophila alternifolia* and *Acacia kempeana.*

Loss of mulga is especially significant because mulga the dominant habitat type over 20 per cent of Australia. Rabbits are not preventing regeneration over much of this area because rabbits are absent from some localities that support Mulga, and because mulga in the north of its range benefits from summer rainfall and grows more quickly. In south-west Queensland, for example, the hotter summers and drier winters disadvantage rabbits (D. Berman pers. comm.). Experts in different states report that Mulga is regenerating adequately in Western Australia, the Northern Territory and Queensland, but regeneration is poor in New South Wales and South Australia.

In western New South Wales problems are evident outside the mulga zone as well. In Kinchega National Park very little recruitment of plants is occurring, and suckers produced by four species (*Acacia carneorum, Alectryon oleifolius*, *Casuarina pauper* and *Santalum acuminatum*) are not surviving browsing, leading Denham and Auld (2004) to conclude that 'the probability of successful recruitment into populations of suckering species in western New South Wales continues to be low even at very low rabbit densities'. Good rains have not fallen since RHD struck and it is possible that seedling recruitment in this park may improve if high-rainfall years produce a flush of seedlings. Denham & Auld (2004) are, however, pessimistic, concluding that 'Despite a substantial reduction in rabbit numbers, grazing continues to have a demonstrable impact on recruitment of these trees and shrubs. In New South Wales the situation is compounded by large number of goats (Section 3) and kangaroos which contribute greatly to total browsing pressure (H. McNee & T. Auld pers. comm.).

Some ripping of rabbit warrens has been funded by the NHT in the Flinders Ranges. Warren ripping has also been undertaken over large areas in western New South Wales. Further warren ripping in mulga woodlands and other woodlands types in South Australia and New South Wales is warranted. Monitoring of mulga regeneration in sensitive areas should become a higher priority.

7.1.9 Pigs in Cape York

Pigs along the western side of Cape York Peninsula are preying heavily on the eggs and hatchlings of endangered Olive Ridley turtles and vulnerable flatbacks, posing a dire threat to their survival. A study by John Doherty (pers. comm.) has found that turtles are losing 80 per cent of their eggs to predation, 70 per cent of them to pigs (dingoes are taking 5 per cent, goannas 2-3 per cent and humans 2.4 per cent.) The pigs shelter in high numbers in thickly vegetated swamps behind the beaches where the pigs breed. Predation is occurring on all the beaches used by these turtles on Cape York Peninsula, extending from the Jardine River to well south of Weipa. Col Limpus (pers. comm.) estimates a predation rate of 90 per cent at some sites. Both turtle species face regional extinction. The populations are geographically (and presumably genetically) distinct from other populations of these species. Olive Ridleys and flatbacks are far more vulnerable to predation than other turtle species because they lay their eggs in shallow sites on mainland beaches, rather than digging deep holes on island beaches.

Various control methods have been applied in a localised or ad hoc way, but there is no satisfactory on-going control of feral pigs on the Peninsula. Aerial baiting with 1080 poses a high risk of killing non-target species such as goannas. At one site near Weipa, nest guards are put over nests by a tourist group, but only on a very small scale (M. read, pers. comm.). At Mapoon, one Indigenous community has been putting mesh over a small number of nests, but Col Limpus describes this as 'hellishly labour intensive'. He says the best recent control action was an aerial shoot by the Australian Quarantine and Inspection Service (AQIS)last year. Because pigs are vectors of serious diseases, including Japanese encephalitis, which appeared in Torres Strait a few years ago and caused two human deaths, their presence on the Cape in large numbers, is a serious quarantine issue. Aerial shooting from a helicopter is the best option. The land is mostly Aboriginal land or mining lease. A program of coordinated long-term culling of feral pigs on Cape York Peninsula, in co-operation with AQIS, is urgently required. Mining companies holding leases along some stretches of coastline may be willing to assist.

Olive Ridleys and flatbacks also nest along the Northern Territory coast but predation by pigs is not a concern there, even though pig numbers are high (R. Chatto pers. comm.). Excavation of turtle eggs is a learned behaviour which Northern Territory pigs seem mostly unaware of.

7.1.10 Dingoes and dogs in the Northern Territory

Dingoes and dogs are preying on the eggs of endangered Olive Ridley turtles and vulnerable flatback Turtles along the Northern Territory coast east of Darwin (R. Chatto pers. comm.). Ray Chatto of the NT Parks & Wildlife Commission is preparing a report on this matter which may recommend dog control at particularly important sites, nearly all of which occur on indigenous lands. Dogs are much fewer in number along the north Queensland coast and they do not pose a threat to turtle eggs there (M. Read pers. comm.).

7.1.11 Foxes, pigs, dingoes and cats in Queensland

A new report, recently completed for the Queensland Government, identifies predation by foxes, pigs, dingoes and cats as threatening the future of two endangered turtle species, the Burnett River snapping turtle (*Elseya albigula*) and the Fitzroy River turtle (*Rheodytes leukops*) (C. Limpus, pers. comm.). These turtles are now failing to breed properly because their communal nesting sites along river banks are now heavily exploited by foxes, pigs, dingoes, cats, goannas and water rats. According to Col Limpus (pers. comm.) well over 90 per cent of nests are being lost to predation, and the turtle population now consists almost entirely of adults, with no juveniles recruiting into the population. The Fitzroy River turtle is listed under the EPBC act as vulnerable, while the other species is not listed because it has only recently been described, but both species qualify as endangered on this new evidence. Long-term programs to control predators are urgently required, but the protocols have not been developed yet. Foxes, dingoes and pigs are worse predators than cats (C. Limpus) although the latter can easily be shot at night using spotlights. Goannas have emerged as a problem because they now forage more intensively along river banks than previously, because vegetation away from rivers has been cleared. Both species of turtle occupy the Fitzroy-Dawson River catchment in central coastal Queensland.

The Burnett River turtle also occurs in the Burnett and Mary rivers, which fall outside the Rangelands.

7.2 Social and industry issues

Three social and industry issues require more government attention to gain better outcomes for biodiversity:

- Indigenous Communities
- New Industries
- Hunting.

Each of these is discussed in turn in the following sections. Better indigenous liason should become a key goal for investment of NHT funding.

7.2.1 Indigenous communities

Large areas of the Rangelands, supporting high biodiversity, are owned by indigenous people. Feral animals are not adequately controlled in many of these areas. The lack of adequate feral animal control on Indigenous lands is one of the major gaps in feral animal management in Australia. This is especially true in the Top End, where Aboriginal lands extend over 195 000 square kilometres, including regions where donkeys, horses, buffalo, banteng and pigs roam in vast and growing numbers. Several of the problems which this report identifies as requiring further investment – buffalo, donkey and banteng damage in the Top End, and pig and dog predation on turtle eggs – are occurring mainly or only on Aboriginal lands. Camels are also a major problem on Aboriginal lands.

The Northern Land Council, which represents Aboriginal interests in the Top End of the Northern Territory, produced a major report on environmental management in November 2004 which highlights many inadequacies in feral animal control in the region (Northern Land Council 2004). As noted earlier, many of the communities surveyed identified buffalo as a worsening problem, causing serious environmental harm in many catchments. In the Victoria River Basin degradation by donkeys and horses is the 'major environmental issue'. Pig damage is also a major concern in some areas, for example the Moyle River basin.

There is adequate control of some feral animals on some Aboriginal lands, but control is uneven for the following reasons:

- Poor communication between pest managers and communities,
- Logistic problems
- Lack of a strategic approach
- Inadequate funding,
- The valuing of feral animals

Poor communication

During the course of this project discussions were held with various pest managers operating within the Rangelands, and it became apparent that their relationships with Aboriginal communities vary. Some have workable relationships, while others are less successful and emphasise the different values held by Aborigines.

Pascale Taplin, an Indigenous Land Management Facilitator for the Northern Land Council, said it was still very common for outside experts to come to Aboriginal communities wanting to implement some program, to lecture the community without listening properly, and to think they had engaged in proper consultation.

There are no training programs to help pest managers understand Aboriginal values, and the effectiveness of individual managers appears to depend upon their own abilities to bridge cultural differences.

In Kakadu National Park and in Garig Gunak Barlu National Park, the rangers want to see horses and banteng culled respectively. Both national parks are jointly managed by traditional owners, and in both parks the rangers believe that traditional owners would agree to a cull, but that it would be desirable for outside facilitators to initiate the discussion about culling.

In Kakadu National Park an 'us-against-them' attitude has developed out of previous conflicts over management. Anne Ferguson, the ranger in charge of pest issues, feels that specialist negotiation skills provided by outsiders are highly desirable. 'My background is as a ranger.' She said the community representatives who act in liason roles get sick of being asked questions and don't want to talk any more. Despite the inadequate liason, Ferguson says that processes for negotiating pest control are more advanced at Kakadu than elsewhere.

At Garig Gunak Barlu National Park, ranger Peter Fitzgerald said that an outsider with good communication skills was needed to demonstrate the damage that banteng do and the need for a cull. The outsider would have to be someone who understood ecosystem impacts and who knew how to communicate well with Aboriginal communities. Without an outside facilitator there was no prospect of the community agreeing to a cull.

One barrier to effective communication is language. Only about 40 per cent of the Aboriginal population speaks English as their first language. Communication can be improved by using plain English and local language photo-based documents, videos and posters using local content, illustrated books with stories about introduced pests, and other culturally-sensitive tools as outlined in the NLC report (Northern Land Council 2004).

Logistic problems

On Aboriginal lands in the Top End, feral animal numbers are highest in remote and rugged landscapes, for example Arnhem Land. Control over feral animals in this landscape is difficult.

Aboriginal people no longer occupy much of this landscape and proper management has lapsed. In 1996 the Northern Land Council instituded the *Caring for Country Strategy* to assist Aboriginal families to manage their country, based upon the principle that the land needs its people. Of the eight objectives of the strategy, the second is to 'Establish best practise approaches to major environmental threats, particularly weeds, feral animals and fire' (Northern Land Council 2004). The website of the NLC devotes a page to feral animal management under the Caring for Country Strategy, listing such goals as:

- Facilitating the involvement of Aboriginal landowners and community-based rangers in the assessment of actual and potential environmental impacts caused by feral animals.
- Preparing and disseminating up-to-date information to Aboriginal landowners and community-based rangers about actual and potential feral animals and related management strategies.

The greatest threat to biodiversity in the Top End and the Kimberley are hot uncontrollable fires which rage over large areas because traditional fire management has lapsed. Late dry season fires need to be replaced by smaller, cooler, early fires. Hot fires are considered the main threat to small mammals in the region, many of which are declining (Woinarski *et al.* 2001), and the main threat, along with grazing, to declining seed-eating birds, including the endangered Gouldian finch (Garnett & Crowley 2000). A traditional burning regime of smaller mosaic fires needs to be reinstated as an urgent priority, but this can only occur if people are living on their lands. Feral animal management would improve from this, because there would be landholders to observe the degradation taking place, and landholders to facilitate control. Many of the traditional landholders are now very elderly and they have not seen their lands for many years and have not observed the damage wrought by feral livestock.

Shooting is almost the only control option for buffalo, donkeys, horses and pigs in remote areas. But gun ownership on Aboriginal lands is declining. According to the NLC report:

> ‘Gun ownership in remote comunities is rapidly declining and this is leading to a real decline in the customary economy. Wildlife harvesting returns from hunting are delining for groups that have limited or no access to firearms – and some outstation families are doing it very hard … This then deepens the pervasive loss in ecological knowledge, makes it more difficult for Aboriginal hunters to contribute to feral animal control…’

Gun ownerships is declining because of stricter gun laws, community concerns over misuse of guns, and because existing guns are becoming old and unsafe. The NLC report contains recommendation to improve levels of gun ownership. Some Aboriginal rangers are engaged in shooting operations. The Wagiman traditional owners in the Daly River Basin have negotiated a contract for harvesting horses and donkeys (for pet meat) and pigs, and they have undergone firearms training (Northern Lands Council 2004).

However, feral animals in rugged areas can only be controlled effectively by aerial shooting using a semi-automatic rifle, and obtaining a licence to discharge such weapons from aircraft is extremely difficult, although some licences have been obtained by Aboriginal rangers. The Northern Territory National Parks Service has a shooter available to do such work for Aboriginal communities when his time is available. However, he is usually heavily booked and a delay of up to four months can be expected. Department of Primary Industry shooters are also available and easier to contract (P. Josif pers. comm.). With more funding, more aerial shooting could occur. These shooters would need to be people known to the communities, or accompanied by someone known to the communities, to establish the necessary trust. Landholders would want to know that animals were not being killed at sensitive sites.

Lack of a Strategic Approach

Paul Josif, manager of the Land & Sea Management Branch of the Northern Land Council, sees a lack of a strategic approach towards feral animal control in the Northern Territory as one of the key problems. Vast tracts of the Northern Territory fall under Aboriginal ownership, but there are also large areas under unfenced pastoral leases, and management needs to be co-ordinated across the whole area. At present there is no cohesive single strategy. Even within the NLC lands there is no cohesive strategy and no funding to achieve such a strategy. With a strategy in place, the communication problems described above could better be dealt with.

Inadequate funding

Feral animal control on remote Aboriginal lands is very expensive and funding is not adequate. Money is needed to survey the locations of feral animals, to liase with the communities, and to undertake control.

The Northern Lands Council report calls for more funding, in the vicinity of $3.4 million per annum, to establish an Aboriginal Land and Sea Management Fund, to consolidate the community-based ranger programs, which engage in weed, feral animal and fire management. Most funding is at present grant-based and thus limited in time. The same report identifies major gaps in regional facilitation. Of the major issues gaps, the first one listed is feral animal management, 'particularly the spread of large ungulates and ants'. The major regional gaps are identified as 'North East Arnhem Land, Western Arnhem Land, the Vernon, the Gulf, and the Barkly Regions'.

The manager of the NLC Land and Sea Management Branch, Paul Josif, emphasises investment as the key to better action. He says that all of the logistic and other problems could be more or less solved if the money were there.

The valuing of feral animals

The claim is often made that indigenous attitudes towards feral animals differ fundamantally from those of white Australians (Rose 1995). A contrast is drawn between pest managers who want to see feral animals eradicated, and indigenous owners who want to see some rabbits, cats, camels, horses, buffaloes, pigs and donkeys on their land.

This difference in attitude is overstated. Many white Australians want to see feral animals roaming free. Efforts by the NSW National Parks and Wildlife Service to remove horses from Guy Fawkes National Park met with fierce public opposition (Carruthers 2000), including criticism from prominent radio host John Laws. A European animal welfare group, the Franz Weber Foundation, has even established a brumby sanctuary on Bonrock Station in the Northern Territory (Carruthers 2000). Feral buffalo are important to the Northern Territory tourist industry as Top End icons, and prominent biologists, including Bill Freeland and David Bowman (Bowman 2003) have argued that they be tolerated in the landscape. Deer, camels, and goats (on coastal headlands), are also popular with large segments of the population. Deer and pigs are sometimes released into national parks and state forests to create future hunting opportunities. Many other examples could be given.

The core difference in values is really between those Australians who would like to see the country rid of feral animals, and those who would like to see some feral animals running free. This difference cuts across social and ethnic lines. There are some Indigenous people who support feral animal control – because they have seen the damage done to their land – more strongly than some white Australians. And there are varied opinions within indigenous communities. Bruce (1995) noted that the Aboriginal manager of Atula homestead on Arrernte land in the Northern Territory wanted camels controlled because they broke down fences, but the community strongly opposed this. There are some communities who want donkeys entirely eradicated and others who prefer them retained. Because values vary there cannot be said to be one indigenous position on feral species.

Among those Australians who oppose feral animal control there are some opinions that are widely shared between white and Indigenous people. Bruce Rose (1995) surveyed the attitudes of Aboriginal people in central Australia and identified various values, some of which are widely shared with white Australians:

- Feral animals should not be killed wantonly (this value is held more strongly in Aboriginal communties – see below)
- Feral animals can be harvested for sale
- When harvesting takes place some feral animals should be left behind
- Horses should not killed or eaten
- Cane toads are highly undesirable
- Claims that feral animals harm the landscape are exaggerated.

To these values could be added the perception that dingoes belong in the landscape. (Rose did not ask about dingoes.)

Some of the values held by Indigenous people are, however, different:

- That camels and donkeys, because they appear in the Bible, are white man's dreamtime animals and should not be harmed
- That cats (and sometimes other species) are native to Australia ('always part of the country')
- That harvesting is more acceptable if animals are removed from the land before they are killed.

Rose (1996) acknowledged that Aboriginal attitudes towards feral animals vary, but attempted to summarise their values:

> 'When feral animals are in large numbers and damage the country, Aboriginal people recognise the impact but generally do not connect such issues with a need to carry out special forms of management. In general, Aboriginal people do not undestand the rationale for feral animal control programs. The effects of feral animals on the country are not seen as a cause for concern. It is seen as a natural phenomenon that animals eat the grass and raise a bit of dust. To separate the impact of feral animals from native species on these grounds is not seen as logical. People see the contemporary ecosystem as an integrated whole so they don't see some species as belonging while others do not.'
>
> 'In many areas, feral animals are looked on as a resource of the country. Their presence confirms that the land is productive and people derive pleasure from seeing them in the wild.'

Rose's summary is perhaps too simplistic, or may apply more to central Australia than the Top End. During this study, ample examples were provided of Aboriginal people recognising the harm done by feral animals and supporting culling. For example, Ray Whear spoke about Jawoyn people wanting donkeys completely eradicated after seeing the damage done to cave paintings and other special sites. Elders had stressed to him the Christian significance of donkeys and the need to conserve them, but as soon as they were shown the damage they strongly supported culling. Culling of camels has occurred on Pitjantjatjara lands in South Australia to preserve desert waterholes. Paul Josif, of the Northern Lands Council, believes that most communities either understand the need for culling or can be convinced of it, although eradication (which is not usually feasible anyway) is likely to be opposed. The Northern Lands Council report provides many examples of Aboriginal communities wanting fewer feral animals on their land.

The key to convincing landholders that feral animals are a problem is to show them the damage caused (Northern Lands Council 2004). Elders are less mobile these days and sometimes they need to be carried by helicopter to see the damage to remote sacred sites.

All of the larger feral animals cause serious harm to resources valued by Indigenous communities. In desert areas camels foul and silt up waterholes, and also devour and kill culturally significant plants such as desert quandongs.

Donkeys are very damaging to cave art sites because they shelter in caverns to avoid sun and rain, where they rub against rock art or kick up dust which sticks to rock art and farms a hard crust (R. Whear pers. comm.). Hundreds of sites north of Katherine are threatened, and NHT funds has been sought to fence off sites.

Pigs have a digestive system more like that of humans than any other feral ainal, and they eat large amounts of bush tucker, especially foods of wetlands and rainforests, the two most productive habitats for Indigenous food plants. When pigs excavate edible tubers and turtle eggs, their diggings are often conspicuous, and many indigenous people are aware of the foods they take. The impact of pigs on food resources can also be gauged by analysing the stomach contents of pigs that are culled. As part of the *Cape York Weeds and Feral Animals Project* the stomach contents of hundreds of pigs were identified and some of them listed in the summary report (Anonymous 2003). They include many significant foods and other culturally important plants such as: water lily (*Nymphaea violacea*), bulgaru (water chestnut *Eleocharis dulcis*), pandanus (*Pandanus spiralis*), grasstree (*Xanthorrhoea johnsonii*), native potatoes (*Ipomoea calobra*), Leichardt tree (*Nauclea orientalis*), sacred lotus (*Nelumbo nucifera*), nonda fruit, lillypillies (*Syzygium* species), turtle eggs and goannas. One performance indicator of the project was that 'Indigenous communities are aware of the environmental and social impacts of pigs and this goal was presumably met by showing community representatives some of the items taken from pig stomachs.

Foxes and cats prey upon threatened species (e.g. bilbies and great desert skinks) which were once the foods of indigenous people. Because these animals were once eaten they feature in Dreamtime stories, and people feel a responsbility for their welfare. Traditional landholders will usually support control measures over foxes and cats if convinced of their role in predation (C. O'Malley pers. comm.). Most of the threatened species in arid areas were once traditional foods and their welfare remains a matter of concern.

But demonstrating the impact of feral animals can be difficult. In Kakadu National Park, feral horses have emerged as a serious issue (A. Ferguson pers. comm.). They are causing erosion gullies and spreading weed seeds in their dung. But because the erosion is occurring in a remote place the harm is not easy to demonstrate. A large number of community members will need to be taken there in troop carriers, and this will prove expensive and difficult to organise.

If there is one value that most impedes feral animal control on Indigenous lands, it is not the idea that feral animals are not harmful, but the belief that animals should not be killed and then wasted. This view is very widely held. Because of this value, and because Indigenous communities desperately need sources of income, much of the focus of feral animal control is on finding markets for animal products. The Northern Lands Council report emphasises this goal:

> 'The NT is currently in a very poor state for managing the large feral ungulates and there is a great need for a strategic approach that involves the economic use of the animals to assuage Aboriginal landowner concerns over what they might perceive as gratuitous destruction.'

Feral animals can return income when their meat is sold (for human consumption or pet meat), they are sold for live export, or they are shot by big game hunters. Unfortunately, there is no evidence to suggest that sufficient markets for feral animals will ever be found. Donkeys are almost completely worthless (P. Josif pers. comm.). Many of the camels, horses, and buffalo occur in remote regions where the cost of harvesting them is prohibitive (as noted in Section 3 for camels). The NLC report includes some recommendations that appear unrealistic, for example the suggestion that trophy hunting of buffalo will help control their numbers. While every effort should be made to create income for Aboriginal communities by establishing markets for feral animal products, the reality is that harvesting for sale will not solve many feral animal problems on Aboriginal lands. This holds especially true for the more remote areas where the problems are most acute. Creating unrealistic expectations about the worth of feral animals can only to disappointment and a delay in effective control.

The best hope is that better markets are found in Asia for feral buffalo meat. In 2004 nearly 4 000 buffalo were shipped to Malaysia and Brunei, but nearly all of these were domesticated animals. The Australian Buffalo Industry Council is actively promoting the merits of buffalo meat and milk, but it represents buffalo farmers, not hunters, and its goal is the genetic improvement of captive breeding stock by hybridising Australian swamp buffalo with imported river buffalo. As domestic buffalo herds increase in number, size and meat quality, the market for feral buffalo meat can only diminish, and currently, prices and demand are low. There seem to be no prospects for a greatly increased market for feral buffalo products at the present time.

Placing a value on feral animals inhibits their control. In Garig Gunak Barlu National Park small numbers of banteng (about 50 a year) are culled by big game hunters, who pay a hunting fee to the community. Because the few bulls that are harvested have high value, community members oppose a cull of female banteng because each animal as seen as having value. When a cull was recently proposed, community members said they expected to be paid for any animal killed (K. Saalfield pers. comm.). In desert areas, many Aboriginal communities and white landholders are unwilling to see Camels culled, because they have been told that Camels have commercial value.

In some situations, payment of a fee for control can be justified. The Northern Lands Council report argues for an 'on country fee for service' for environmental management services. In the Tanami Desert, cats need controlling to conserve rare bilbies, and local Aborigines are skilled at hunting them (R. Paltridge pers. comm.) They could be paid a fee for this service, just as white rangers are paid to control other pests. On Jawoyn lands near Katherine, feral buffalo are multiplying rapidly but the manager is waiting for prices to rise to earlier levels before agreeing to a muster (R. Whear pers. comm.). If the community could be paid the price differential, control could be achieved now for a relatively low price.

Conclusions

Paul Josif of the NLC sees lack of money and lack of a strategic approach as the two main barriers to better control over feral animals on Indigenous lands. In the past, too much emphasis has been placed on differing cultural values, whereby Aboriginal people are assumed to want feral animals on their land. The real problem is a lack of funding to demonstrate the harm done by feral animals, to explain the merits of control programs, and to do the actual control. Many communities already want some culling but lack the necessary resources. Markets for feral animal products should be sought where possible, but these will always remain limited. Economic exploitation of feral animals will do little to solve the feral animal problem, except in a few areas.

The key region for attention is the northern half of the Northern Territory, from the Victoria River Basin to the Top End and south to the Gulf Country, because the rugged landscape provides refuge for large numbers of feral animals and limits access by the traditional owners. Buffaloes, donkeys, horses, pigs (and in certain locations banteng and dogs – see Section 7) are the pests having most impact in this region. Outside of this area, camel numbers are a major problem on Indigenous lands in desert and semidesert regions (Section 7), and pigs are a dire concern on Cape York Peninsula (Section 7).

7.2.2 New industries

Some of the growing pest problems in the Rangelands have been created or made worse by new industries. Deer farming as an industry has directly or indirectly led to the creation of 127 new feral deer populations of four species spread across four states. In New South Wales the feral goat problem has been worsened by the introduction of a new goat breed from Africa, the boar goat, resulting in larger, hardier and more damaging feral goats. The buffalo problem is likely to worsen in the same way from imported new buffalo breeds. In central Australia the camel industry has discouraged culling by arguing unrealistically that camels are a valuable resource.

Less significant, though still of real concern, are recent releases onto unfenced land on Cape York Peninsula of buffalo, deer and blackbuck antelope by two enterprises engaging (or trying to engage) in big game hunting. Escapes and releases from Ostrich farms may also be creating new feral populations (Section 3) but information is limited.

Other pest problems have arisen from the promotion of yabby farming and neem trees, and problems seem likely to arise from olive and snail farming as well. [yabbies have formed many feral populations in Western Australia as a consequence of escapes from farm dams (Low 2002) and Neem is becoming a serious weed in the Northern Territory and north-western Queensland. Olives are major weeds in South Australia.]

All of these new industries have been promoted by government. The Rural Industries Research and Development Corporation (RIRDC) has promoted deer, ostrich and buffalo farming, and in 2004 they produced a major report: *Safari Hunting of Australian Exotic Wild Game* (Dryden & Craig-Smith 2004). The Northern Territory Government is supporting the camel industry, and the Queensland Department of Primary Industries has bred feral goats with African Boer goats to create hybrids (www.dpi.qld.au/news/newsreleases/8970.html), which are adding to the goat problem. Their fast growing hybrids are meant to be farmed, but they have also become part of the feral goat problem, contributing to its genetic diversity and ultimate destructiveness. Buffalo breeders have imported river buffalo to breed with Australia's swamp buffalo, seeking improved growth rates and milk production in captive Buffalo, and when some of their hybrid buffalo escape into the wild they will broaden the genetic diversity of feral populations.

Because commodity prices are declining, farmers are often urged to diversify into new enterprises. The proponents of alternative enterprises are often very upbeat about the profits to be made. A 1978 book on deer farming, *Gold on Four Feet*, claimed that deer would return seven times the income of traditional livestock, and talked about yearly profits in the range of $100 000 to $200 000 (Anderson 1978). The RIRDC report on big game hunting claims (page vii) that 'this is a potentially very lucrative market segment'.

When the deer, ostrich (and emu) industries were in their early growth phase, prices paid for stock were very high because farmers were selling breeding stock to new farmers. These early prices created unrealistic expectations about long term profitability. When prices inevitably crashed, and markets for deer and ostrich products proved more elusive than promised, many farmers found they had stock they could not afford to maintain. Deer and ostriches were released, or they escaped when fences were not maintained.

The Standing Committee on Agriculture (1980) expressed the view that escapes from deer farms would be of little consequence and would not result in deer expanding their range (Jesser 2005). But deer farms account for 77 of the feral herds found today (Moriarty 2004). In truth, the problem was predictable. Anderson's 1978 book on deer farming had much to say about deer knocking down and leaping over fences. It was inevitable that prices would crash and farmers would be caught with more stock than they could afford to feed. Anderson warned in 1978 that deer prices would fall when their numbers rose.

Problems like these will keep recurring unless governments put in place forward-thinking policies. New industries should be subjected to risk assessment protocols to ensure that new pest problems do not arise. Preventing pest problems should be a core goal of new enterprises where any such risk may be posed. At present, RIDC and state departments of agriculture promote new enterprises with little or no concern for any pest problems that may ensue. Pest concerns are left for other departments to deal with.

Landholders in Australia today are expected to practise ecologically sustainable development, but governments promote new enterprises with no such constraints. If Boer goats had been subjected to a risk assessment they might not have been released, because it might well have predicted that they would do Australia more harm than good. A risk assessment on deer might have led to some constraints on where deer could be farmed (as applies in New Zealand) and which species could be used, and could have led to better protocols on fencing and sales, forbidding sales to anyone who could not demonstrate that they had a suitably fenced property.

The Queensland Department of Natural Resources and Mines has recently conducted a risk assessment of deer (Jesser 2005) that is likely to lead to some policy changes along these lines. Similar risk assessments should be conducted by other states, and other industries such as big game hunting also need assessing.

RIRDC is also promoting aquaculture, including the culture of aquarium fish, and this is another alternative industry that could create dramatic pest problems. The RIRDC Report, *Integrated Agriculture Systems: A Resource Handbook for Australian Industry Development* (Gooley & Gavine 2003), promotes *in situ* cage culture in lakes, and combined crop irrigation and fish culture systems, listing aquarium fish as one possibility. The report has nothing to say about pest issues apart from one paragraph noting that non-endemic species should not be used in farm dams if flooding is likely.

Another concern is that new deer species will go feral. According to Anderson (1978) white-tailed deer, Pere Davod's deer, Wapiti and Muntjac are held in captivity in Australia, and Jesser (pers. comm.) has heard that sika deer were imported recently from New Zealand to interbreed with red deer.

7.2.3 Hunting

The sport and business of hunting is contributing significantly to Australia's feral animal problems. During this study the following problems were noted:

- One hundred and twenty seven new feral deer populations have been created by hunters Australia-wide (Moriarty 2004)
- Buffalo, deer and blackbuck have been freed on Cape York Peninsula
- The newly-created Game Council of New South Wales has been given a mandate to manage Californian quail, pheasant, chukhar partridge, peafowl and turkey, even though not of these species do not (yet) occur in the wild on mainland Australia.

New problems are emerging because the sport of hunting is changing in response to the following influences:

- Hunters are losing access to state forests as these are converted into national parks
- Hunters are losing access to private lands because of public liability concerns and bad experiences with irresponsible hunters
- Changes to gun laws after the Port Arthur massacre have led to many gun-owners joining the Sporting Shooters Association, from whose newsletter they learn about hunting opportunities
- Big game hunting has been promoted as a business opportunity
- Deer have become readily available because of deer farming.

Hunters have responded to these changes in various ways. Because hunting access to private lands has become more difficult, deer have been released into national parks, state forests, catchment lands and other secluded places for future sport (Moriarty 2004, Jesser pers. comm.). Deer suitable for stocking have become readily available from deer farms because of the collapse in deer prices. Landholders are also buying deer, releasing them on their land, and then charging hunting fees (Jesser 2005). According to Moriarty (2004), 127 of Australia's 218 feral deer populations have arisen because of hunting. The Sporting Shooters Association is said to be very concerned about the creation of new deer populations and has a policy of opposing this (P. Jesser pers. comm.).

Pigs are also released into national parks and other lands to create future hunting opportunities. Such pigs can often be recognised by their torn ears, showing they have previously been held down by dogs. In north-western New South Wales, Sydney hunting groups are buying properties and stocking them with pigs and goats (M. Braysher pers. comm.).

Hunting and Conservation, a program of the Sporting Shooters Association (New South Wales) has recently acquired Tilterweira Station (32088 hectares) near Wanaaring, western New South Wales, to run as a hunting resort for its members. Pigs and goats are the main interest. The station borders Nocoleche Nature Reserve. According to an article appearing on their website

(www.huntingandconservation.com.au),

'Bag limits – of one trophy and one meat animal per hunter – will need to be enforced as a basic step towards achieving a sustainable population capable of routinely producing trophy quality animals'. Bag limits will not be compatible with the conservation needs of the adjoining reserve. The same article states that 'The primary goals of Hunting and Conservation (New South Wales) Ltd will be to acquire large tracts of rural land…' They may come into many conflicts with neighbours over pest control or lack thereof.

Havago Australia, which operates a 12 000 acre sheep station three hours drive west from Brisbane, makes the following offer on its website (www.havagoaustralia.com.au):

> 'We have five species of deer [fallow, red, chittal, rusa [Javan and Molluccan] and feral goats that roam the area. We also offer feral/vermin game hunts. We can also organize sambar, hog deer hunts but will be offering these and turkey hunts at this location in the near future.'

Hog deer and turkeys are not known to occur in the wild anywhere in Queensland, although both species have feral populations in southern Australia.

The newly-created Game Council of New South Wales has a mandate to manage Californian quail, pheasant, Chukhar partridge, peafowl and turkey for hunting, yet none of these species occur in the wild on mainland Australia. All of them can fly, so they cannot not be constrained by fencing. All of them have formed feral populations in various parts of the world. Californian quail are feral on King Island in Tasmania, Norfolk Island, and in New Zealand, Canada, South America, Hawaii and other islands. Ring-necked pheasants are feral on King Island, Rottnest Island (Western Australia), and in New Zealand, North America and Europe. Chukar partridge are feral in New Zealand, North America and Hawaii. Peafowl are feral on various islands around the Australian coast (King, Flinders, Kangaroo and Rottnest). Turkey are feral on islands in Bass Strait and in California, Canada and Hawaii. In Australia these birds are confined to islands, suggesting that predators such as foxes and dogs may constrain them on the mainland, but the evidence from other parts of the world, where they occur on continents supporting various predators, suggests that that is a false hope.

Game hunting is a growing business, promoted by the RIDC, as noted in the previous section. Various Australian enterprises advertise over the internet the hunting opportunities they provide, including blackbuck antelope, buffalo and various deer species. A Google search on 'blackbuck' (or 'black buck') and 'Australia' produces many hits. The clients who hunt are mainly American and European. Foreign hunters are especially interested in species that are seldom available elsewhere including buffalo, blackbuck and hog deer. Hog deer were until recently confined to one population in Gippsland but now there are at least nine feral populations in three or four states (though none as yet in the Rangelands) (Moriarty 2004). Bioclimatic modelling suggests that hog deer could occupy vast tracts of land in northern and eastern Australia (Moriarty 2004).

On Cape York Peninsula two hunting enterprises have freed livestock onto unfenced land. Blackbuck antelope, deer and Buffalo were released. The release of blackbuck was illegal and the animals died or were destroyed. Due to recent changes in Queensland law the releases of deer and buffalo did not contravene any law but the Queensland Government is now likely to change their regulations to prevent further releases.

There is also a report of a couple of hundred blackbuck seen on Cape York Peninsula (P. Jesser pers. comm.).

Governments should be monitoring the sport and industry of hunting to prevent new pest problems arising. The New South Wales Rangelands may soon support feral populations of Californian quail, pheasant, Chukhar partridge and turkeys. There needs to be a better understanding of the motives and goals of hunters and hunting lodges. Any subsequent changes to legislation and policy should take account of the fact that some hunters are mavericks who ignore laws.

Section 8 Best practice planning and a checklist to assist regional planners

8.1 Best practice planning

Over the last decade or so, the approach to managing feral animals has changed. Rather than trying to kill as many pests as possible, it is now realised feral animal management needs to be carefully planned and co-ordinated. Feral animal control is usually just one aspect of an integrated approach to the management of natural resource systems. Ideally, feral animal management needs to be set within broader regional and local management plans. Most feral animals are highly mobile and can readily replace those that are killed in control programs. Unless actions are well planned and co-ordinated across a broad area, individual control programs are unlikely to have a lasting effect. When planning pest management, there are some important steps that should be considered.

1. Decide if there is a problem and exactly what the problem is. Clearly understand the impacts of feral animals in the area. Their presence alone may not be enough to require management.
2. Determine how big the problem is.
3. Who is affected by the problem and who will take responsibility? Pests don't respect boundaries and all those affected by the problem will need to be involved in solving it. Also they will have different views, needs and resources.
4. Where is the problem? Identify and describe the area of concern
5. Measure the problem. This is difficult enough in farmland, but it is much more difficult in bushland. Often, much research is needed over a considerable time.
6. Examine all the possible solutions to the problem and decide on a management plan. It is necessary to have all those people affected agree to the level of control you are aiming for, the timing of the program and the expected cost.
7. Implement the control program.
8. Monitor the results of the program. This must include the changes in biodiversity values. It should also include the costs of the initial program and any ongoing costs and improvements in bushland quality as a result of the control program.

8.1.1 Eradication or control

The objective of many feral animal control programs in the past has been eradication, whether it is localised or widespread. Eradication is appealing because it requires no ongoing investment in control. To determine if the eradication of a pest species is possible, six criteria must be addressed (Olsen 1998):

- Pests can be killed at a rate faster than they can replace themselves
- Immigration can be prevented
- All reproductive individuals must be at risk
- Monitoring can occur at low densities
- The socio-political environment supports eradication
- The costs of eradication can be justified.

Much as we might like it, the widespread eradication of most feral animals in the Rangelands is currently not possible. Feral species that are newly established or only occur in isolated populations are the only possible targets for eradication. During this study, localised eradication was identified as practical and desirable for the species shown in Table 18. The four deer species are the highest priority for eradication (see Section 7). They occur in small populations at widely separated locations, and the prospects of reinvasion are slight unless there are further escapes or releases from deer farms. The banteng and horses inside Garig Gunak Barlu National Park are an example where eradication is feasible but the socio-political environment is not conducive. Because they are constrained inside a fenced peninsula reinvasion would not be possible, but their eradication would be opposed by the traditional owners of the park.

Table 18 Pest populations susceptible to eradication over all or part of their range within the Rangelands

Pest Animal	Location
Bali Banteng	Garig Gunak Barlu National Park, Northern Territory
Horse	Garig Gunak Barlu National Park, Northern Territory
Fallow Deer	Inland New South Wales and southern Queensland
Red Deer	SA, inland New South Wales and southern Queensland
Rusa	Central and northern Queensland
Chital	New South Wales, Queensland, Northern Territory
Helmeted Guineafowl	Charters Towers, Broome
Spotted Turtle-dove	Alice Springs
Barbary Dove	Alice Springs

Where eradication is not feasible the level of control to be implemented needs to be decided. This will depend upon many factors including available resources, control tools, the objectives for control and motivation/community interest. The general options for control levels include:

1. No control - if numbers of the pest are low and having only minimal impact, it is only affecting a very small area, there is no satisfactory method of control or control is too expensive. Feral cats are an example of a pest that is usually not subjected to any control in the Rangelands. Their impact may be substantial but there is no satisfactory method of control. 'No control' is an unsatisfactory option if a pest is increasing in numbers and impact. Camels have not been adequately controlled in the past and their populations are now reaching highly destructive levels. Deer are heading along the same trajectory. Buffalo were controlled in the past, but are not adequately controlled at present, and their numbers are also rising to disconcerting levels. Low numbers of a pest should not be used as a justification for non control if the pest is multiplying and will incur much higher costs in future. The age-old principle, 'A stitch in time saves nine', applies especially well to pest control.
2. Management only when a crisis occurs e.g. when hundreds of camels congregate around a desert waterhole during a drought.

3. Management to keep numbers within reasonable limits with short-term programs, sustained efforts or targeting certain areas when needed. Short term programs are often an inefficient use of resources because pest numbers soon return to their former levels. Too often they are the norm because funds are only made available on a short term basis.
4. Management by commercial harvesters e.g. hunting of wild pigs for the game meat trade or the netting of quantities of carp for the production of pet food or fertilisers. The value of commercial harvesting is often overstated, because those who harvest pests view them as a valuable resource rather than a pest to be removed. They want pest populations maintained not eliminated.

8.1.2 Nil tenure approach – manage animals by distribution not tenure

The high mobility of many feral animals complicates their effective management. A control program may effectively manage the animals currently in the area, but frequently reinvasion quickly occurs through immigration. Management of only part of the feral animal population leaves a reservoir of animals available to repopulate and reinvade controlled areas. In order to overcome this, barriers to reinvasion need to be established or the population need to be managed across its entire extent. As discussed in Section 4, establishing barriers to feral animal movements is expensive, difficult and not always effective and is mostly suited to smaller areas. Managing feral animals across their population also has many difficulties, however these are often more social and political than technical. By encouraging communities to address feral animal issues with a co-ordinated approach, more substantial and long-term control can be achieved. This is termed a nil-tenure approach and can be defined as the collective identification of a feral animal problem, irrespective of tenure boundaries and legal obligations, and a stakeholder-community commitment to implementing a solution (Buller *et al.* 2005).

8.1.3 Management objectives – conservation vs production

Feral animals in the Australian Rangelands are managed for a variety of reasons, although the primary causes are the conservation of biodiversity and agricultural production. The diverse nature of the impacts that feral animals have also involves a range of stakeholders with varying interests and objectives for feral animal management. As an example, let's look at the role of the agricultural sector in feral animal control. Feral animals such as rabbits, foxes and wild dogs are all extensively managed by the agricultural sector, with the primary focus of control the reduction of negative impacts on farm productivity. By implementing control for economic benefit, agriculturalists are also potentially assisting in reducing the environmental impact. It is important to note however, that the level of control required for primary productivity can vary significantly from that required for conservation. A farmer may find that reducing the density of rabbits on his land down to two per square kilometre leads to insignificant damage to his crops; however at that density the rabbits may still be common enough to restrict or prevent regeneration of nearby native flora (R. Henzell pers. comm.). In this instance there will be a mismatch of management objectives and the thresholds of pest density that are desired. There have been many economic models developed for determining the level of investment in control that provides the greatest net economic return to the agriculturalist. However this level of investment will not be suitable for conservation purposes. Unless the farmer receives incentives to undertake additional control efforts, he will achieve a suboptimal

conservation outcome. In such a situation, supplementary resource investment by governments or those concerned with conservation can turn suboptimal outcomes into ones that benefit both parties. The extra control allows the farmer to further reduce the impact of rabbits to his crops for no extra cost, whilst the conservation agency only has to provide part of the control costs. This is an ideal situation where combining resource investment leads to a benefit for both parties, but unfortunately this does not always occur. Some feral species, such as goats, are actually valued by landholders as a supplementary source of income, regardless of their environmental impact. In this situation, the landholders do not want control implemented on the goats because it will reduce their income. In such a case, management efforts on nearby conservation reserves prove difficult because goats quickly reinvade from the farmlands. Goats invading from private lands pose one of the major unresolved challenges for national park managers in Western Australian and western New South Wales. One option may be to allow the farmer to assist in controlling the goats in the conservation reserve to help supplement the potential loss of income, in return for maintaining lower goat densities on the farmlands. Such a situation would require much negotiation and would face many obstacles before resolution.
Obviously there are many other scenarios that can occur. Many landholders do take a strong interest in caring for the environment and are proactive in the management of feral animals for the conservation purposes. However, landholders are more likely to invest resources in conservation when they are economically secure, and not preoccupied with other problems such as droughts and low commodity prices. As Mike Braysher once said, "It's hard to be green when you are in the red!"

8.2 Checklist for best practice planning

Regional NRM planners need to consider a wide range of issues when developing feral animal management plans for biodiversity conservation in the Rangelands. They will often be restricted by resources, immense land scales of land size, minimal residency and unknown impacts. The following checklist, based on the principles of best practice planning, highlights most of the issues to be considered:

- ***What impact are feral animals actually having in the region?***

One of the most important components in the development of a feral animal management plan is a clear understanding of the problem being addressed. Therefore, accurate information on the impacts of feral animals in the area needs to available. The presence of feral animals alone is not evidence enough, because they may be having little or no impact. The aim of the management plan needs to be the mitigation of the negative environmental impacts these species are having. This may sound quite simple, however much of the information on feral animal impacts is circumstantial and either site-specific or incorrect. Wherever possible, solid and objective evidence needs to be obtained, either through direct observations by conservation managers, or preferably through scientific research and assessment.

As an example, malleefowl are under threat across their range from habitat loss and fragmentation, fire, foxes, livestock, goats, rabbits, overabundant kangaroos, infertility and road kills (Garnett & Crowley 2000). At some sites foxes may pose a significant threat, but at other sites fires, goats or livestock are a more serious problem. Fox baiting is often undertaken at malleefowl sites because foxes are listed as a threatening process, even though the significance of the threat varies from place to place. In central Australia, according to Peter Copley (pers. comm.), fire poses the main threat to malleefowl, and he rates the threat from foxes as low. He worries that fox baiting could lead to an increase in feral cats, which may prove more harmful to overall biodiversity than foxes and dingoes (which are poisoned by fox baits, and which suppress cat numbers). Joe Benshemesh (pers. comm.), who wrote the recovery plan for malleefowl, is also concerned that fox predation may be overrated. He does not question that foxes take many young malleefowl, but mortality among young malleefowl is naturally high, with most recruitment occurring in wet years. He says there is very little evidence to show that baiting for foxes has brought about any benefit for malleefowl.

In other examples, bilbies appear to be strongly threatened by foxes in temperate Australia, but in the Gibson and Sandy Deserts, Bilbies are doing well, despite substantial populations of foxes and cats (C. O'Malley pers. comm.). Cats appear to threaten Julia Creek dunnarts at some localities but not others.

General statements about threats appearing in books or on websites should not be taken as the sole basis for action. Managers should instead be asking the question: 'Can we confidently say that pest X poses a threat to species Y in this particular location?' The expertise of local biodiversity managers should be sought. Where this information is unavailable, the management plan will most likely be based on 'best bet' rather than 'best practice', and is likely to be less effective. Often there is a considerable risk involved in deciding the level of resources that should be invested. The alternative risk is that no management is undertaken and biodiversity values are lost.

- ***What is the scale of feral animal impacts in comparison to other influences on biodiversity in the region?***

The scale of feral animal impacts in comparison to other negative influences on biodiversity in the region will determine the priority of a feral animal management plan within a region. If feral animals are having an impact but it is significantly less than that inflicted by weeds, pollution, salinity or any other anthropogenic activity then resources may be better invested in controlling the activity having the greatest impact. For example, there would be little point in controlling feral predators in remnant vegetation if land-clearing practices will soon clear that area. On the other hand, feral animal control is sometimes necessary to meet other management goals. Feral animals often promote the spread of weeds, both by disturbing the soil and by carrying their seeds, and the control of feral animals may become a necessary component of a weed control program. Feral animal control may also contribute to the goals of improving water quality and halting soil erosion.

- ***What is the area to be managed and who are the stakeholders affected by the feral animals?***

Determining the distribution of feral animals in the region allows the area for control to be established. This is best achieved by mapping pest distribution and problem areas. It is also essential to identify and involve from the beginning, all stakeholders who are impacted by feral animals and all who may be impacted or involved with the implementation of the management plan. Cooperation is vital for any broad-scale management plan to be effective and by including all concerned parties from the beginning, ownership of the problem and commitment to a solution is likely to be more forthcoming.

- ***Are the control efforts coordinated over the feral animals' distribution?***

Implementing a coordinated '*nil-tenure'* approach to feral animal management provides for the highest chance of success. This can only be achieved through community consultation and agreement. All land holders and managers need to work together for maximum benefits and minimum costs.

Where a control operation is limited to one property, the animals that are killed may be replaced by newcomers from surrounding properties, and the problems may worsen. Joe Benshemesh (pers. comm.) suggests that when one experienced fox is killed, younger foxes moving in may establish smaller territories, leading to a higher fox density.

- ***What are the objectives of the management plan?***

It is very important that clear objectives are set down and agreed upon by all those involved in the development of the plan. All too often proper objectives are not set. Braysher (1993) summed up the situation in a guidebook to managing feral animals:

> 'All too often, sporadic control is the norm, whether to protect conservation or production values. There is usually no clear objective for the control other than to kill pests, and pest numbers rapidly return to pre-control levels until the next hit. Considerable resources can be wasted in this strategy.'

The objectives should be measurable and include time-frames where relevant. They should outline the level of control desired based upon the conservation needs in the area being considered, including special consideration of endangered species or ecosystems being impacted by the feral animal activities. Will the plan aim for eradication, containment or suppression?

The goals should be set in terms of biodiversity benefits, not numbers of pests killed. As Braysher (1993) notes: 'Much current practise concentrates on the pest and its numbers, and the links between pest density and impact are poorly quantified. Consequently, it is often difficult to determine the cost-effectiveness of control action.'

Bomford *et al.* (1995) are blunter: 'Unfortunately, killing pests may often do little to prevent environmental damage. We cannot assume that reduced pest numbers leads to reduced environmental damage.'

To assess whether the objectives are being met, adequate monitoring is essential (see below).

- ***What legislation is relevant?***

It is important that any management plan developed adheres to relevant local, state and Commonwealth legislation. Knowledge and understanding of the relevant Acts, Regulations and obligations should be sought before a management plan is developed.

- ***Do the objectives of the plan align with those of regional, state or Commonwealth plans or policies?***

A hierarchy of NRM planning exists in Australia, based on the different levels of government. These start with broad scale Commonwealth plans through to small-scale local or regional plans at the bottom. As one moves down the hierarchical scale, specificity and detail in the plans increases. Thus a Commonwealth plan may suggest control of feral predators in arid zones whilst a state plan will discuss management of foxes in a part of the state, and a regional plan may suggest fox control in a single property or catchment. Each of these plans needs to align for strategic management to occur. Thus regional planners need to have a thorough understanding of broader scale plans that are relevant to their region and align their objectives accordingly.

Examination of broader-scale plans will also assist regional planners in determining appropriate priorities, control options and management strategies.

- ***Who will champion the management plan?***

It is very important that a core group, usually involving a key agency and/or community participants, is willing to champion any feral management plan. The enthusiasm of others involved in the management of feral animals in the region may wane with time, but a core group committed to seeing the project through to completion will provide the impetus for completion. This group will need to take responsibility for initiating, developing and implementing the management plan. Importantly, the core group should also take responsibility for monitoring and evaluation of results. All too often, landholders lose interest in a project once the control measures have been put in place. The core group should maintain its commitment to the project to the point of monitoring and documenting the final outcome.

- ***Have the views of Indigenous landholders been taken into consideration?***

Indigenous communities are an integral component of the Australian Rangelands. Large tracts of land are under Indigenous control and they possess a wealth of experience in managing the landscape that can provide important and insightful information into the planning process. Indigenous communities are also likely be one of the primary groups involved in implementation of feral animal control in the Rangelands. Their cultural beliefs, views and opinions need to be taken into consideration and respected. Indigenous issues are considered in detail in Section 7.2.1.

- ***Are the most effective and humane management tools being used in the most efficient way?***

Once the objectives of the management plan are clear, it is important that the most effective and humane management techniques are utilised. A variety of complimentary techniques should be used in an integrated approach. The specific details of various management tools and their effectiveness across a range of environments can be sourced from State and Commonwealth agencies, Threat Abatement Plans (TAPs), the BRS publication series on vertebrate pest management and many other sources. Codes of Practice (COPs) on the control of particular feral species should be followed where they exist and Standard Operating Procedures (SOPs) adhered to for individual techniques to ensure safety, humanness and effectiveness.

- ***Has an integrated management plan been developed?***

Feral animal management plans need to be integrated, both with other NRM plans and across species. Often common techniques are used or can be slightly modified to include a range of target species. It can be more cost-effective to manage the impacts several feral species in an integrated manner, producing potentially larger biodiversity benefits for the investment. For example, in semi-arid New South Wales, Newsome *etal.* (1989) found that rabbit numbers increased significantly in areas where feral cats and foxes were systematically removed, compared to areas where the predators were left alone. Again an integrated approach would be most effective by controlling all three species. Integrated management is also the best approach where feral animals contribute to the spread of serious weeds or other forms of land degradation that managers are tackling.

- ***Have the non-target impacts of control been considered?***

Many of the recommended control techniques have impacts on non-target species. For example, poison baits are often consumed by native fauna. It is important that non-target impacts are carefully considered when selecting the feral animal control techniques. This can be particularly important when implementing control to reduce threats to endangered species. The most effective techniques may not be able to be used due to the threat they pose to these species.

- ***What will be the consequences of target species eradication or population depletion?***

Sometimes the eradication of control of one feral species may have indirect impacts on other feral animals or native species. These need to be carefully considered before implementing control. For example, feral cat numbers have been observed to rise and fall with fluctuations in rabbit numbers (Williams *et al.* 1995), and control of rabbits, particularly in Rangelands, is considered important in lowering feral cat numbers and possibly reducing feral cat damage to conservation values (Newsome 1990). Thus rabbit control may also help reduce the impacts of feral cats. However, in some areas feral cats will increase their predation upon native animals when rabbit numbers decline (Williams *et al.* 1995, Newsome *et al.* 1996). This can place extra pressure on the the native fauna species that conservation efforts hope to protect. If such impacts are expected, an integrated control program targeting both rabbits and cats is needed. Similarly, dingoes may protect a range of native species by controlling exotic predators like feral cats through direct predation (Palmer 1996a, 1996b) and by excluding them from carrion during droughts (Pettigrew 1993, Corbett 1995). Control programs removing dingoes, deliberately or accidentally (non-target kill), are likely to increase predation from feral predators. Pest animals that are controlled to some extent by dingoes include pigs, goats, foxes, hares, overabundant kangaroos and wallabies, and probably deer.

- ***Does the management plan contain adequate monitoring?***

Most feral animal management programs in the Rangelands have lacked adequate monitoring. Monitoring tells you if your management actions are working, as well as allowing variables such applicability to other regions to be evaluated.

'Monitoring and evaluation', says Braysher (1993), 'are often forgotten aspects of vertebrate pest management.' Because there is never enough money for optimal pest control, most of the effort goes into actual control, and monitoring is neglected, or it is very limited in scope. We are seldom able to say what has been achieved.

Monitoring is sometimes dismissed as an academic exercise, promoted by researchers to provide them with employment, of limited value compared to the 'real' work of killing pests. Funding bodies are often reluctant to see pest control money 'diverted' into monitoring. People want action not words, results not observation. We thus remain ignorant about the merit of many pest control operations. In some cases money continues to be wasted on ineffective actions because no monitoring goes on.

Where monitoring is undertaken it is usually inadequate. It may consist only of counts of animals killed or numbers of baits removed. But the number of dead pests may not correlate with any benefit, because the pests may be multiplying fast enough to replace any losses. Where pests are controlled for biodiversity, the focus of monitoring should be on the benefit to biodiversity, when all too often it is on numbers of pests killed. Operational values such as cost-effectiveness, non-target effects, efficacy and humanness of control techniques should also be monitored to allow management strategies to be refined.

Monitoring seldom goes on for long enough. A fall in fox numbers may be recorded in the year after baiting, and everyone is satisfied, but because the monitoring does not continue, no one notices that fox numbers rebound in a couple of years.

Inadequate monitoring often produces misleading results. A fall in the number of pests, or a rise in the number of threatened animals, may be taken as a sign of success, when it may owe to some other factor, such as a drought, above average rains, or a fire on a nearby property. If monitoring is undertaken consistently over many years, other factors are less likely to skew the results. The slow rate at which biodiversity is likely to recover provides another reason why monitoring should continue over many years to detect changes.

Proper monitoring is difficult and costly, and this helps explain why it is seldom done well. But because it is seldom done well, we cannot assess the impact of many pest control operations. If there was better monitoring far fewer resources would be wasted on misguided actions. Although it is expensive, proper monitoring saves money in the long term.

Adequate funding must be included in feral animal management programs to cover monitoring costs. One of the major problems with monitoring both feral animal impacts and changes in biodiversity is that standard protocols do not exist. Often the impact of feral animals is unclear and management is undertaken because the animals are believed to be having detrimental impacts. Research into feral animal impacts on biodiversity and how they can be monitored is urgently required. Similarly, robust monitoring techniques for biodiversity in the Rangelands are also required. This could take the form of indicator species or vegetation cover/composition, but again requires urgent research.

- ***Does the management plan have sufficient sustained funding?***

It is important for any feral animal management plan to have sufficient funding for sustained control efforts and monitoring. Because of normal budgetary and election cycles, funding for pest control is often provided intermittently or as one-off allocations. Control over only short time frames often results in feral animals quickly recolonising treated areas, with little to show for the resource investment. Sustained efforts can suppress feral animal impacts and provide longer-term benefits. Even if eradication is attempted, sustained investment is required to ensure that adequate monitoring takes place.

- ***Will the management be strategic?***

A strategic approach aims to prevent damage rather than having to deal with damage that has already occurred; in other words, acting pre-emptively not reactively. In feral animal management the overall strategy is usually to reduce the feral animal numbers wherever they are having detrimental impacts, rather than rectifying the problem once damage occurs. For example, strategic sustained control of rabbits can produce long-term reductions in their population size and environmental damage. Reactive management would be to only manage the rabbits when outbreaks occur or their numbers go above a threshold. This method allows the rabbits to build up to high numbers and inflict damage before they are controlled. The strategic approach results in less damage and should be the aim of all control programs. Buffalo and deer provide opportunities for strategic control in the Rangelands at present, whereas camels are fast becoming a lost opportunity because their numbers are rising rapidly.

We recommend that PESTPLAN should be followed to identify the priorities for investment and address the issues in the above checklist.

8.3 PESTPLAN

PESTPLAN is a process developed to assist regional NRM bodies to address these issues when developing feral animal management plans. It helps identify and address best practice planning steps when looking at developing a feral animal management strategy and whether the resources and time are better spent elsewhere. The myriad of stakeholders with interest in feral animal control can achieve the most effective outcomes by working together towards a common set of goals. It is sometimes difficult to reach a solution to a pest problem that is acceptable to all of those concerned. PESTPLAN is a guide developed to assist managers set priorities for managing feral animals and to develop and implement a management plan that are agreed to by those affected. PESTPLAN can be applied to primary production or conservation land uses, or a combination of both. It helps by asking a structured series of questions and issues to be considered about pests and the problems that they cause. PESTPLAN provides a process for groups to tackle pest management planning based on a clear understanding of the pest problem, asking what can be realistically achieved and how to implement it at the local level. It was developed to assist those responsible for planning and undertaking pest animal management, including Commonwealth, State and Territory agriculture, forestry, environment and water agencies, local pest management agencies (such as New South Wales Rural Lands Protection Boards or their equivalent in other regions), Landcare groups, local councils, and other regional and local community-based groups.

In practice, on-ground management of pest animals is most likely to occur at the regional or local level, and as such Landcare, catchment management and similar groups are the primary targets for the guide. PESTPLAN is best managed through workshop groups of key stakeholders, but requires a core group to initiate and facilitate the process. Views about pest animals and their management change with time, advances in knowledge and from place to place. PESTPLAN recognises this and outlines a structured but flexible approach that can help make the most appropriate decisions about pest animal management. Importantly, PESTPLAN assumes that pest animal control is just one aspect of an integrated approach to the management of production and natural resource systems. It stresses the need to assess pest animal management as part of a regional or local management plan. It also recognises that pest animal management will not be practical in some areas because resources are scarce, the benefits are not justified by the cost or there are limitations to control techniques. Part of the process is to identify these potential areas of concern. PESTPLAN can be applied in areas where either primary production or conservation is the major land use or where both uses overlap. An integral part of the process is to integrate pest management planning and its implementation into the broader regional resource management planning process that is being adopted by the Commonwealth, States and Territory governments for the delivery of Stage 2 of the Natural Heritage Trust.

PESTPLAN involves a three-stage process. Stages one and two are run in a workshop forum and stage three in smaller, post-workshop groups. Each stage involves a number of steps. The three stages are:

1. Planning
2. Prioritising key land management units
3. Developing and implementing local pest management plans

Developing and implementing an effective pest management plan can be complex, time consuming and expensive. It is important that the groups involved in the process are clear about why they want to manage pests and that they are sure that any action will be supported by the wider community and with the necessary resources. PESTPLAN requires strong community support to be most effective. Where this support does not occur, alternative approaches to PESTPLAN will be necessary, however the PESTPLAN process will highlight where the support does not occur. It is important to remember that PESTPLAN will highlight what needs to be done but does not provide the technical information on how it should be done. This information is available in technical manuals such as TAPs, COPs, SOPs and the BRS publication series on the management of vertebrate pests.

Section 9 Priorities for investment

Investment needs to targeted at minimising the impacts of feral animals in regions where the impact is greatest, and preventing the establishment of new feral species. Identification of species and regions that will benefit most from coordinated feral animal control activities is vital. Recovery plans for threatened species identify those species at risk and areas of habitat critical for their survival. Implementation of these plans should be accorded a high priority in national action to abate the threat posed by feral animals. Available resources will seldom, if ever, be sufficient to fully implement all the control measures required or recommended in recovery plans. Areas will need to be ranked on a nationally consistent basis to ensure that decisions about funding for control activities result in maximum conservation benefits. An agreed national methodology for ranking areas should be developed to cover protecting existing populations of endangered species, facilitating their expansion, and preparing areas for translocation

A high degree of priority should also be given to managing newly established feral animals or populations where control or eradication is possible (Sections 3 and 7). Effectively managing these species before they become widespread and well established is by far the most cost effective form of control and the type of investment that will provide the greatest return. Imagine the triple-bottom-line benefits if foxes or rabbits had been eradicated from Australia before they became established and widespread.

The effectiveness, humaneness and cost of implementation for control methods should also be a priority area for investment. Improving the range and availability of tools for land managers in their efforts to mitigate the impacts of feral animals on biodiversity, will lead to greater management effectiveness and higher participation rates in control programs. Some current methods of control are deemed inhumane and to cause the animals great distress and discomfort. They are often only used because suitable alternative techniques are not available. Development of more humane options will likely lead to higher implementation rates and help improve the general public perception and acceptance of feral animal control.

9.1 Regional priorities

This section identifies those regions in the Rangelands where increased effort is required. It is a summary chapter that draws upon the detailed information presented in Section 7, which is partly based upon assessments provided in Section 3.

The Northern Territory emerges as the jurisdiction requiring the highest level of investment, because of the large number of pests in the Territory not under adequate control. This lack of control partly reflects the rugged landscapes and low population base of the Northern Territory, but also reflects the large area of land under Indigenous ownership, within which feral animal control is usually inadequate due to lack of resources.

9.1.1 Western Australia

In the Kimberley region, Feral Cattle are identified as the most damaging feral animal (Sections 3.7.15 and 7.1.5). They pose a serious threat to monsoon rainforest remnants (partly by facilitating destructive fires) and they are damaging fragile riparian habitats deep inside reserves. There is no effective management of feral Cattle within most of the Kimberley region. Further investment is needed.

A widespread cull of camels is necessary in arid areas of the state (Sections 3.7.12 and 7.1.2). Camel numbers are multiplying out of control, and camels are fouling and depleting outback water supplies and altering vegetation structure by selectively grazing certain plants. The need for culling is most evident in the western and central deserts. Camels are also expanding in range in the Northern Goldfields, northern Nullabor Plain, and slightly in the South Pilbara. Culling in these areas would be prudent if there is evidence to suggest the populations will increase in future.

Goats are degrading many sheep properties in the southern Rangelands of Western Australia (Section 7.1.7) Support should be given to landholders who manage their lands to reduce Goat numbers by fencing off water supplies and install traps.

9.1.2 South Australia

In the Rangelands of the state, camels are multiplying to very destructive levels, and a widespread cull is needed (Sections 3.7.12 and 7.1.2).

Rabbits are preventing or inhibiting Mulga regeneration in the Flinders and Gammon Ranges (Section 7.1.8). Support should be given to landholders to rip rabbit warrens where this assists with mulga regeneration, especially in areas of known conservation values.

Two herds of red deer occur near Port Augusta (Jesser 2004). They are the only herds of feral deer known from the Rangelands of South Australia and they should be eradicated before they multiply out of control (Section 7.1.1).

The population of Barbary doves in Adelaide, if not controlled, will spread into the Rangelands. This population should be eradicated.

9.1.3 New South Wales

Goats are degrading many sheep properties in western New South Wales, for examples on MacCullochs Range, west of Cobar, and areas west of Engonnia (Section 7.1.7). Support should be given to landholders who manage their lands to reduce goat numbers and impacts by fencing off water supplies and installing traps.

Rabbits are preventing regeneration of woodland in western New South Wales, for example in Kinchega National Park (Section 7.1.8). The situation is compounded by large numbers of goats and kangaroos. Warren ripping has been undertaken over large areas in western New South Wales, and further ripping is merited in areas where woodland regeneration is not occurring.

Feral deer did not occur in the Rangelands of New South Wales until recently, but now there are small herds of red deer, fallow deer and chital deer, which may results in large deer populations in future (Sections 3.7 and 7.1.1, and Jesser 2004). Red deer are so widespread that this species might be beyond eradication in the Rangelands of New South Wales, except for one isolated population on the Murray River. Fallow deer may also be beyond eradication. Chital offer the best prospects of eradication because there is one isolated population in the Ivanhoe region (Moriarty map page 295). Andrew Moriarty, who conducted the deer survey upon which these comments are based, has mapped the localities of all feral deer populations in New South Wales. He now works for the Rural Lands Protection Board in New South Wales, and can be contacted for exact locations of deer populations, including herds that were overlooked during his survey period. He was unable to supply this information in time for this report.

9.1.4 Queensland

Deer control should be a very high priority for investment in Queensland because complete eradication of many small populations is achievable, and will offer a very high return on investment by preventing the establishment of new feral pests with the capacity to spread over wide areas (Section 7.1.1).

Red deer occur as one herd of fewer than 100 animals near Rockhampton (Moriarty 2004), and two populations in the Roma-Injune-Mitchell area, totalling between 100 and 500 (Jesser 2005). The latter populations may be beyond eradication, but the Rockhampton herd should be a high priority for removal. Further assessment of the Roma-Injune-Mitchell population is needed before any decision is made about control.

Rusa deer occur as one population near Townsville, one west of Mackay, and one near Rockhampton (Moriarty 2004). There may also be population on Cape York Peninsula north of Bamaga. These populations should be a very high priority for eradication.

Chital deer occur as two separate populations near Burketown and Normanton in the Gulf Country (Moriarty 2004). There are also three populations in the northern Brigalow Belt west or north-west of Rockhampton (Moriarty 2004) and one at the mouth of the Burdekin River (Jesser 2005). These should all be a high priority for eradication. There are also outlying populations around the Charters Towers that should be investigated as prospects for eradication.

Andrew Moriarty, who conducted the deer survey upon which most of these comments are based, has mapped the localities of feral deer populations in Queensland. He now works for the Rural Lands Protection Board in New South Wales, and should be contacted for exact locations of deer populations. Peter Jesser, who works for the DNRM in Queensland, also has information about Queensland deer populations.

To avert extinction for two turtle species in the region, pigs urgently need to be controlled around turtle nesting beaches on the western side of Cape York Peninsula, mainly on Aboriginal lands extending from the Jardine River to south of Weipa (Section 7).

Foxes, pigs, dingoes and cats should be urgently controlled around breeding colonies of the Fitzroy River turtle and Burnett River snapping turtle in the Dawson-Fitzroy Catchment, to avert extinction of these species (Section 7). (The same actions should be undertaken outside the Rangelands in the catchments of the Burnett and Mary Rivers.)

9.1.5 Northern Territory

Swamp buffalo are highly destructive. Their numbers were heavily controlled during the 1980s, but they are multiplying rapidly and culling should be undertaken as a high priority throughout their range in the Top End and Victoria River District (Section 7.1.3). Catchments where control is urgently required include the Buckingham River, Koolatong River, Liverpool River, Goyder River, Goomadeer River and the Blyth

River. Buffalo invading the Victoria River Basin should also be eradicated before their numbers grow.

Banteng numbers in Garig Gunak Barlu National Park on Coburg Peninsula have reached unsustainable numbers and a cull should be undertaken as a high priority (Section 7.1.4), especially in the wake of Cyclone Ingrid which caused massive habitat damage.

Donkeys are very damaging and their numbers have been controlled in the past. High numbers remain occur on Jawoyn Aboriginal lands, especially in the Beswick Land Trust area (397 000 ha.) and the Eva Valley Land Trust area (=Manyalluk, 174,000 ha.). Donkey numbers are also high in the Victoria River Basin, where they are identified as the 'major environmental issue'. Further investment is needed to control donkey numbers in these areas.

A widespread cull of camels is necessary in arid areas of the state (Sections 3.7.12 and 7.1.2). They are multiplying out of control, and fouling and depleting outback water supplies and altering vegetation structure. The Northern Territory population more than doubled between 1993 and 2001 and, if not controlled, will double again in about eight years (Edwards *et al.* 2003).

Dingoes and dogs probably need controlling along the Northern Territory coast east of Darwin (R. Chatto pers. comm.). Ray Chatto of the Northern Territory Parks and Wildlife Commission is preparing a report on this matter which may recommend dog control at particularly important sites, nearly all of which occur on Indigenous lands.

More funding should be provided to Aboriginal communities to achieve better pest control on their lands, as outlined in detail in Section 7.2.1. The priority areas are in the northern half of the Northern Territory, from the Victoria River Basin to the Top End and south to the Gulf Country, in regions where the rugged landscape provides harborage for feral animals and limits access by the traditional owners.

9.2 Gaps in management tools and priorities for investment

Reducing non-target impacts

The majority of feral animals in the rangelands are controlled using a suite of similar techniques. These have been summarised in Section 5. However, many of these control techniques also have detrimental impacts on native wildlife and the development of more species-specific control techniques should be considered a priority area for investment. It is also an area of feral animal control that holds great potential for improving control effectiveness and efficiency.

The geographical isolation of the Australian continent has allowed a unique range of flora and fauna to develop in this country. Most of the feral animals in the rangelands are quite evolutionarily distinct from native species and thus phylogenetic differences may provide physiological and behavioural differences that can be exploited. The 'Achilles heel' approach is to look for these biological differences and examine methods of exploiting them to create more feral-animal specific control techniques. The technique is most applicable to poison baiting techniques where specific foraging behaviours or physiological tolerances to toxins can be exploited. As an example, when ground baiting with 1080 meat baits for foxes, baits are usually buried. In this instance, the Achilles heel of foxes is that they will willingly dig for baits, whereas most native carnivores will only scavenge surface baits. This increases target specificity greatly, whilst affecting the effectiveness of ground baiting in a minimal way. Achilles heel research should be a priority because it can enhance the effectiveness of current feral animal control techniques, minimize the impacts of these techniques on biodiversity, and potentially provide a high return on investment. It may also allow for currently restricted control techniques to be applied over broader scales, such as the development of a canid specific toxin that would allow aerial baiting to occur in areas where native species are not tolerant to 1080, and conventional 1080 aerial baiting cannot occur.

Humaneness

The RSPCA believes that it is unfortunate that most control techniques do not achieve a humane death (Jones 2003). To remedy this, they propose that a priority research and development area in government management programs should be development of humane alternatives. The RSPCA stance is for non-lethal control unless suitable techniques are not available, and they strongly advocate fertility control of wild populations (Jones 2003). A priority area for investment is the assessment of integrated feral animal control techniques based on the most humane techniques. The SOPs and COPs being developed by Sharp & Saunders (2004) provide a good starting point, but these need to be extended further to include integrated control practices.

Broad-scale control of feral animal populations

Effective broad-scale feral animal control methods will allow feral animal populations and their impacts to be controlled over large management units. Research is needed to develop broad-scale control methods for many feral animal species. The application of an effective and broad-scale means of feral animal control to areas of high conservation impact is potentially the greatest means of controlling feral animal impacts on the environment. Currently aerial shooting is the only effective means of broad-scale control of many feral species on conservation estates, particularly in remote or inaccessible locations. Ground baiting and trapping may allow broad-scale control over areas where road access occurs. Aerial baiting is potentially an alternative means of delivering effective feral animal control if it can be made more target-specific.

Integrated management

The use of multiple and integrated control methods has been advocated to increase the efficacy of feral animal control operations. However, there are many different combinations of control methods and these methods can be applied at varying intensities and in different orders. In many scenarios, it is unknown which combinations of methods and efforts will produce the greatest conservation outcomes in the most effective way. The optimal combinations will vary across species, space and time, and will depend on the impact that feral animals are causing at different densities. However, research may reveal how best to apply integrated control programs. Research should be pursued to investigate how multiple control methods should be effectively applied during control operations to most effectively reduce impacts and maximise conservation benefits whilst minimising control costs. It must be remembered that feral animals do not 'respect' property and jurisdictional boundaries and control needs to be implemented across entire feral animal populations where possible. A priority should be to develop mechanisms to improve the coordination of pest animal management programs across *all* relevant land tenures and interest groups.

Strategic control

A high priority for investment should be the funding of strategic feral animal management. Investing in programs where the objectives are long-term reductions in feral animal impacts on biodiversity will ultimately provide the best return on investment. These programs aim to curb feral animal impacts through proactive management rather than seek the short-term benefits from reactive management practices.

9.3 Knowledge of biodiversity and the impacts of pest animal

The impacts of feral animal populations on ecosystems

The impacts of many feral animals on ecosystems are not clearly known. This was highlighted at the workshop, where some natural resource managers described some current control as best bet rather than best practice. Lack of knowledge of ecosystem impacts is mostly due to a lack of resources needed to carry out creditable ecological research in areas of potential feral animal impact. It also partially results from the difficulty in clearly identifying cause and effect. Many of the experts consulted had witnessed damage, but knowledge of the potential population impacts on susceptible species by was deficient. This information is needed to allow the determination of which feral animal control methods are effective. Research to investigate the actual impacts of feral animals on natural resources, especially threatened species or ecological communities is needed. This research should initially focus on nationally listed threatened species and ecological communities. Research should also trial the effectiveness of different feral animal control methods in reducing the impact to ensure that such methods do actually reverse the damage to the species or community in question.

Regional biodiversity

A poor knowledge of the biodiversity in many parts of the Rangelands is a serious issue that urgently needs to be addressed. Without this knowledge it is difficult to determine the impacts feral animal species are having, let alone predict the damage to biodiversity that could occur if the distributions of feral species change. The lack of basic knowledge of both native species and feral animal distributions proved to be the greatest hindrance in providing priority recommendations for regional management hotspots.

Feral animal distribution and abundance

A lack of detailed information on the distribution and abundance exists for many feral animal species within the rangelands. This information is crucial for the implementation of effective control for conservation. It is heartening to see that more attention is now being focussed on this issue. The National Land and Water Resource Audit is placing more emphasis on the abundance and distribution of feral species in its work, and the Invasive Animal CRC is attempting to address the issue by developing a national database and mapping system of feral vertebrates across the country. However, much more detailed information is still required for many of the remote regions in the arid and semi-arid zones of Australia.

Density-dependent impacts on conservation

This information is required to allow the appropriate level of feral animal control to reduce the impacts by feral animals to occur. The knowledge of desirable feral animal density reductions will affect the method of control that is most effective and cost-efficient in any given situation. Research to establish a relationship between feral animal population densities and the level of impacts on conservation outcomes is urgently required. This may allow the determination of the optimum level to which feral animals are required to be reduced in order to reduce conservation impacts to acceptable levels. This research will also allow management to be carried out in the most cost-effective manner and maximise use of the limited resources available in a strategic way.

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Appendix A Ferals animals in the Rangelands workshop summary

A workshop held in Canberra on 22 February 2005, brought together experts on pest animal control and policy to discuss options for better pest management for biodiversity conservation within the Australian Rangelands. This report summarises key issues raised, but does not review the various methods of control that were mentioned.

What are the goals?

There was some disagreement about what biodiversity conservation means. Some participants said that any control measure that helps native species is a gain for conservation. Others disagreed, saying that 'conserving biodiversity' really means assisting rare and threatened species. Bob Henzell, (South Australia Animal and Plant Control Commission), expressed a third view, saying that a more important goal is to save whole habitats. He spoke about a national park where rabbits are preventing mulga woodlands from regenerating; this habitat may vanish over large areas along with all the species it contains.

Along with this disagreement about 'biodiversity' is uncertainty about the goals of many control programs. Culling and baiting programs have often been implemented with agricultural objectives, but often without specific conservation goals. In the past especially, too much emphasis has been placed upon numbers of pests killed, not upon biodiversity gains. Control needs to minimise the impacts of the feral animals, not just their presence. For example, park rangers might bait their parks once a year to suppress foxes, but not be able to specify any target measure they were expecting to achieve (i.e. they want to reduce the impact of foxes on biodiversity or species Y by X percent). Infrequent baiting may not necessarily produce any long-term biodiversity benefit. In the Top End, Keith Saalfield, (Northern Territory Parks and Wildlife Commission) said that most control programs have not produced any significant long term gains. In New South Wales, Paul Mahon, (Dept. of Environment and Conservation), found that the infrequent fox control in most parks – all too often undertaken to assist neighbours breeding sheep - were not reaching any measurable goals, although the rangers believed – without evidence – that small mammals were benefiting. Strategic, targeted control programs have proven to be the most effective. Paul wants fox control concentrated into areas where a clear benefit can be shown, i.e. into parks where foxes are known to threaten rare species.

Where do they apply?

Pests are a problem at the landscape level. Pest management should therefore operate at the landscape level, i.e. via a nil-tenure approach where the actions of many landholders are coordinated to meet a common goal. PESTPLAN, offers a best-practice tool for doing this, by bringing together neighbouring landholders, including national park managers, to decide upon realistic and common goals and put them into action.

PESTPLAN can prove very effective. But its capacity to deliver can be limited when:

1. The goals of conservation and surrounding land management are wildly divergent

2. Landholders are too preoccupied with other problems (poverty, drought, locusts)
3. There is no local champion to drive the process
4. Absentee landlords cannot be incorporated readily into the process
5. Interest is lost after initial successes are achieved, or after new problems emerge.

As an example of (1), Keith Morris (CALM) spoke about parks acquired in Western Australia, surrounded by landholders who value feral goats. Mike Braysher mentioned hunting groups based in Sydney which acquire rural lands and stock them with pigs and goats.

While pest management can operate on a nil-tenure approach, biodiversity conservation usually cannot. Biodiversity within the Rangelands is spread across three key categories of land tenure:
1) Grazing lands (private land and leasehold)
2) Public lands (including national parks)
3) Indigenous lands.

Conservation on each kind of land tenure is constrained in different ways.

Grazing lands

On grazing lands, biodiversity conservation is often a low priority compared to productivity. Graziers may care about biodiversity but they are too preoccupied with problems (drought, plague locusts, low incomes) to do anything, and rate it as a low priority. As Mike Braysher (UC), said: ‘It’s very hard to be green when you’re in the red’. Graziers in this situation need incentives and resources, or at least support.

Those who are making a profit are more likely to practise conservation, but making a profit need not translate into conservation.

Many, if not most, landholders practise some feral animal control. Agricultural pests are more likely to be controlled through co-ordinated efforts because there is a common goal between the farmers and conservation agencies. However, when control is undertaken primarily for conservation, motivating landholders can become difficult. Major pests on farms are likely to be controlled more heavily than the same pests in national parks, leading to complaints from nearby farmers. But the levels of control that meet production needs are not always high enough to benefit the local biodiversity. The rabbits preventing mulga regeneration in South Australia occur at such low densities that landholders cannot be convinced there are any rabbits there. The level of goat culling that suits landholders is not necessarily sufficient to bring back rare plants.

Public Lands

A range of techniques are used to control various feral animals on public lands. As noted in the next section, effective control is often compromised by lack of knowledge about pest impacts, lack of resources in remote regions, lack of suitable control techniques, and lack of adequate monitoring.

Success is more likely if control is part of a larger co-ordinated campaign involving adjoining landholders. PESTPLAN offers a way to achieve this. If PESTPLAN cannot be made to work, the fall-back position is control undertaken in isolation on public lands.

Indigenous lands

Indigenous lands are unusual in being private lands by tenure but public lands by management.

Aboriginal communities often come to value feral pests (camels, cats and rabbits) and may oppose their control.

<u>What don't we know?</u>

Lack of information emerged as a key theme for the workshop. The information gaps fell into four main categories:

1. All too often we don't know what impact feral animals are having. Very little is known, for example, about the impacts of deer, camels and donkeys. We don't know enough about cats. Even among those species that are well-studied, major information gaps remain. For example, there is clear evidence that foxes suppress certain rare species (e.g. rock wallabies), but that does not mean that foxes are causing biodiversity losses everywhere they occur. Unrealistic assumptions are often made, for example that foxes threaten black cockatoos.
2. We don't know enough about interactions between species. Do dingoes suppress foxes or is that a myth? Do foxes help in some situations by eating rabbits which might otherwise eliminate rare plants? Does dingo control increase rabbit numbers? How do overabundant kangaroos influence feral animal impacts and contribute to them?
3. There is too little monitoring of control programs. Baits are laid and pests die but all too often without any quantified benefit to biodiversity. We are often unable to say that this baiting regime delivers better biodiversity outcomes than some other regime, because no monitoring is undertaken, or it does not last long enough. Monitoring can be very difficult, e.g. how to count cats when they are shy and their numbers are low, and is thus expensive. And where biodiversity monitoring is undertaken it is sometimes inconsistent between states. Because monitoring is expensive, innovative monitoring techniques involving community observers would be desirable, but community members are difficult to motivate and the data they submit might not be reliable.
4. While there are many methods of control available, gaps remain. Protocols for controlling deer have not been developed, cat control in some states 'remains in the *too hard* basket', methods are needed for controlling rabbits at very low densities, and better baits are needed for pigs.

Of these four categories: 1 and 3 were emphasised strongly during the workshop. We do not know enough about the impacts of feral animals on biodiversity, and we do not know enough about the impacts on biodiversity of feral animal control. We often operate on 'best bet' rather than 'best practice'. Good results are often achieved despite lack of precise information, but all too often control efforts are wasted.

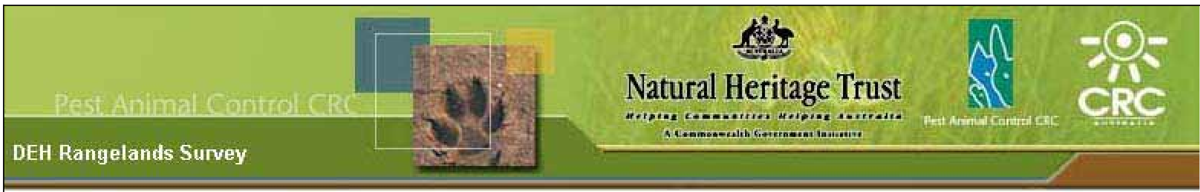
<u>Some comments</u>

The workshop was undertaken largely to help guide DEH funding into pest management.

The Rangelands are vast and sparsely-populated. There will never be enough funds or manpower to control pests throughout. Control actions should be concentrated into key areas rather than spread dilutely over large areas. Conservation goals need to be prioritised carefully. Given the limited resource base, saving threatened species and threatened habitats should be priority goals for DEH funding.

More needs to be known about the impacts of pests and the impacts of pest control. Research is expensive and funding is difficult to obtain. The DEH should look favourably upon NHT applications that incorporate proper research on pest impacts and proper monitoring. The monitoring programs should be sound enough that they measure genuine impacts upon biodiversity, but realistic enough that they will be maintained through time, not abandoned after early successes are achieved.

Appendix B Stakeholder survey form



Feral animals have been identified as one of the main threats to biodiversity in Australian rangelands. The Department of Environment and Heritage and Pest Animal Control CRC are seeding a greater understanding of the effectiveness of current legislation and management arrangements for the management of feral animals in the rangelands to:

- help identify priorities for action;
- target Australian Government investment;
- inform national and regional natural resource management decision-making; and
- assist in setting strategic directions for programs and policies to achieve biodiversity conservation in the rangelands.

To most effectively understand the current state of affairs, we need information from those who work closely with such issues on a day-to-day basis - the stakeholders. We would therefore like to invite your input into the future of feral animal management for rangeland biodiversity conservation. Please complete and submit this survey which will take approximately 20 minutes. Thankyou for your time and cooperation.

Respondent Information

Please enter your full name ______

Position ______

Organisation ______

Contact number ______

Email address ______

Please enter the location or region where you are based. ______

Are you happy for your individual responses to be made available to the Australian Government Department of Environment and Heritage?

○ Yes ○ No

In what capacity are you involved in biodiversity conservation and / or feral animal management in Australian rangelands?

○ State agency
○ Rural lands Protection Board
○ Community Group
○ Catchment Authority
○ Researcher
○ Private land manager
○ Other - please specify below

Please enter further details for the 'other' item you entered above. ______

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Introduced Species

What introduced species are a key threat to the natural environment and biodiversity in your region? In your experience, are the problems getting better or worse.

	Scale of Impact				Is the problem getting worse?		
	None	Low	Medium	High	Worse	Same	Better
Feral pigs							
Wild Dogs (including dingoes)							
Feral Cats							
Foxes							
Rabbits							
House Mouse							
Feral Camels							
Feral Goats							
Feral Horses							
Feral Cattle							
Water Buffalo							
Deer							
Cane Toads							
Common Starling							
Indian Mynah							
Carp							
Tilapia							
Other - please specify below							

Other species

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Threatened species - National

How many threatened or endangered species, listed on the **National Threatened Species List (EPBC Act 1999)** are there in your region? Which of these are threatened by feral animals?

Number of NATIONALLY threatened / endangered PLANT species: 0

NATIONALLY threatened PLANT species most effected by feral animals:

Number of NATIONALLY threatened / endangered ANIMAL species: 0

NATIONALLY threatened ANIMAL species most effected by feral animals:

Threatened species - Local

What species are **LOCALLY** threatened in your region (i.e. NOT nationally threatened)? Which of these are threatened by feral animals?

Number of LOCALLY threatened / endangered PLANT species: 0

LOCALLY threatened PLANT species most effected by feral animals:

Number of LOCALLY threatened / endangered ANIMAL species: 0

LOCALLY threatened ANIMAL species most effected by feral animals:

Regional Biodiversity

What areas of rich biodiversity or environmental significance are in your region? Are these threatened by feral animals?

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Impacts

What type of impacts are introduced animals having on the natural environment in your region?

	Predation	Habitat destruction	Resource competition	Displacement of natives	Spread of disease
Feral pigs	☐	☐	☐	☐	☐
Wild dogs (including dingoes)	☐	☐	☐	☐	☐
Feral cats	☐	☐	☐	☐	☐
Foxes	☐	☐	☐	☐	☐
Rabbits	☐	☐	☐	☐	☐
House mouse	☐	☐	☐	☐	☐
Feral camels	☐	☐	☐	☐	☐
Feral goats	☐	☐	☐	☐	☐
Feral horses	☐	☐	☐	☐	☐
Feral cattle	☐	☐	☐	☐	☐
Water buffalo	☐	☐	☐	☐	☐
Deer	☐	☐	☐	☐	☐
Cane toads	☐	☐	☐	☐	☐
Common starling	☐	☐	☐	☐	☐
Indian mynah	☐	☐	☐	☐	☐
Carp	☐	☐	☐	☐	☐
Tilapia	☐	☐	☐	☐	☐
Other - please specify below	☐	☐	☐	☐	☐

Other species for Impact question

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Best Practice Management

What feral animal and biodiversity best practice plans are available and implemented in your region?

Management Tools

What management tools are currently implemented to curb the impacts of feral animals on biodiversity in your region? How effective are these strategies?

	Extent of use				Effectiveness			
	Not used	Limited use	Moderate use	Widely used	Not Successful	Limited Success	Average Success	Very Successful
Baiting & poisoning								
Shooting								
Trapping								
Repellants								
Fencing								
Habitat Restoration								
Harvesting								
Habitat destruction (eg. warren ripping)								
Biological/Disease/Viral control								
Other - please specify								

Other management tools

Hindrances

What do you perceive to be the most important hindrances to feral animal management in the Rangelands?

	Not Important	Somewhat Important	Important	Very Important
Knowledge of the biodiversity of the region				
Knowledge of feral animal impacts				
Funding				
Strategies and best practice management plans				
Community support				
Political support				
Legislation				
Understanding of the significance of biodiversity				
Conservation reserves				
Appreciation of 'common habitat' as important regional biodiversity				
Management tools				
Ownership of the problem				
Landholder incentive				
Other - please specify below				

Other

What types of new management tools and strategies would you like to see developed?

Co-ordination

Is feral animal management co-ordinated between landholders within your region or with other regions? ○ Yes ○ No

If so, how many people, groups or regions are typically involved?

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Legislation

What legislation currently influences management of feral animals in your region (please specify State or Commonwealth)? How effective is this legislation and what improvements can be made?

What amendments to legislation would you like to see implemented?

Risk Assessment

Are we doing enough to curb the spread of established feral animals in the Rangelands and how can this be improved?

Is enough being done in Australia to prevent new feral animal incursions?

○ Yes ○ No

How do you think the next feral animal incursions in the Rangelands are likely to occur?

- ☐ Escape of domesticated stock
- ☐ Unassisted expansion of range
- ☐ Other
- ☐ Release of pets
- ☐ Accidental importation
- ☐ Human assisted movement
- ☐ Malicious release

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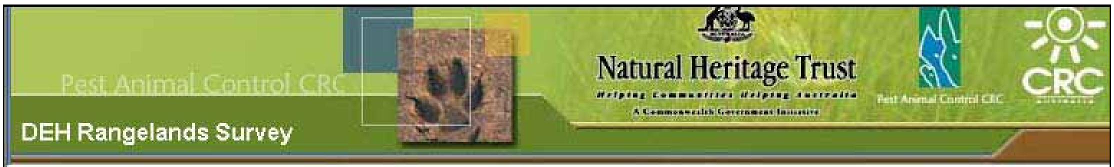

Knowledge

What knowledge would assist in better management of feral animals in your region - i.e. where do you think future research should be focussed?

	Not Important	Somewhat Important	Important	Very Important
Feral animal distribution	○	○	○	○
Feral animal impacts	○	○	○	○
Local biodiversity	○	○	○	○
Threatened species ecology	○	○	○	○
Biodiversity hotspots	○	○	○	○
Management tools	○	○	○	○
Management strategies	○	○	○	○
Land owner responsibilities	○	○	○	○
Legislation	○	○	○	○
Other - please specify below	○	○	○	○

Other [ ]

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Do you have any other comments, suggestions or concerns? For example, are there specific ways in which the Australian Government can more effectively help in the management of feral animal impacts on biodiversity in your region?
Thankyou for your time and cooperation.
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Appendix C Database on past NHT funded projects

A database of NHT funded feral animal control projects for biodiversity conservation within the rangelands accompanies this report. Where the information has been provided, the projects within this database have be labelled with key search words so they can be sorted by project code, state, NHT region, feral animal species and control technique. The lack of information provided for many projects made this task somewhat difficult and it is recommended that more detailed project descriptions be entered on the DEH database in the future to enable more effective data searches.

The projects that have been or are being undertaken on feral animals in the rangelands are listed below. Please refer to the full database for more details.

NHT Region	Project title
NSW	
Border Rivers	BMPs for NREM management in the Border Rivers/Gwydir (salinity riverine ecosystem soils and biodiversity focus)
Border Rivers	Extension activities for improved natural resource management in the Border Rivers/Gwydir
Border Rivers/Gwydir	Nullamanna native vegetation enhancement and management stage two
Border Rivers/Gwydir	Nullamanna Catchment corridor stage II
Border Rivers/Gwydir	Revegetation to combat salinity in the Bannockburn area project
Border Rivers/Gwydir	Reduction of feral pigs in the Woodside Road Landcare group's area
Border Rivers/Gwydir	Protection of rainforest and rainforest riparian areas
Border Rivers/Gwydir	F.E. Richardson conservation site
Border Rivers/Gwydir	Relocate watering points to prevent creek degradation north of Warialda
Border Rivers/Gwydir	Biodiversity enhancement, feral animal and weed control program, Keera
Border Rivers/Gwydir	Nest boxes for native birds at Boorolong, Armidale, NSW
Border Rivers/Gwydir	Initial data and information requirements for Border Rivers catchment blueprint implementation
Border Rivers/Gwydir	Managing vegetation for conservation in the Darling Riverine Plains and Brigalow Belt South bioregions of the NSW Border Rivers Catchment
Border Rivers/Gwydir	Data/Information Analysis in the Gwydir Catchment
Border Rivers/Gwydir	BMPs for NREM management in the Border Rivers/Gwydir (salinity riverine ecosystem soils and biodiversity focus)
Border Rivers/Gwydir	Salinity control in the Spring Creek Catchment, South of Bonshaw
Border Rivers/Gwydir	Salinity control in the Long Flat Creek Catchment, Northeast of Inverell
Border Rivers/Gwydir	Staggy Creek streambank erosion control project
Border Rivers/Gwydir	Erosion control in the Rob Roy Creek Catchment, West of Inverell
Border Rivers/Gwydir	Horton River riparian zone restoration and drought proofing scheme - Bingara
Border Rivers/Gwydir	Nullamanna drought action and land rehabilitation plan
Border Rivers/Gwydir	Reducing the risk of intensifying gully erosion after drought, Warialda
Border Rivers/Gwydir	Reducing the Impact of drought at sensitive areas within the Malpas Catchment
Border Rivers/Gwydir	Gully erosion stabilisation and revegetation
Border Rivers/Gwydir	Severn River protection and alternative watering points
Border Rivers/Gwydir	Reducing the impact of erosion and stock on Kentucky Creek
Border Rivers/Gwydir	Erosion control and gully reclamation
Border Rivers/Gwydir	Revegetation, salinity awareness and control in the Pindari Creek Catchment
Border Rivers/Gwydir	Myall Creek waterway protection and erosion control project
Border Rivers/Gwydir	Ngoorabul Lands - riparian management on Severn River
Border Rivers/Gwydir	Gineroi Landcare group salinity and erosion reduction plan, Gwydir Catchment

Border Rivers/Gwydir	Protecting the riparian area along Beardy Waters at "Ben Venue"
Border Rivers/Gwydir	Mosquito Creek headwater erosion and revegetation project, Delungra
Border Rivers/Gwydir	Creek Bank restoration and erosion control
Border Rivers/Gwydir	Sustainable living and production practices demonstration site S.E. of Inverell
Border Rivers/Gwydir	Protecting and restoring eroded gullies and extending wildlife habitat in the Upper Gwydir River Catchment
Border Rivers/Gwydir	Furracabad Catchment revegetation for sustainable agriculture and Biodiversity
Border Rivers/Gwydir	Erosion stabilisation, cleaner water, enhanced biodiversity, in the Upper Gwydir Catchment, Armidale, NSW
Border Rivers/Gwydir	Riparian zone protection, biodiversity enhancement and salinity reduction at Gineroi
Border Rivers/Gwydir	Stage two - revegetation of Postman's Creek, Warialda
Border Rivers/Gwydir	Land management works on "Silver Dale" and "Lone Pine"
Central West	Wuuluman remnant vegetation Preservation
Central West	Catombal range natural vegetation preserve
Central West	Re-establishment of native vegetation and reduce siltation of Bourbin Catchment
Central West	Urabrible dung beetle reintroduction project to improve water quality and nutrient cycling
Central West	Future progress - will the nasties increase in the Little River Catchment, NSW?
Central West	Little River fencing project stage 5
Central West	Blitz on feral animals, Warrumbungle, NSW
Central West	Continued brush-tailed rock-wallaby protection
Central West	'Thurn' remnant native vegetation and grazing pressure management project
Central West	Little River fencing project stage 3
Central West	Trail for baseline water quality using biological indicators in the Macquire Marshes
Central West	Habitat corridor enhancement for three recently identified threatened species
Central West	Barbigal/Talbragar salinity project
Central West	Environmental rehabilitation and community education in Boundary Road Reserve, Bathurst NSW
Central West	Protecting fragile river frontage to Macquarie River and adjacent land, Wellington NSW
Central West	Drought recovery and protection of Poplars Shearing Shed riparian zone along Curra Creek
Central West	Talbragar Catchment waterway protection
Central West	Relocating watering points and fencing-off sensitive vegetation and creek areas
Central West	Improving water quality and sustaining native riparian Biodiversity of Davy's Creek
Central West	Improving the quality of water leaving the Tallawang Sub-catchment
Central West	Queen Charlotte Vale Creek regional rehabilitation and revegetation program - stage 3
Central West	Upper Castlereagh Rivercare
Central West	Belgravia watercourse and revegetation project
Central West	Nature conservation area on Tinda Hill (NSW Rangelands)
Central West	Bell River system flora and fauna corridor development NSW
Central West	Reducing erosion, controlling salinity and improving water quality in the Talbragar River
Lachlan	Bruie Plains Landcare stabilisation and revegetation
Lachlan	Creating a nature conservation area on "Traquair" in the NSW rangelands
Lachlan	Bruie Plains Landcare drought recovery project
Lachlan	Benchmarking community attitudes towards natural resource management within the Lachlan Catchment
Lachlan	Foundation building for strategic investment in vegetation management at a landscape scale - Lachlan Catchment

Lachlan	Rehabilitation of Boorowa River / Hovell's Creek Catchment at Graham, NSW
Lachlan	Bolong restoration and conservation project
Lachlan	Conapaira West Landcare riparian zone fencing project
Lachlan	Restoration and revegetation of Morongla Creek Catchment
Lachlan	Stabilisation and revegetation of the Eulimore Catchment
Lachlan	Fencing off four sensitive sites in the Upper Lachlan to regenerate remnant vegetation and wetland vegetation
Lachlan	Burrangong Creek protection and replacement planting project
Lachlan	Yass River riparian restoration - phase 1
Lachlan	Continuation and extension of the Saltshaker project
Lachlan	Rehabilitating the catchment of Hovell's Creek and Boorawa River, Graham
Lachlan	Revegetation and salinity management of Riley's Creek headwaters
Lachlan	Restoration and revegetation of Morongla Creek Catchment - stage 2
Lower Murray/Darling	Rabbit warren ripping to enhance the regeneration of *Acacia carnei* post RCD
Lower Murray/Darling	Endangered species protection through fox control at Sunnyside Station
Lower Murray/Darling	Lower Murray Darling rangeland management action plan
Lower Murray/Darling	Rabbit eradication on Glen Esk Station
Lower Murray/Darling	'Our Darling' - The anabranch revival
Lower Murray/Darling	Threatened species recovery via restriction of artifical water sources and feral animal control at Scotia, NSW
Lower Murray/Darling	Protecting and restoring the habitat of threatened species west of Wentworth
Lower Murray/Darling	Lower Murray Darling Catchment rangeland management project
Lower Murray/Darling	Lower Murray Darling Catchment aquatic health project
Murray	Community Sandhill ecosystem reconstruction
Murray	Manoora Sanctuary
Murray	Upper Red Creek Catchment stabilisation
Murray	Fox baiting - North Conargo
Murray	Better pest animal management in Holbrook's nature conservation sites
Murray	Cunninyeuk Sandhill habitat restoration and protection project
Murray	Protecting the plover - fencing out foxes in the Jindera District
Murray	Fish management benchmarking and monitoring
Murray	NHT - benchmarking and monitoring
Murray	Culcairn community wetland
Murray	Yambla Creek erosion and nutrient mitigation project
Murrumbidgee	Picaree Hill conservation project
Murrumbidgee	South-west rabbit control management plan phase 3
Murrumbidgee	Enhancing the environment for preservation of superb parrots
Murrumbidgee	Restoration of riparian vegetation in the Sandy Creek Catchment to enhance wildlife habitat
Murrumbidgee	Benara Sandhill conservation project
Murrumbidgee	Revegetation enhancement method trial to return to pre-grazing conditions
Murrumbidgee	Aquatic biota enhancement
Murrumbidgee	Identify and locate high conservation value terrestrial and aquatic sites within the Murrumbidgee Catchment
Murrumbidgee	Flora of the Murrumbateman District - a pocket guide
Murrumbidgee	Moppity Road revegetation
Murrumbidgee	North Matong revegetation project
Murrumbidgee	Winchendonvale remnant vegetation enhancement and perennial pasture establishment
Murrumbidgee	Sandy Creek & Lake Albert Catchment stabilisation
Murrumbidgee	Riparian restoration in the Yass River Sub-Catchment
Murrumbidgee	Addressing erosion, salinity and biodiversity in the Oura Catchment
Murrumbidgee	Hartfield gully rehabilitation
Murrumbidgee	Wetland protection on 'Nalyappa' in the Yaouk Valley

Murrumbidgee	Oura wetland enhancement
Murrumbidgee	O'Brien's Creek Wetland biodiversity project
Murrumbidgee	Extending the restoration of the Upper Reaches of Jugiong Creek
Murrumbidgee	2005 Wallandoon East tree planting
Murrumbidgee	Increasing biodiversity in Kingsvale
Murrumbidgee	Turvey's Fall wildlife corridor and erosion control project - stage 1
Murrumbidgee	Rehabilitation of Native Dog Creek - "The Trig", Muttama
Murrumbidgee	Addressing erosion, Biodiversity and Salinity in the Coreinbob Catchment
Murrumbidgee	Environmental Management of the Jugiong Creek Catchment
Namoi	Melita Gully control and revegetation
Namoi	Best management practices for the management of wetlands and identification of environmental weeds and pests of the Namoi
Namoi	Enhancing the riparian ecosystem of Coomoo Coomoo Creek
Namoi	Asset cost-benefit analysis
Namoi	Biodiversity benchmarking for the Namoi Catchment
Namoi	Protection of vegetation on Waterfall Creek and Lone Pine
Namoi	Waterway protection on catchment of Boiling Down Creek
Namoi	Creating a buffer zone around Dry Creek in the Namoi Catchment
Namoi	Fencing and maintenance of Nobby's Rock Landcare tree corridor project
Namoi	Stabilisation of incising waterways on Quipolly Floodplain
Namoi	Reversing erosion and enhancing biodiversity in the Namoi
Namoi	Protecting remnants and creating wetlands in the Kangaroo Creek Catchment
Namoi	Heifer Creek and Sandy Creek rehabilitation
Namoi	Protecting Grassy Box woodland in Bolton's and Clay Creeks, Tamworth, NSW
Namoi	Wildlife corridors and fencing to protect riparian vegetation, Woolbrook
Namoi	Solutions for a healthy catchment on the Liverpool Plains
North Central	Cummeragunja sandhill revegetation
Western	Role of goat production as a range restoring alternative enterprise
Western	Regeneration of native perennial grasses hard red mulga country
Western	Wetland rehabilitation north-west of Goodooga on the Culgoa River
Western	Darling River natural heritage initiative
Western	Feral animal control on Bellara
Western	Integrated total grazing pressure project at Gumbooka
Western	Minimise land and water Degredation, north of Brewarrina, NSW
Western	Protecting the dry Bogan River bank
Western	Improve grazing management practices during drought conditions
Western	Fencing off Warrego at Lower Lila and polly piping water
Western	Prioritising pest animal and weed threats in the Western Catchment
Western	Fencing to protect riparian vegetation and minimise erosion on "Glen Villa", Bourke, New South Wales
Western	Fencing for management and conservation of Paroo River floodplain
Western	Wetland managed grazing, Darling River
Western	Protecting the Paroo River at Talyealye
Western	Fencing off Mukudgeroo Waterhole on the Cuttaburra
Western	Protecting Barwon River and linking 3000 ha coolabah/blackbox woodlands
Western	Reducing total grazing pressure on the Warrego River, Ford's Bridge

NT

Northern Territory	*Ptychosperma bleeseri* recovery plan phase 2 (interim action)
Northern Territory	Titjikala bush regeneration and dust suppression project
Northern Territory	John Holland bore community land rehabilitation
Northern Territory	Stock exclusion fencing Mount McMinn Roper River
Northern Territory	Longevity of 1080 meat baits in arid Australia
Northern Territory	Central rock-rat interim recovery plan (implementation)

Northern Territory	Integrated rangeland management in the Victoria River District
Northern Territory	Implementation of the carpentaria rock-rat (*Zyzomys palatalis*) recovery plan
Northern Territory	Goat management on Weyirra
Northern Territory	Demonstration of ecologically sustainable management of camels on Aboriginal and pastoral land
Northern Territory	The impact of wild dog control on cattle, native and introduced herbivores and introduced predators
Northern Territory	Post-RCD rabbit control to benefit threatened species in the Finke Bioregion
Northern Territory	Rangelands rehabilitation - Paddy's Plain
Northern Territory	Co-ordinating a Jawoyn "One Nation" land management workforce
Northern Territory	Stock exclusion fencing of the Hodgson River on Mt McMinn Station
Northern Territory	Exclusion fencing along Jalboi and Flying Fox Rivers, Big River Station
Northern Territory	Flying Fox Station stock exclusion fencing of the Roper River
Northern Territory	Land management and capacity building of traditional owners of Wagiman Aboriginal lands
Northern Territory	Lonesome Dove stock exclusion fencing along the Roper and Flying Fox Rivers
Northern Territory	Vegetation and feral animal management around Mabunji outstations
Northern Territory	Managing vegetation around Wurlbu outstation
Northern Territory	Feral and stock exclusion fencing of nillabongs on West Elsey
Northern Territory	Feral animal and stock exclusion fencing of the Beswick Creek
Northern Territory	Protection and restoration of Lake Duggan - Lakefield Station
Northern Territory	Lajamanu outstations environmental rejuvenation project
Northern Territory	*Acacia Peuce* conservation on Andado Station
Northern Territory	Developing home land rangers for healthy water, healthy land, healthy people
Northern Territory	Wardaman Landcare
Northern Territory	Weemol Landcare
Northern Territory	Jodetluk and Werenbun Landcare
Northern Territory	Barunga Landcare
Northern Territory	Wugularr Landcare
Northern Territory	Manyallaluk Landcare
Northern Territory	Biodiversity conservation on private lands in central Australia through the land for wildlife program
Northern Territory	Surveying and planning for sustainable land management on Wagiman Lands, NT
Northern Territory	Vegetation management and monitoring at Daminmin Rainforest to protect *Ptychosperma bleeseri* (Endangered EPBC)
Northern Territory	On-ground works including volunteer supervision and training, Newhaven Reserve
Northern Territory	Wanga Djakamirr ranger footwalk of the Arafura Swamp
Northern Territory	Crazy ant management and eradication in north north-eastern Arnhem Land
Northern Territory	Feral animal control in the VRD region
Northern Territory	Land & learning extension - building capacity for species recovery work in Aboriginal communities
Northern Territory	Fencing of *Acacia peuce* relict populations on Andado Pastoral Station
Northern Territory	Wagiman rangers capacity building through environmental management in the Upper Daly Region
Northern Territory	NRM management for the Groote Archiplego (NT National Statewide)
Northern Territory	Building capacity for land management and biodiversity survey at Kaltukatjara (Docker River), NT
Northern Territory	Biodiversity conservation on private lands in central Australia through the land for wildlife program
Northern Territory	Fencing Nangalala Waterhole and Springs
Northern Territory	Crazy ant management and eradication
Northern Territory	Dust suppression Epenarra community
Northern Territory	Raising awareness of biodiversity issues in relation to grazing management

Northern Territory	Continued implementation of the carpentarian rock rat recovery plan
Northern Territory	Natural Resource Management Inventory
Northern Territory	Regional priorities for threatened species management in the Northern Territory
Northern Territory	Development of environmental management status reports for Aboriginal lands in the Northern Land Council region
Northern Territory	Relocating stock watering points to restore riparian vegetation, Mittiebah Station
Northern Territory	Extending sustainable management of the Playford River
QLD	
Border Rivers (QLD)	Improving water quality through revegetation of catchment and riparian areas
Border Rivers (QLD)	Conservation of the Moonie River riparian ecosystem and adjacent endangered ecosystems
Border Rivers/Gwydir	Reducing delays to fish spawning migrations at barriers with fishways
Burdekin	Modified northern hairy-nosed wombat recovery plan phase 2
Burdekin	Rehabilitation of fish habitats in the Burdekin Delta distributary streams
Burdekin	Management of native pasture, water and feral pigs in the Seventy Mile Range savanna woodlands
Burdekin	Rehabilitation of fish habitats in the Burdekin Delta distributary streams (NRC)
Burdekin	Northern hairy-nosed wombat recovery plan phase 2
Burdekin	Riparian zone management - Central Upper Burdekin Catchment (NRC)
Burdekin	Riparian zone management - Central Upper Burdekin Catchment (NLP)
Burdekin	Minimising grazing impacts on waterways, Cape/Campaspe region, Charters Towers
Burdekin	Identification and management of endangered plants of the Townsville region
Burdekin	Management of critical fish habitat in the Haughton River catchment
Burdekin	Indigenous training and aquatic habitat management - Paluma and Running River, Queensland
Burdekin	Completion of the fence of Rainmore nature refuge
Burdekin	Protection of natural waterholes in the headwaters of the Belyando River Catchment
Burdekin	Integrated riparian zone management of Upper Ross River
Burdekin	Protection of the intrinsic waterholes and banks of Maryvale Creek, Burdekin Catchment, Queensland
Burdekin	Protection of natural waterways through efficient water use in the Three Rivers Catchment
Burdekin	Relocation of watering points to rehabilitate the Kinrara Wetland
Burdekin	Practical solutions for gully erosion on sodic soil - an erosion hotspot in the Burdekin Catchment, Queensland
Burdekin-Fitzroy	Whole-of-catchment assessment and prioritisation of wetlands and waterways
Burdekin-Fitzroy	Development and implementation of a community and stakeholder NRM infobase and community involvement process for the Burdekin dry tropics region
Burdekin-Fitzroy	Engaging Aboriginal traditional owner participation in NAPSWQ in the Burdekin dry tropics
Cape York	The Cape York weeds and feral animal project
Cape York	Rehabilitation of Cullen Point to Janie Creek-Mapoon
Cape York	Land and sea management co-ordinator for the Wik and Kugu momelands and ranger service
Cape York	Land and sea management plan and MOU for co-operative management - Hopevale
Cape York	Rehabilitating degraded sites for community education, Hopevale DOGIT, Upper Endeavour River Catchment
Cape York	Cape York - weed and feral animal program - Landcare
Cape York	Cape York - Hopevale Rangers

Cape York	Ambiilmungu-Ngarra traditional owner management and protection of coastal foreshore vegetation
Condamine	Eastern Darling Downs escarpment project - stage 2
Condamine	Restoring the ecology and biodiversity of Klein Creek
Condamine	Securing the natural resources of the Upper Willowvale Catchment
Condamine	Balancing ecological sustainability and economic profitability via environmental management systems
Condamine	Upper Perrier Gully Catchment conservation group
Condamine	Bunya Mountains and Western Foothills biodiversity enhancement project
Condamine	Yamison - Rangemore Upper Myall Creek protection and rejuvenation project
Condamine	Working together to reduce degradation in the Jandowae Cooranga Catchment
Condamine	Further expanding the creek and gully fencing areas of Gin and North Myall Creeks, Queensland
Desert Channels	Artesian Springs Fishes, recovery plan
Desert Channels	Protecting the natural resources of Regleigh Holding
Desert Channels	Desert Channels - cross catchments weeds and feral animal initiative Landcare
Desert Channels	Rehabilitation of Western and Dominie Creeks
Desert Channels	Tower Hill and Blackfella Creeks' rehabilitation project
Desert Channels	Improved grazing management of the Channel Country on "Dover" (Boulia)
Desert Channels	Thornton project - protecting the environment of Towerhill Creek
Desert Channels	Restoration of degraded areas on Back Creek Catchment
Desert Channels	Rehabilitating Thomson River floodplain and Horseshoe Creek channels
Desert Channels	Fencing to protect "Bellview" nature refuge
Fitzroy	Exotic fish road signs
Fitzroy	Bridled nailtail wallaby recovery plan - bringing back the flashjack (combined projects bridled nailtail wallaby recovery plan (phase 2) and bringing back the flashjack)
Fitzroy	Springton Creek native ecosystem regeneration project
Fitzroy	N320 - fencing and monitoring infrastructure on the bush heritage Goonderoo Reserve
Fitzroy	Riparian and land management on the Maranoa River
Fitzroy	Protection and management of remnant softwood scrub surrounding the Bomboolba group of mountains
Fitzroy	Toadbusters
Fitzroy	Preservation of remnant vegetation at the headwaters of Injune Creek, Queensland
Fitzroy	Protection of unique swamp area adjacent to the Great Dividing Range, Injune
Fitzroy	Protection of artesian spring on Carnarvon Station reserve
Fitzroy	Central highlands bird monitoring and mapping project
Fitzroy	Identification of common eucalypts of the Dawson and Callide Valleys
Fitzroy	Dawson River riparian management - vegetation protection and stock condition improvement
Fitzroy	Protecting the upper catchment of Poor Man's Gully and North Kariboe (North Branch)
Fitzroy	Reducing point source sediments in the headwaters of Bridge Creek
Fitzroy	Fencing to protect endangered flash jack on "Avocet" nature reserve
Mackay Whitsunday	Proserpine rock-wallaby recovery plan, phase 2
Maranoa Balonne	Evaluation and development of best practice wild dog management
Maranoa Balonne	Fish habitat issues in the Murray-Darling Basin
Maranoa Balonne	Implementing sustainable land use techniques on degraded land types in the Maranoa River/Neabul Creek watershed
Maranoa Balonne	Improve water wuality, biodiversity and stop soil erosion over 10.2km section of Wallum

Maranoa Balonne	Action to stabilise soil resources in the Bungeworgorai Creek Sub-catchment, Roma, Queensland
Maranoa Balonne	QMDC - On ground weed and pest animal prevention and management in the Maranoa Balonne & Border Rivers - Bushcare
Maranoa Balonne	Protection and preservation of the Balonne River on Binnieanna
Maranoa Balonne	Fencing 2200ha for preservation of habitat for native flora and fauna
Maranoa Balonne	Riparian fencing of Coxson Creek, Wallumbilla
Maranoa Balonne	Protection of anabranch riparian areas - Pialaway, Upper Balonne River
Maranoa Balonne	Dargal Creek
Maranoa Balonne	Gully erosion and revegetation project
Maranoa Balonne	Maintain the Biodiversity and enhance the stream habitat of the Colamba Creek riparian zone
Maranoa Balonne	Stabilising soil resources in the Hunters Creek Catchment
Northern Gulf	Strategy development Eastern Gulf-Gilbert River Catchment
Northern Gulf	Report on environmental issues Norman River Catchment
Northern Gulf	Protecting a natural spring in partnership with the Takalaka people and Alehvale Station
Northern Gulf	Protecting the natural values of Dingo Spring on Huonfels Station
Northern Gulf	To protect the environmental values of Whitewater ancient remnant rainforest
South West (QLD)	pasture regeneration in mulga lands
South West (QLD)	Rabbit control demonstration at Bulloo Downs and assessment of value of rabbit control in the south-west Queensland region
South West (QLD)	QLD save the bilby: predator proof breeding enclosure and reintroduction program
South West (QLD)	Integrated rabbit control in south-west Queensland
South West (QLD)	Integrated feral predator control in south-west Queensland
South West (QLD)	Setting conservation priorities and management guidelines for SWQ wetlands
South West (QLD)	Dish Hole feral goat management
South West (QLD)	Fencing off Junee Creek at "Teeswater" to protect head waters and remnant vegetation, Queensland
South West (QLD)	Reducing grazing pressures and controling feral animals
South West (QLD)	Participative monitoring of natural resource condition in south-west Queensland
South West (QLD)	Alpha Station wetlands regeneration project
South West (QLD)	Redistributing cattle away from Hoganthulla and Kennel Creeks, Augathella, SW Qld
South West (QLD)	Yanna Hill native vegetation restoration, Queensland
Southern Gulf	Julia Creek dunnart recovery plan (preparation and interim actions)
Southern Gulf	Producers implementing sustainable grazing to improve natural ecosystems
Southern Gulf	Southern Gulf Region Gulf riparian management- Rivercare
Wet Tropics	Wet tropics community based feral pig trapping program
Wet Tropics	Monitoring systems for feral pigs
Wet Tropics	Accelerated community based NRM outcomes in the Wet Tropics - component 2
Wet Tropics	Mazlin Creek rehabilitation project (stage 2)
Wet Tropics	Economic evaluation of feral pig control strategies in north Queensland
Wet Tropics	Clancy Estate wetland remnant rehabilitation project
Wet Tropics	Tolga scrub rehabilitation project - phase 2
Wet Tropics	Rehabilitation process for Barney Springs - a significant natural and cultural Site
Wet Tropics	Regeneration and enhancement of bushland and water quality in Warrama
Wet Tropics	Rehabilitation of degraded wetlands of the Leslie Creek Upper Catchment, Queensland
Wet Tropics	Hypsi forest and tree kangaroo recovery project
Wet Tropics	Grazing management demonstration to restore and protect key riparian ecosystems

Wet Tropics	Expansion and protection of endangered ecosystem 7.8.2, Malanda, Southern Atherton Tablelands
Wet Tropics	Protection of Michael Creek headwaters and springs
Wet Tropics	Rehabilitation of Pittendreagh Swamp, Molo Creek, Johnstone River Catchment
Wet Tropics	Increasing ground cover to stabilise Burdekin River frontage, "New Moon" Station, Queensland
Wet Tropics	Cattle exclusion and alternate watering facility at Berner Creek, Palmerston
SA	
Aboriginal Lands	Anangu Pitjantjatjara native vegetation threat abatement project
Aboriginal Lands	Maralinga native vegetation protection and Regeneration project
Aboriginal Lands	Preservation of local natural rock holes under threat from fouling by camels
Aboriginal Lands	Anangu Pitjantjatjara Yankunytjatjara land management feral herbivore control
Aboriginal Lands	Management of Yalata Indigenous Protected Area for the conservation of biodiversity
Aboriginal Lands	Anangu Pitjantjatjara Munta Atunmankuntjaku (caring for country)
Aboriginal Lands	Feral animal control on Aboriginal managed lands in South Australia
Aboriginal Lands	Reducing the damage caused by feral species to the Anangu Pitjantjatjara Lands
Aboriginal Lands	Watinuma feral enclosures
Aboriginal Lands	Management of the unique Everard Ranges utilizing traditional ecological knowledge
Aboriginal Lands	Tjilpil # 2 Wildlife Centre - conserving emus and kangaroos in the Anangu Pitjantjatjara lands
Aboriginal Lands	Feral animal and plant control – MT/Yalata/ALT
Aboriginal Lands	Feral carnivore and plant control- APY
Aboriginal Lands	Feral herbivore control program – APY
Aboriginal Lands	Feral herbivore control program – Develop strategies for control of ferals – APY
Aboriginal Lands	Feral animal and plant control Strategies - ALT
Eyre Peninsula	Feral animal threat mitigation - protecting and repairing Lower Eyre Peninsula's biodiversity
Eyre Peninsula	Integrated pest management for biodiversity
Eyre Peninsula	Protection of key threatened species and habitat on Eyre Peninsula
Eyre Peninsula	Wind erosion prevention in the central Eyre Peninsula Soil Board District
Murray Darling Basin	Gerard native vegetation project
Murray Darling Basin	Raukkan Aboriginal farm land conservation program
Murray Darling Basin	Improved flow management for the Markaranka Wetlands
Murray Darling Basin	Akuna Station River catchment and wetland rehabilitation
Murray Darling Basin	Piawalla Wetland rehabilitation
Murray Darling Basin	Katarapko Island habitat and species restoration program
Murray Darling Basin	Jaeschke Lagoon rehabilitation project
Murray Darling Basin	Thiele Flat wetland complex rehabilitation program
Murray Darling Basin	Barmera Scout Group Landcare project
Murray Darling Basin	Revegetation of Lot 1 Pt Sec 421 Hd Burdett
Murray Darling Basin	Native fish habitat restoration in the Angus River Catchment
Murray Darling Basin	Revegetation & protection of native scrub & animals west of Murbko South Australia
Murray Darling Basin	Implementation of the black-eared miner recovery plan
Murray Darling Basin	Riverglades Wetlands European carp eradication in Northern Lagoon
Murray Darling Basin	Eradication and control of poison buttercup and feral pigs from the Chowilla flood plain
Murray Darling Basin	Prioritise pest targets and locations to facilitate integrated efficient and effective control
Murray Darling Basin	Develop an integrated regional pest animal and plant program
Murray Darling Basin	Fencing Spectacle Lakes Wetland for habitat protection

Murray Darling Basin	Middle Bremer community riparian biodiversity enhancement project
Northern and Yorke Agricultural District	Revegetation and preservation of natural vegetation in vicinity of old Petherton Estate
Northern and Yorke Agricultural District	Gawler Ranges revegetation project
Northern and Yorke Agricultural District	Revegetation and preservation of natural vegetation in vicinity of Old Petherton Estate
Northern and Yorke Agricultural District	Restoration and native vegetation and Preservation of Nationally Endangered Plants in Halbury
Northern and Yorke Agricultural District	Managing remnant habitat for conservation in Beetaloo Valley
Northern and Yorke Agricultural District	Protection of native vegetation in the Coomooroo District (STB/OBT)
Northern and Yorke Agricultural District	Protection of native vegetation in the Coomooroo District
Northern and Yorke Agricultural District	Central Yorke Peninsula bush conservation project
Northern and Yorke Agricultural District	Lower North riverine project
Rangelands (SA)	Nantawarrina habitat restoration project
Rangelands (SA)	Nepabunna community revegetation project
Rangelands (SA)	Walatina native vegetation protection and regeneration project
Rangelands (SA)	The arid recovery project: erection of a rabbit proof fence
Rangelands (SA)	Arid recovery project - Roxby Downs
Rangelands (SA)	N535 - Secret Rocks Conservation Reserve
Rangelands (SA)	The arid recovery project: Roxby Downs (The Roxby Downs ecosystem restoration project)
Rangelands (SA)	Aroona Catchment biodiversity enhancement project
Rangelands (SA)	Arid recovery project
Rangelands (SA)	Control goats to reduce grazing pressure and protect biodiversity values
Rangelands (SA)	Revegetation and protection of degraded lands on Leigh Creek Station
Rangelands (SA)	Feral camel control program
Rangelands (SA)	Rangeland action project
Rangelands (SA)	Integrated rabbit control and revegetation recovery in pastoral areas
Rangelands (SA)	Arid recovery project
Rangelands (SA)	Arid recovery
Rangelands (SA)	Mulga (Acacia Aneura) revegetation at Bunkers Conservation Reserve, South Australia
Rangelands (SA)	Arid recovery
Rangelands (SA)	Bounceback
Rangelands (SA)	Lake Eyre Basin cross border and cross-catchment weeds and feral animals initiative – SA component
Rangelands (SA)	Rangelands action project
Rangelands (SA)	Identifying biodiversity priorities for the Stony Plains IBRA bioregion
WA	
Avon	Protection of the threatened rock wallabies at Querekin Rock ("The Granites")
Avon	Remnant vegetation protection and linkage project
Avon	Mount Caroline farm revegetation project Phase 2, Quairading - Yoting Road Kellerberrin
Avon	Implementation of the Narrogin District threatened flora management program
Avon	Implementation of recovery actions for threatened species and an ecological community in the Katanning District.
Avon	Freindy's creekline and remnant protection project

Avon	Protecting and rehabilitating Joshua's Wetland, South of Pingrup, WA
Avon	Implementing the protection priority listed remnants in the Chinocup Catchment
Avon	Talgomine Catchment better managing and protect our remnants project - Belmore Farm creek line
Avon	Protecting and enhancing Jordina's Granite outcrops
Avon	Woodland and biodiversity protection in the Upper Bonnie Rock Catchment, Mukinbudin
Avon	Fencing, covenanting and revegetation of woodland and granite ecosystems in the Upper Welbungin Catchment, Mt Marshall
Avon	Protecting Danberrin Catchments waterways through revegetation and Remnant protection
Avon	Protection of woodlands and heath in South Trayning, WA.
Avon	Remnant and waterway protection east of Lake Buchan
Avon	Revegetating creeklines in the Upper Yorkrakine Catchment
Avon	Protection and enhancement of remnant vegetation on Carlo Guerini's property
Avon	Protection and enhancement of remnant vegetation on Wayne Della Bosca's property
Avon	Protection and enhancement of remnant vegetation for biodiversity/conservation benefits
Avon	Protection and enhancement of remnant vegetation on Danny Quadrio's property
Avon	Protection and enhancement of remnant vegetation on Kim Stephen's property
Avon	Freindy's creekline and remnant protection project part 2
Avon	*Xanthorrhoea pressii* - sandalwood project - Quellington Hill - York WA
Avon	Remnant and waterway protection east of Lake Buchan - stage 2
Avon	Williams remnant protection project
Avon	Protection of remnant vegetation and hilltop catchment project, Westdale, Beverley
Avon	Protecting and enhancing remnant vegetation in the Cramphome Catchment
Avon	The Boyanning Creek restoration project
Avon	Mt Grey Catchment waterway Restoration and Karomin Road Reserve buffer Near Nungarin, WA
Avon	Remnant protection and revegetation at Mills Lakes Catchment, Ongerup, WA
Avon	Protecting creeklines on Kingswell, WA
Avon	Watercarrin catchment protection and restoration project
Avon	Protecting remnants and revegetation areas, Kuringup Catchment
Avon	Protection and rehabilitation of bushland at East Pithara
Northern Agricultural Region	*Eucalyptus rhodantha* (rose mallee) recovery plan phase 2
Northern Agricultural Region	West Mullewa Catchment revegetation and remnant protection project 1998-2000
Northern Agricultural Region	Irwin River catchment strategy (NVI)
Northern Agricultural Region	Irwin River catchment strategy (NLP)
Northern Agricultural Region	Kalannie revegetation and stabilization of drainage systems
Northern Agricultural Region	Yarra Yarra streamline evaluation and environmental impact survey (NLP)
Northern Agricultural Region	Mullewa District Bushcare and corridor network revegetation project
Northern Agricultural Region	East Three Springs Catchment corridor project
Northern Agricultural Region	Malleefowl preservation in drought stricken north-cental WA wheat belt
Northern Agricultural	Wetland and remnant vegetation rehabilitation, Upper Irwin River

Region	
Northern Agricultural Region	Classification and evaluation values and threat assessment of wetlands in the northern agricultural region
Northern Agricultural Region	Survey, protection and restoration of the Lower Hill River
Northern Agricultural Region	Lower Murchison River restoration project
Northern Agricultural Region	Fencing remnant vegetation, revegetation of creek line including planting habitat trees for breeding Carnaby's black cockatoos in the area
Northern Agricultural Region	Carnaby habitat protection
Rangelands (WA)	Fox population dynamics and control - isp#04
Rangelands (WA)	Djoongari (Shark Bay mouse) recovery plan phase 2
Rangelands (WA)	Thevenard Island mouse research and recovery phase 2
Rangelands (WA)	Developing total grazing control strategies in WA rangelands
Rangelands (WA)	Development of a cheap and efficacious fox bait (1999/2000)
Rangelands (WA)	Operation Wanjarri - optimising feral cat baiting strategies in the arid zone
Rangelands (WA)	Goat eradication on Peron Peninsula
Rangelands (WA)	Goat control on Zuytdorp Nature Reserve and pastoral leases in the Shark Bay World Heritage Property
Rangelands (WA)	Fox control on Nanga and Hamelin Stations
Rangelands (WA)	Aerial survey techniques for feral goats
Rangelands (WA)	Murchison Land Conservation District Committee's Murchison River restoration project
Rangelands (WA)	Assessing the effect of a reduction in baiting rates for wild dogs
Rangelands (WA)	Protection of Bullwolya Spring
Rangelands (WA)	Saunders Spring fencing project, WA (W082)
Rangelands (WA)	Moolyall - Woodenup Catchment land & water rehabilitation project
Rangelands (WA)	Meeline Station conservation, education and restoration project, Mt Magnet WA
Rangelands (WA)	Combating cane toads in the East Kimberley
Rangelands (WA)	Community NRM Planning for innovative land and wild dog management
Rangelands (WA)	Cane toad education project for Aboriginal people in the Kimberley region
Rangelands (WA)	The integrated conservation of *Baeckaea sp*. London Bridge and surrounding landscapes
Rangelands (WA)	Restoration of Lake Nallan and Milly Soak (Austin Lake Catchment)
Rangelands (WA)	Upper Murchison River restoration project
Rangelands (WA)	Fencing and reinstating watering points along the Pear Creek, Coongah Station WA
Rangelands (WA)	Fencing and erecting water points to protect Jabaddar Pool, "Peedamulla Station", WA
Rangelands (WA)	Conservation of riparian biodiversity in the Fitzroy River system (Central Kimberley)
Rangelands (WA)	Karajarri Land management project