AUSTRALIA'S

PEST ANIMALS

New Solutions to Old Problems

PENNY OLSEN

Bureau of Resource Sciences
AUSTRALIA

Australia's Pest Animals is based partially on the Bureau of Resource Sciences' Pest Animal Guideline series:

- Braysher, M (1993). Managing Vertebrate Pests: Principles and Strategies. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra
- Caughley, J, Bomford, M, Parker, B, Sinclair, R, Griffiths, J & Kelly, D (in preparation). Managing Vertebrate Pests: Rodents. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra
- Choquenot, D, McIlroy, J & Korn, T (1996). Managing Vertebrate Pests: Feral Pigs. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra
- Dobbie, WR, Berman, D McK & Braysher, ML (1993). Managing Vertebrate Pests: Feral Horses. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra
- Parkes, J, Henzell, R & Pickles, G (1996). Managing Vertebrate Pests: Feral Goats. Bureau Resource Sciences & Australian Nature Conservation Agency. Australian Government Publishing Service, Canberra
- Saunders, G, Coman, B, Kinnear, J & Braysher, M (1995). Managing Vertebrate Pests: Foxes. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra
- Williams, K, Parer, I, Coman, B, Burley, J & Braysher, M (1995). Managing Vertebrate Pests: Rabbits. Bureau of Resource Sciences & CSIRO Division of Wildlife and Ecology. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra

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Penny Olsen

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Contents

FEATURED SECTIONS

Foreword

Pest animals are those which threaten the agricultural, environmental and personal resources humans value. European settlement is mostly responsible for the large number of such species in Australia today.

Beginning last century, many animals were released deliberately for food production, game hunting, companionship or aesthetic reasons. Other species established accidentally, originating from incidental immigrants or are domestic animals which escaped to establish wild populations. Changes in land use have also caused some native animals to become pests.

Despite concerted effort to manage pest animals, their populations remain large and widespread and cause considerable damage.

The Bureau of Resource Sciences recently reviewed pest animal management in Australia and overseas. State and Territory pest management agencies, CSIRO, Environment Australia and representative community groups including the National Farmers' Federation, the Australian Conservation Foundation and the National Consultative Committee on Animal Welfare collaborated in the undertaking. The result is a series of national guidelines which outlines a revised, strategic approach to the management of particular pest animals, including feral horses, rabbits, foxes, feral goats, feral pigs and rodents.

The guidelines build on Australia's sound understanding of the biology of pests, and expertise in the development and application of pest control techniques. They bring together the experiences of resource managers and researchers across Australia and overseas, challenge old assumptions and ask how to do it better.

Australia's Pest Animals draws on these guidelines and other sources to give an overview of pest animal problems in Australia and promote the use of scientifically based strategic management that is humane, cost-effective and integrated with ecologically sustainable land management. The book is written for a general audience. It will assist farmers and natural resource managers to deal with their pest animal problems. It represents a useful overview of pest animal management in Australia for policy-makers and a source reference for students. Conservationists and other interested readers will gain better insight into one of the most significant conservation issues in Australia. Not least, the strategic management approach advocated in *Australia's Pest Animals* has application to a range of other natural resource management issues.

Peter O'Brien
Executive Director
Bureau of Resource Sciences

Preface

When I told a friend that I was writing a book on vertebrate pest management he inquired whether it was about sheep. One thought led to another and it occurred to me that this book is not about pest management at all, but about management of people. It is people who decide whether an animal becomes a pest either by moving it physically, by modifying habitats or land uses or by altering their own perceptions. It is people who decide whether an animal stays a pest either by managing it or by softening their perception of it. It is people who decide how, when and where to manage a pest; and people who determine whether a management program will be successful. So, this is a book about people managing themselves and cooperating in order to better manage their environment, be it farm or nature reserve, to minimise the damage caused by pests.

The book is based on the well-shaped principles, practical approaches and ready-made examples, developed and espoused in the national guideline series *Managing Vertebrate Pests* by the Bureau of Resource Sciences, with published volumes written by Dave Berman, Mary Bomford, Mike Braysher, John Burley, Judy Caughley, David Choquenot, Brian Coman, Will Dobbie, Robert Henzell, John McIlroy, John Griffiths, Dana Kelly, Jack Kinnear, Terry Korn, Ian Parer, Bob Parker, John Parkes, Greg Pickles, Glen Saunders, Ron Sinclair and Kent Williams.

The preparation of *Australia's Pest Animals* would have been immeasurably harder without the generous contribution, enthusiasm and support of Mike Braysher. Much of the text was drafted by him and his philosophies on pest management influenced the entire book.

A number of other people were generous with their knowledge and assistance. Quentin Hart gave valuable guidance at all stages of the preparation of the book and was responsible for general compilation of text, figures and photos for publication. Thorough reviews by John Parkes and Mary Bomford greatly improved the manuscript. Ron Sinclair was particularly helpful with the compilation of the case study on ravens, David Choquenot assisted with one on pigs and Quentin Hart prepared the study on the Sutton Grange project. Steve McLeod kindly drafted material on experimental design and population dynamics and Sandy Thomas checked the section on biological control. Information on immunocontraception and on mice was kindly provided by Lyn Hinds and Grant Singleton. Graham Garner gave advice on various sections and Dana Bradford helped with the boxes on introduced species. Thanks are also due to the various photographers whose work adds colour, information and interest, and to Brett Cullen for skilled preparation of the illustrations.

I am also grateful to Andrew Cockburn, Head of the Division of Botany and Zoology, Australian National University, where I am a Research Fellow, for his unstinting support.

Introduction

Despite ongoing improvements in established pest control methods and the development of new techniques, Australia has basically the same suite of pests now as at the turn of the century, and animals that were critical pests then continue to cause concern. Each year hundreds of thousands of foxes, rabbits, kangaroos, goats, pigs, mice, cats, rats and parrots are trapped, poisoned, shot or otherwise destroyed because of the agricultural losses and environmental harm they cause. The hope has been that with lots of effort and the support of governments, pests can be all but eliminated. Yet, although several native animals have become rare or extinct because of human activities, pests continue to thrive. Clearly, it is time to review the past, and to plan pest management that is smarter and more successful.

Effective pest management must be sensitive to the ever changing needs of land managers and the wishes of the community. In recent years several developments have changed the way in which Australians approach pest animal management in particular, and land management, in general. These include:

- recognition that land systems should be managed as a whole and that pest animals are only one factor influencing sustainable use of the land and protection of biodiversity;
- consistently declining commodity prices—as primary producers are increasingly required to compete on deregulated world markets—which place even greater importance on the need for cost-effective pest animal control;
- better understanding of the range of groups—including community Landcare, animal welfare and conservation groups, research organisations and financial institutions—interested in pest animal management and recognition of the need to involve them in the planning and management of pest animals;
- concern over extensive reduction in native habitat, particularly in areas converted to broad-scale cropland. This reduction results in many small, fragmented habitat remnants which isolate native plant and animal communities and make them more vulnerable to damage by pest animals;
- recognition that conservation of much of Australia's biodiversity now depends on management of wildlife outside reserves, often on private land; and
- a decline in government assistance for pest animal control.

In the light of past experiences and present conditions, the Bureau of Resource Sciences recently reviewed pest animal management both in Australia and overseas. State and Territory pest management agencies, CSIRO, Environment Australia and representative community groups including the National Farmers' Federation, the Australian Conservation Foundation and the National Consultative Committee on Animal Welfare collaborated in the undertaking. The result is a series of national guidelines which outline an updated and strategic approach to pest management. The guidelines build on Australia's knowledge of the biology of pests, and expertise in the development and use of pest control techniques. They incorporate the wealth of experience of resource managers and researchers across Australia and overseas, challenge old assumptions and ask how to control pests better.

Australia's Pest Animals draws on the guidelines to give an overview of pest problems in Australia, and describes the processes of better management in a clear, thought-provoking way. The new approach to pest management is based on a whole land system plan, and emphasises control of the damage that pests cause rather than simple reduction in pest numbers. It is built around a central framework of five interrelated steps that:

- define the problem in terms of pest damage;
- determine objectives;
- identify and evaluate management options;
- implement a management plan; and
- monitor and evaluate the outcome.

Pest control is not easy and there is still much to learn. For most pests there is little good information about the type and amount of damage they cause. Without accurate damage assessment, it is not possible to know what benefit to expect from a given level of pest control. There is a need for basic research on these issues and on biological, social and economic pest management systems in general, but often there is neither the time nor the funds to spend on long-term research before control begins. A quicker solution is to adapt management so that it functions as a productive ongoing experiment, often in the hands of the land managers. The outcomes are fed back into improving management. This adaptive management, or 'learning by doing', combines observation, experience and research to help land managers care for their land in a more sustainable and cost-effective way.

Some of the answers to past failures and keys to future management can be found in the attitudes of people to pests and in pests' special characteristics; these are discussed in the early chapters of this book. Later chapters deal with practical management issues, from identifying the pest problem to choosing control techniques, and formulating and implementing a management plan. A series of case studies illustrates the application of the five-step approach to a variety of pest animal problems, and the final chapter speculates on future developments and directions in pest management.

1 More than an attitude: perceptions of pests

What is a pest?

... an animal that causes more harm than good to a valued resource.[30,27]

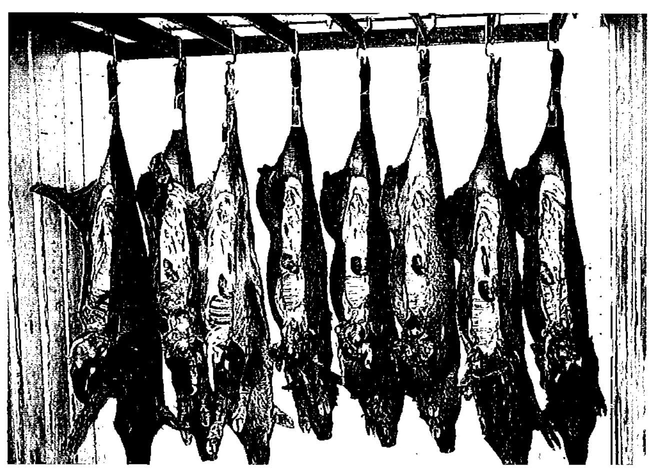
The word 'pest' is generally used to describe an animal that conflicts with human interests. Such a pest may be destructive, a nuisance, smelly, noisy, out of place or simply not wanted. A more precise and workable definition includes only those animals that cause serious damage to a valued resource. A pest may be an animal that was originally spread by humans to new lands—this is particularly the case in Australia. Or, it might be a native animal such as a kangaroo, possum or parrot.

It is important to note that people decide whether an animal is a pest. What is a pest to one person may be a valuable resource to another.[86] For example, a feral pig might be worth $100 at the chiller, where it is processed into game meat for the European gourmet market, and viewed as a valuable resource by the hunters and meat processors. Others believe that feral pigs are a menace to the environment and agriculture. Such diversity of opinion is one of the main reasons that past pest control has had varying success.

Attitude: origins of a problem

What it comes down to is a value judgement about whether an animal fits in with your view of the world or not.[212]

Australians have inherited the consequences of past attitudes, which have left almost insurmountable pest problems. In the mid-1800s, settlers had a very different attitude toward many of the animals now regarded as pests. Between



LEFT *The European Red Fox was introduced in 1871, or earlier, for hunting with horses and hounds. It adapted well to Australian conditions and by the 1930s had spread over the mainland apart from the tropical north. Although regarded by many as an attractive animal, it is a major environmental and agricultural pest.*
Source: CSIRO

RIGHT *The total value of Australia's feral pig meat exports is in the order of $10–20 million annually. Shooters, meat processors and recreational hunters may regard the pig as a resource rather than as a pest.*
Source: Peter O'Brien, BRS

1840 and 1880 alone more than 60 species of vertebrate animals were introduced into Australia.[149] Many were brought in by English immigrants to bring a semblance of England to the new colony[118,193] Some, such as the Song Thrush, were considered superior songsters to the Australian natives and reminded the settlers of home. The members of acclimatisation societies worked actively and enthusiastically to spread the world's 'useful and bountiful' species.[149] Rabbits, foxes, trout and deer were released for sport or food and the mongoose imported to control rats in sugar-cane. Other introductions were accidental: captive stock, such as horses, pigs, goats and camels; and pets and ornamental species, such as the cat and goldfinch, escaped and established feral populations.

Fortunately many introductions failed despite the efforts of acclimatisation societies,[193] but others prospered.[211] About 96 species of birds have at one time or another been introduced to Australia.[123] Of these, 32 have become established in the wild, a further 12 have probably established and 52 have died out. But only a few of the successful introductions are considered to be serious pests.

Table 1.1 The Australian distribution of some of the introduced species that have established wild populations. Many are pests or have potential to become pests.

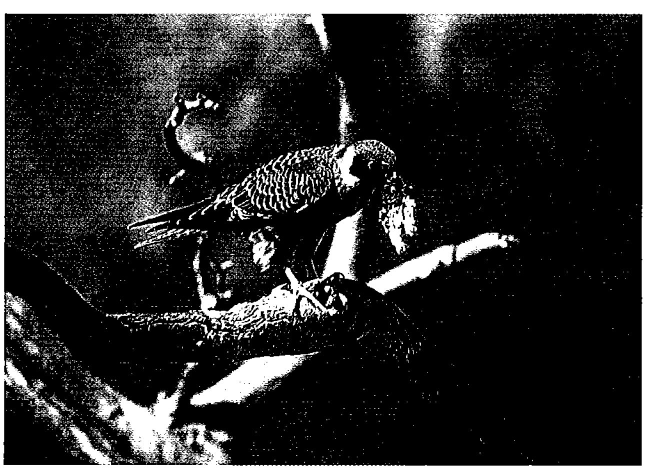
Species	*General distribution in Australia*
Fish	
Rainbow Trout	south-eastern Australia
Atlantic Salmon	south-eastern highlands; southern ocean
Brown Trout	south-eastern Australia
Brook Trout	south-eastern Australia
Goldfish	south-eastern Australia
European Carp	south-eastern Australia
Roach	south-eastern Australia
Tench	south-eastern Australia
Topminnow (Mosquito Fish)	southern and eastern Australia; Christmas Island
European Perch (Redfin)	south-eastern Australia
Black Mangrove Cichlid	Victoria, Queensland
Mozambique Tilapia	Victoria, Queensland
Oriental Weather Loach	New South Wales; Victoria
Amphibians	
Cane Toad	north-eastern Australia
Reptiles	
House (Barking) Gecko	northern Australia; Cocos (Keeling) Island; Christmas Island
Grass Skink	Christmas Island
Birds	
Common Pheasant	Rottnest Island, Western Australia; King Island, Tasmania
Mallard	south-eastern Australia; Perth, Western Australia
Weka (New Zealand Woodhen)	Macquarie Island
Rock Dove (Domestic Pigeon)	cities and towns, coastal eastern, southern and south-western Australia
Senegal Turtledove	south-western Western Australia
Spotted Turtledove	south-western Western Australia; coastal northern Queensland to South Australia
Skylark	southern and south-eastern Australia
House Sparrow	southern and eastern Australia; Norfolk Island
Eurasian Tree Sparrow	south-eastern Australia
Nutmeg Manakin (Spice Finch)	pockets of the eastern coast
Java Sparrow	Christmas Island

Species	*General distribution in Australia*
European Greenfinch	south-eastern Australia
European Goldfinch	south-eastern Australia; Albany and Perth, Western Australia; Norfolk Island
Red-Whiskered Bulbul	Adelaide, South Australia; Sydney, New South Wales; Melbourne, Victoria
Common Blackbird	south-eastern Australia; Norfolk Island
Song Thrush	south-eastern Australia; Norfolk Island
Common Starling	eastern and south-eastern Australia including Tasmania; Norfolk Island
Common Myna	eastern and south-eastern Australia
Mammals	
House Mouse	Australia-wide
Brown Rat	mainly coastal cities of eastern, south-eastern, south-western mainland; western Tasmania
Black Rat	mainly coastal Australia including Tasmania; Christmas Island; Norfolk Island; Cocos (Keeling) Island
Dog	mainly coastal southern and eastern Australia
Fox	southern 2/3 of mainland Australia
Cat	Australia-wide
Rabbit	southern 2/3 of mainland Australia
Brown Hare	eastern and south-eastern Australia
Horse (Brumby)	throughout Australia; mainly northern and Central
Donkey	north-western, western and central Australia
Pig	mainly eastern, northern and south-western Australia
One-humped Camel	Central and mid-western Australia
Swamp Buffalo	northern Northern Territory
Bali Banteng	Cobourg Peninsula, Northern Territory
Goat	mainly south-central Queensland; New South Wales; south-eastern South Australia; mid-western Western Australia
Sheep	isolated, Western Australia; New South Wales
Fallow Deer	scattered, coastal south-eastern Australia
Red Deer	south-eastern Queensland; southern Victoria
Rusa Deer	Sydney area, New South Wales; Melville Island; Prince of Wales Island, Queensland
Sambar Deer	Gippsland, Victoria, to Australian Capital Territory; Cobourg Peninsula, Northern Territory
Chital (Axis Deer)	Maryvale Creek, Queensland
Hog Deer	far southern Victoria

Sources: 6; 7; 12; 36; 49; 51; 55; 64; 76; 115; 121; 123; 124; 131; 138; 140; 186; 188; 208; 210; 227.

In the 1800s, acclimatisation societies actively promoted the destruction of native predators, particularly birds of prey, to protect introduced songbirds. The tide turned and today many introduced animals are regarded as pests, and native birds such as this Australian Hobby are protected.

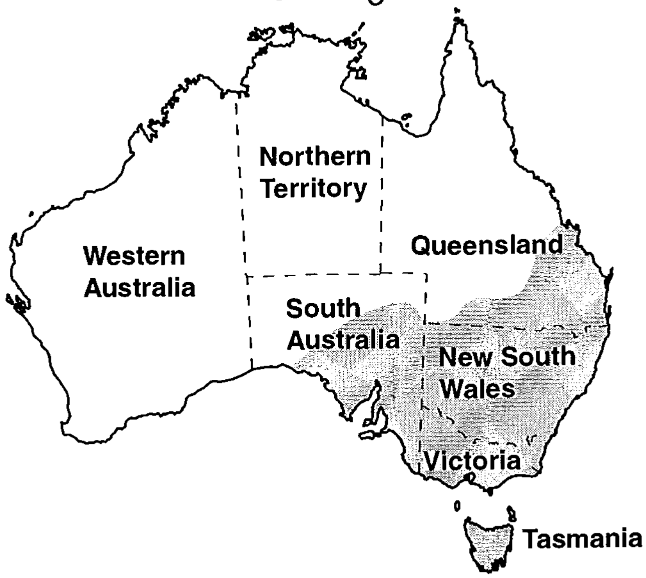
Source: Nicholas Birks



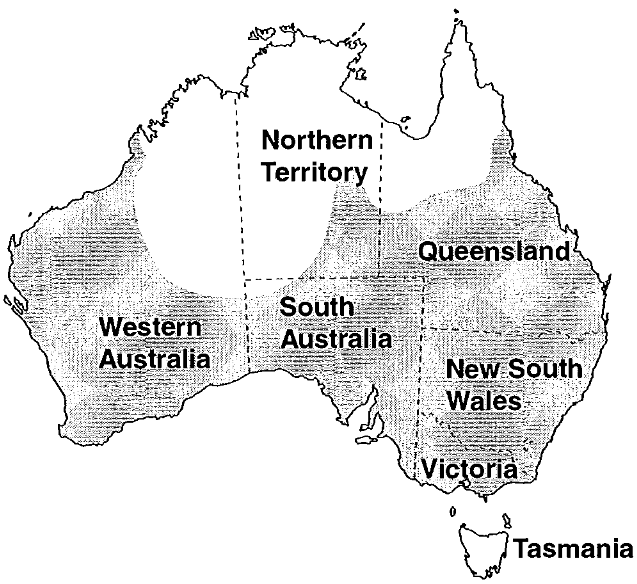
Source: Environment Australia

The main distribution of some of some of the better known animals that have been introduced to Australia and become pests.

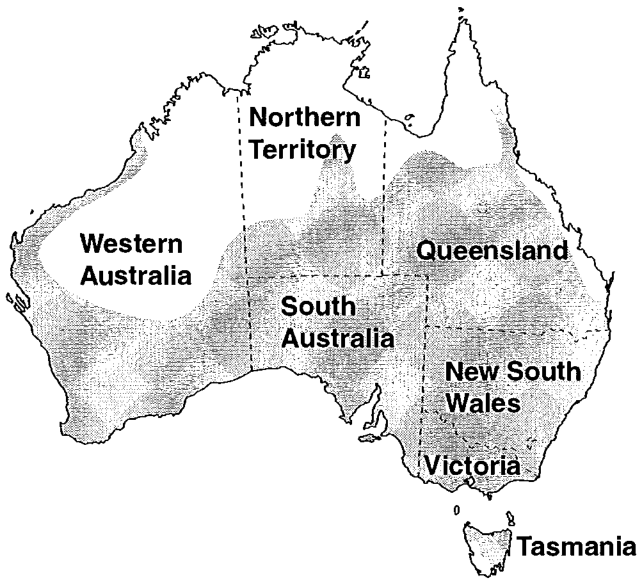
Starlings



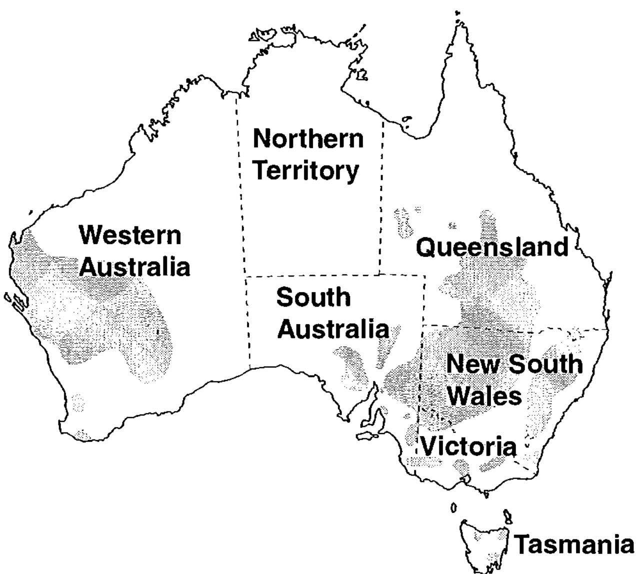
Foxes



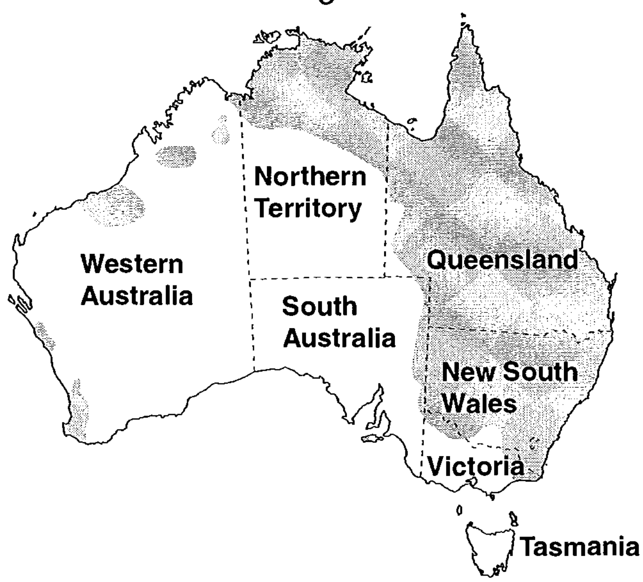
Rabbits



Goats



Pigs



Camels were introduced as beasts of burden but some escaped and established feral populations that range over Central and mid-western Australia.
Source: David Wurst, CCNT

Nevertheless, the attitudes that led to the successful introductions had serious repercussions. Rabbits, foxes and goats are some of the better-known introduced animals that wreak havoc on the environment, cause great losses to farmers, and endless cost and effort in ongoing attempts at control. In some Australian habitats, the Common Starling steals scarce nesting sites in tree hollows from native birds. House Sparrows, introduced to eat the caterpillars that were ruining the livelihood of many farmers, themselves became minor pests that damage fruit. European Carp, not even regarded as good fish for the table, dominate many waterways.

Australia, of course, is not alone in suffering the consequences of the actions of acclimatisation societies. The societies also introduced many Australian animals to New Zealand, including the endearing Common Brush-tailed Possum. The possum is now one of New Zealand's most serious pests.[174] It carries tuberculosis, which is a menace to agriculture, causes extreme damage to native forests and, through predation and habitat changes, threatens populations of native animals.

Table 1.2 A selection of Australian animals that have been introduced successfully to New Zealand, some of which have become pests.

Species	*Abundance*	*Pest status*
Amphibians		
Green and Golden Bell Frog	Common	Not regarded as a pest
Brown Tree Frog	Common	Nuisance
Birds		
Sulphur-crested Cockatoo	Rare	Not regarded as a pest
Eastern Rosella	Common in north	Perhaps a pest
Laughing Kookaburra	Rare	Unknown
Australian Magpie	Common	Minor pest
Mammals		
Common Brush-tailed Possum	Abundant	Major pest
Tammar Wallaby	Locally common	Minor pest
Parma Wallaby	On one small island	Not regarded as a pest
Red-necked Wallaby	Locally common	Minor pest
Brush-tailed Rock-wallaby	On one small island	Being eradicated
Swamp Wallaby	On one small island	Not regarded as a pest

Source: 106.

Australians have also been great transporters of their own wildlife around the country. Platypus, Koalas, Common Brush-tailed Possums, Tammar Wallabies, Emus, Australian Brush-turkeys, Cape Barren Geese, Laughing Kookaburras and perhaps Australian Magpies, are some of the species introduced successfully to Kangaroo Island off South Australia. Recently, the possums were found to be the main reason for the poor breeding success of the endangered Kangaroo Island Glossy Black-Cockatoo, because they eat nestlings,[235] and the Koalas have become so numerous that they have stripped the eucalypts on which they and other animals depend for food and shelter.

Perceptions of pests

Attitudes to animals, whether native or introduced, change with time and circumstance. An example is the ever changing fortunes of the kangaroo (see below 'Kangaroos: from curiosity to resource'), Australia's National Emblem. Even today it is regarded by sections of the community as being any combination of the following: a damaging pest to fences and pastures; a cause of road accidents; an animal to hunt; a source of commercial gain; a unique member of the Australian fauna; an attractive animal with rights; and in need of conservation.

Kangaroos: from curiosity to resource

Kangaroos embodied the earliest European settlers' reactions to the nature of Australia: at once threateningly unfamiliar and fascinatingly unique.[65] They were considered curiosities and dangerous to handle, but were also kept as pets and put on display. By First Settlement, in the late eighteenth century, they were harvested to supply meat for public consumption. As the colony became more comfortable, clubs were formed for the popular sport of hunting kangaroos and Dingoes. A special kangaroo-dog was developed—a cross between a swift greyhound and a mastiff or similar powerfully jawed breed.

Such was the slaughter that even as early as 1822 concerns were expressed about kangaroos' survival in the Blue Mountains: 'the stockmen hunt them and the cattle and sheep supplant them. In a few years, the kangaroo will be as rare as the native burghers ...'[9] This was echoed by the famous evolutionary biologist Charles Darwin[62] who, in the 1830s, after being taken on an unsuccessful hunting trip during which no kangaroos were seen, observed that, 'It may not be long before these animals are altogether exterminated...'[65]

While there are no reliable records to substantiate these perceptions of a serious decline in kangaroo numbers, it is clear that by the mid-nineteenth century another change in attitude had occurred. The kangaroo had come to be regarded as a serious pest that competed with stock for precious pasture. In order to remove large numbers, a highly successful technique, called a battue, was borrowed from the Aboriginal people. This was an organised round-up with the objective of heading kangaroos into an ambush, such as a fenced enclosure or pit, where they were either clubbed to death or shot. Slaughter for pest control soon developed into a commercial enterprise. About one million kangaroos per year were destroyed and there was a lucrative market for kangaroo products such as skins. In 1880, one firm in America received 6000 kangaroo skins weekly. During the second half of the nineteenth century, the Melbourne market for skins alone accounted for at least 500 000 animals per year.

In the late 1960s, a severe drought reduced kangaroo numbers and there were concerns about the added pressure on populations from harvesting. An anti-harvesting lobby became influential in the United States (then the major importer of kangaroo products), and in Australia. Both Red and Grey Kangaroos were placed on the USA threatened fauna list and an embargo was placed on the import of kangaroo products. With much of the market lost, several commercial harvesters left the industry and for a time the harvest declined dramatically.

Despite persecution and exploitation and concerns that numbers were falling, most authors believe that, since European settlement, kangaroo numbers have increased substantially in Australia's rangelands, at least in the eastern pastoral zone.[203] Estimates made in 1990 showed that the four most common species of kangaroo numbered 8.6 million for the rangeland areas of New South Wales alone.[137]

Today, only the larger, more abundant species of kangaroo can be harvested commercially and there are three recognised objectives for their management. The primary aim is to ensure the conservation of all harvested species and to maintain them over their natural ranges. Secondary aims include reducing the damage they cause to rural production and, where appropriate, ensuring sustainable use of the resource.[137] Under the *Commonwealth Wildlife Protection (Regulation of Exports and Imports) Act* 1982, commercial harvesting of kangaroos for export requires prior Commonwealth approval of a kangaroo management program. Under approved management plans, the 1995 and 1996 national harvest of kangaroos was just over 3 million annually, and the quota for 1997 is 4.4 million.[237]

Even today the pest status of Kangaroos is controversial; are they valued native animals, a harvestable resource or competitors with stock? Source: BRS

In reality, the true status of an animal is often irrelevant—it is how the animal is perceived that determines its pest status.[165] A good example of this is the Cane Toad, which has been branded a pest and has attracted the attention of the public and media largely because it is unattractive, toxic and highly visible. Yet there is little reliable information about the damage it causes to native wildlife. Indeed, the few studies that have been done indicate that Cane Toads have little or no impact. The toad can kill family pets and native animals by exuding a poison when it is eaten or bitten. However, most pets learn to avoid the toad, and in all cases studied, native animals appear to recover to original population levels in a relatively short time after the toad has invaded the area[78] (also see 'Cane Toads: a real or perceived pest problem?', pages 82–84).

Until recently many Australians regarded cats as family pets that took the occasional bird or lizard. A public awareness campaign by Commonwealth and State conservation agencies over the past decade dramatically changed this attitude. Today cats are often presented in the media as a major threat to native wildlife,[212] even though there is little sound research to support this viewpoint.[28, 40]

Source: Environment Australia

Whereas Cane Toads and feral cats are widely perceived to be serious pests, without good evidence one way or the other, some animals elicit more mixed reactions. Indeed, at any one time attitudes towards an animal can vary widely (see Table 1.3). In the Flinders and Gammon Ranges in South Australia, feral goats are pests that threaten the survival of rare plants and animals in significant national parks.[152] Yet, in other parts of Australia they are increasingly harvested for their meat and skins.[173] Mixed feelings also exist for fish such as introduced trout, which are prized by anglers but are also environmental pests that devour native aquatic life.[38]

Community attitudes can determine the success or failure of a pest control program.[30]

Although public understanding of pests and pest management is variable, it is generally poor.[77] Nevertheless, community attitudes can determine the success or failure of a pest control program. Initially, the debate that occurred in the media about proposed culling of feral horses in the Northern Territory tended to be adverse, and public outcry might have brought an end to the proposed culling program.

Management of popular species such as horses can be a sensitive issue. This starving herd gathered at a Queensland waterhole during drought vividly illustrates the need for humane control.
Source: Queensland DEH

Fortunately, public input had been sought and considered carefully in the program and the debate matured into one about the damage caused by feral horses and the need to implement humane control. Most animal welfare organisations now accept, albeit reluctantly, that control of feral horses is necessary.[67, 153]

Table 1.3 Some examples of the diversity of opinion about feral rabbits and their control

Legislators	'landholders are compelled by law to suppress rabbit populations'
Rabbit control authorities	'rabbit control is necessary and desirable'
Concerned intensive landholders	'control is necessary and desirable'
Unconcerned intensive landholders	'myxomatosis is still doing a good job; I will control my rabbits when my neighbours control theirs; a few good rabbits are good for dog food; the rabbit inspector has not
told	me to do anything; the next drought will kill them off'
Arid zone, rangeland or extensive landholders	'properties are too large and returns per hectare too small to make control economic'
Landholders whose land is unsuitable for rabbits	'I can't understand why some people cannot control their rabbits'
Foresters	'control is essential in young plantations'
Hobby farmers	'rabbits? what are they?'
National park authorities	'control or eradication is desirable but insufficient money is available; damage to vegetation from a few rabbits is insignificant'
Conservationists	'the only good rabbit is a dead one'
Commercial harvesters	'CSIRO ruined the industry by introducing myxomatosis'
Recreational hunters	'it would be good to see a few more rabbits around'
City people	'it's nice to see the odd rabbit but there are not as many as there used to be; my father lived on them during the depression'

Source: 169

Attitudes to animal welfare

> *The Australian and New Zealand Federation of Animal Societies is concerned about the interest of all non-human animals and is amazed at the treatment of these animals once they have been labelled by our community as pests. A lack of public debate enables much of this treatment to persist when reform is possible and well overdue.*[165]

Today it is no longer acceptable to treat animals as objects without rights. There is an increasing expectation in many sectors of the community that all animals, including pests, will be treated humanely. Aside from the moral obligation, failure to adequately consider animal welfare can cause major problems for pest control. It may lead to bans on the introduction and use of certain techniques. During 1992 and 1993, the proposal to introduce myxomatosis to New Zealand for rabbit control sparked a major, protracted and often bitter debate[165]. The importance of animal welfare was also recognised in the extensive treatment it received in the recent assessment of the costs and benefits of introducing rabbit calicivirus disease (RCD) into Australia.[34,146]

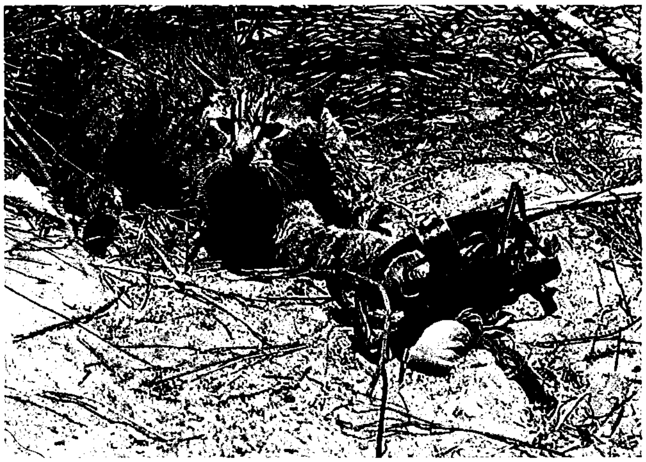
Failure to improve the humane treatment of pest animals can also have major implications for trade. For example, there has been pressure by animal welfare organisations to ban the live export of goats, most of which are feral.

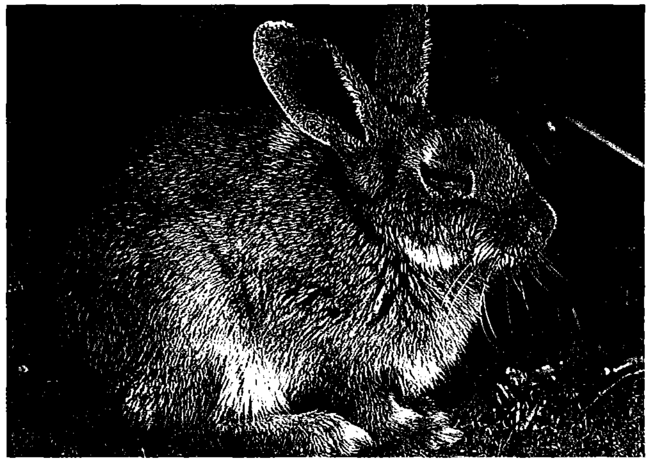
The National Consultative Committee on Animal Welfare (NCCAW), which is composed of both government and community representatives concerned with animal welfare, recognises that pest animals cause extensive environmental and agricultural damage and that their numbers need to be controlled. NCCAW also understands that a judgement on a pest control program must take all factors into account, not just animal welfare. They further recognise that in some cases it may not be possible to guarantee the humaneness of control methods for each pest animal although this should be the goal.[231]

Pest control might be acceptable to the community in one place but cause great concern if it is carried out elsewhere, as this quote from the Director of the Australian and New Zealand Federation of Animal Societies demonstrates: 'Rabbits dug burrows, fed in the open and were more or less contained by feral cats, some winter flooding of burrows (and consequent death of [rabbit] kittens), and the occasional piecemeal control by land managers. But some cat control and a dry year recently led to the announced need to reduce rabbit numbers to restore the other values of the area. There was a storm of protest from those living close to the land. You see the land and the wild rabbits were situated in the middle of Centennial Park in Sydney. Right under the noses of members of the public that usually do not even consider what their country cousins are doing to rabbits in the semi-arid or grazing areas of New South Wales.'[165]

Often it is the pest control method that causes most animal welfare concerns. NCCAW concluded that people concerned about some pest control methods are not always well informed about them and that better information and more open debate might overcome their objections. Strategies for increasing public awareness and the need to consider animal welfare concerns in the context of the costs and benefits of control are integral parts of successful pest management.

Any pest animal management program should be appropriately planned and coordinated using the most effective, humane methods available.[22] Where practicable, such programs should also aim to reduce the need for extensive





LEFT *Animal welfare organisations have done much to promote the use of humane pest management techniques. Traps such as this are discouraged or banned in most States.*
Source: Jonathan Lee

RIGHT *The signs of myxomatosis begin about a week after infection. The rabbit is listless and a clear watery discharge weeps from the eyes. The eyelids, anal and genital areas swell and lumps form on the body. A virulent strain of myxomatosis kills in less than 13 days.*
Source: NSWAF

ongoing treatment.[30] Land managers have several potentially cost-effective methods to reduce pest animal impact, each with different animal welfare implications:

- killing or removing by poisoning, shooting, trapping or mustering;
- exclusion;
- biological control;
- habitat manipulation; and
- other management practices (these are explained in Chapter 4).

It is not possible to quickly develop new, humane techniques to replace those that are questioned on animal welfare grounds. Nevertheless, animal welfare groups expect pest controllers to be able to show that the animal welfare costs from control can be justified in terms of the production and environmental gains. In other words, if techniques are used that cause pest animals to suffer, the resulting reduction in pest damage must be clear.

Cage traps for pigs are considered humane as long as the traps are checked regularly and the trapped animals humanely destroyed. Using dogs to control pests such as feral pigs is considered to be inhumane, not only because of the stress of capture and injuries inflicted on pigs prior to death, but also because of the risk of injury to the dog.[48]

Shooting from helicopters is an effective control technique for several pest species and, partly due to the influence of animal welfare groups, the professionalism of shooters is generally very high. Shooting from helicopters is considered to be acceptable provided that control operations are conducted by trained marksmen and that there is a follow-up inspection for any injured animals. Although it can be humane, shooting pests from the ground has limited pest control potential for smaller pests, such as rabbits and foxes, because in most situations it removes only a small proportion of the population.[153,198,225]

Another relatively humane method of controlling pests such as feral horses, donkeys, and goats is mustering, usually for sale for meat. However, the necessary live transport of wild animals such as feral horses and goats to abattoirs can cause suffering, especially when they travel long distances.[67,153]

The humaneness of poisoning is variable because of differences in poisons and variation in the pest species' response. Some poisons, specifically yellow phosphorus (CSSP) and chloropicrin, used on feral pigs and rabbits, respectively, are inhumane and should be phased out.[48, 225] More humane alternatives are available and include pindone and cholecalciferol.

Concern over the suffering caused by myxomatosis is one reason that, in 1993, the New Zealand government decided against the introduction of myxoma virus to control rabbits. The new rabbit calicivirus disease (RCD) is considered to be much more humane, in part because it kills more quickly and the rabbits show no signs of suffering (see 'RCD, a potential biological control agent for rabbits', pages 66–67).

It is important that governments and other organisations responsible for pest animal control ensure that animal welfare concerns are appropriately considered, put into perspective and effectively communicated to the community. Most States and Territories have comprehensive animal welfare legislation. The relevant State and Territory agencies and national committees, such as NCCAW and the RSPCA, have an important role in safeguarding the welfare of animals, including pests, by developing Codes of Practice for the control of animals. Pest management should be consistent with these codes, which include the Subcommittee on Animal Welfare's 'Model Code of Practice for the Welfare of Animals, Feral Livestock Animals (1991).'

The guidelines expressed in the 'Australian Code of Practice for the Care and Use of Animals for Scientific Purposes'[153] apply equally well to pest control: 'Pain and distress cannot easily be evaluated in animals, and therefore investigators must assume that animals experience pain in a manner similar to humans. Decisions regarding their welfare in experiments must be based on this assumption unless there is evidence to the contrary.'

Attitudes of Aboriginal peoples

Feral animals come into the country and settle down. Now they belong here.[194]

Aboriginal peoples are major Australian landholders with an increasing interest in returning to or remaining on traditional lands. Among indigenous peoples, attitudes to feral animals are as varied as those held by non-Aboriginal peoples. Nevertheless, the prevailing view that introduced animals are less valuable than native species is not shared by many Aboriginal people.[194] Indeed, feral species are quite often perceived to belong to the land and to have taken the place of the animals that disappeared when Europeans arrived. Some introduced animals have even been incorporated into Aboriginal law and spirituality—for example, cats in some Central Australian Aboriginal communities.[160,194]

Several Aboriginal communities depend on feral animals for subsistence.[25] For example, feral pigs are a favoured food of the indigenous communities on Cape York; rabbits and cats are hunted by women in the Yuendumu–Willowra region of Central Northern Territory; and, after kangaroo, rabbit is the meat most often consumed by Aboriginal people on outstations in the Maralinga lands of South Australia. Indigenous people are also involved in commercial exploitation of introduced animals. For example, they are employed to hunt pigs to export as game meat and they harvest buffalo for export and to sell to breeders and local abattoirs.[52]

Conservation programs for native species such as the Bilby, which involve control of cats, can conflict with Aboriginal peoples' use of the feral animals for food. Where feral species have been removed (such as the buffalo which degraded wetlands in Kakadu National Park) an important resource to the indigenous people may also have disappeared. In Kakadu, to replace the feral buffalo, traditional owners negotiated with the Australian National Parks and Wildlife Service and are allowed to maintain a small herd of buffalo in the Park for their use; they have also increased their harvest of estuarine crocodiles.

A review of the attitudes and perceptions of Central Australian Aboriginal people to land management issues[194] uncovered a diversity of opinions, including that feral animals belong to the country, feral animals are so numerous that they should be used, and that there are too many feral animals and too few native animals. A common viewpoint was that feral animals are a resource rather than an environmental threat[160] and better use of them is the most desirable management option when they cause environmental damage.[212] An example is that of feral horses, which have a commercial value to some desert people who believe that, if horses are to be controlled, they should be killed in an abattoir and not on the land where the carcass is wasted.[194]

When introduced species are perceived to have a negative impact on an important wildlife resource, or to compete for food with cattle on Aboriginal pastoral land, many Aboriginal people support their removal.[25] Some Aboriginal peoples also recognise that introduced species can damage sacred sites.

> *Many of the concerns of non-Aboriginal land managers are not shared by Aboriginal people. Explanations for the nature and condition of land and resources have their root in Aboriginal culture rather than in the western scientific paradigm. This is an issue of great importance when looking at any activities which take place on Aboriginal land.*[194]

Particularly where the use of introduced species as a subsistence resource conflicts with a need for their control to conserve native species or prevent environmental damage, and where rare or endangered species are hunted, it is important that the goals and aspirations of all concerned are considered in any management initiatives.[24] Although the views of Aboriginal land managers stem from greatly different cultural roots to those of non-Aboriginal peoples, a common

Feral animals have often replaced native species, such as these wallabies, in the diet of Aboriginal peoples and pest management may cause conflict.
Source: Jon Altman, CAEPR

commitment to sustainable use of the land may help to reconcile the sometimes disparate perspectives. The belief systems of indigenous peoples may promote sustainable use of the environment, and the people may be sympathetic to pest control if pests are shown to cause serious damage to valued resources.[25] Discussing the issue of pest management objectively, in terms of the damage pests cause, may identify mutually acceptable solutions.

Attitudes of governments

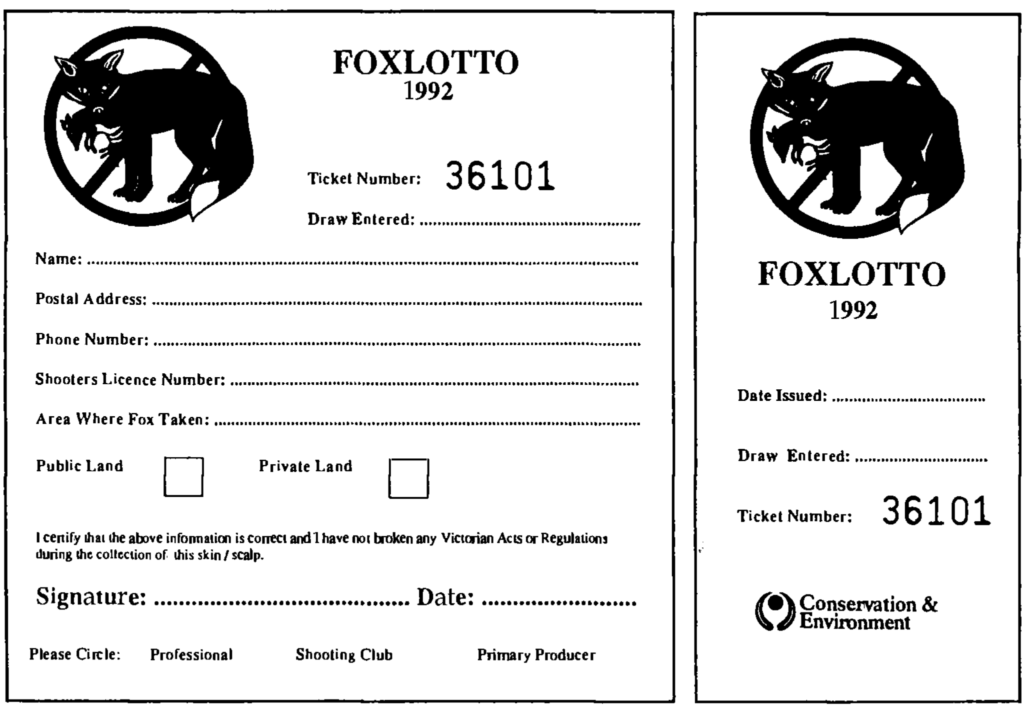
In the past, pest animal control was often heavily subsidised by government, which provided bounties and cheap equipment and labour. For example, in 1885 alone, the South Australian Government spent $2.1 million as bounty on rabbit scalps.[157] Between 1945 and 1959, the Queensland Government paid bounties on 240 000 fox scalps at a cost of $1.15 million[74] and, between 1901 and 1907, to prevent the westward movement of rabbits, the Western Australian Government spent $33 million on a rabbit-proof fence 1700 kilometres long.[193] All of these initiatives failed to control the pests.

More recently, the Victorian Government introduced a bounty called Foxlotto. For each fox scalp, hunters received a ticket in the Foxlotto pool prize. In 1992–93, 15 000 fox scalps were received and in the next year 5600. This had no significant effect on the population and the scheme was abandoned the following year.[165]

Governments generally recognise that traditional bounty schemes are ineffective for controlling pest animals such as pigs.[48]

It is now well accepted that bounties do not work.[88,206] One reason for this is that, when someone else is paying for control, there is little incentive to ensure that the money is spent wisely to achieved desired targets. Some scientists have suggested that there may be a role for 'smart bounties'. For example, farmers could subsidise commercial feral animal harvesters to reduce and hold the pest

With the intention of encouraging fox control in the early 1990s, the Victorian Government allotted a ticket in Foxlotto for every fox scalp. Foxes continued to thrive and interest in the scheme quickly waned.



In the past, governments subsidised rabbit control by paying bounties on scalps, and supplying equipment and labour to build barriers to rabbit movement, but these initiatives proved unsuccessful. Today governments are more likely to assist by providing advice on management and by funding one-off control strategies such as the release of rabbit calicivirus.
Source: Peter Bird, APCC

animal population at a level below that which would be economic for farmers if they were unassisted. However, it is now argued that even these forms of payment should not be seen as a bounty, but as part of overall farming costs.

Government agencies have a major role in pest animal management as legislators, representatives of the wider community, and managers of areas such as national parks. It is important that governments do not encourage inappropriate action by subsidising landholders' management practices, for example through bounties. The costs of pest control on private land should be shared equitably between the private good (production) and the public good (conservation). If there is no public benefit, there is no case for action by the government. Good management can be encouraged through appropriate incentives which benefit both the land manager and the public, and through research, education and training. If governments wish to subsidise the private good it is best done through actions that do not require on-going funding. One way a government might assist is by providing a coordinator to help plan and oversee the implementation of a pest management scheme developed by local private and crown land managers, as now occurs under the National Landcare Program. Another is by funding one-off control strategies such as biological control.

2 The changeable pest

The fluid nature of pest status

The previous chapter outlined how the pest status of an animal can change considerably, depending on the way the animal is regarded by a particular individual or group. In other words, humans decide whether an animal is a pest. In this chapter, some of the reasons that the pest status of an animal can alter are explained in more detail. For a variety of reasons, an animal may increase in numbers or distribution and threaten a valued resource. Introduced animals, and even pets and native wildlife, in the wrong place at the wrong time, can become pests. A harmless animal can become a pest when land use is changed or because it is found to carry a disease of concern to humans, stock or wildlife. Conversely, if a market is created, a harvestable pest can become a valued resource, and an innovation in management may lessen pest animal damage to such an extent that the animal is no longer regarded as a pest.

Change in the number of animals

The pest status of an animal can vary along with its fortunes. A good example of this is the infamous Black or Ship Rat, once feared as the carrier of human (bubonic) plague, which spread around the world with humans to become a major threat to a variety of small animals. The rat is now so scarce in England, where it was introduced in pre-Roman times, that it may need protection.[86] An Australian example is the Long-billed Corella, which is regarded as a major pest in the Victorian grain belt. However, its numbers have declined to the point where it is now considered endangered and in need of management for conservation.[2] The question of how best to manage the corella and the damage it causes is a major dilemma for farmers and conservation agencies.[243]

On the other hand, after several years of high breeding success, animal populations may reach a size where they begin to be regarded as pests. For example, in south-east Australia, the House Mouse is mostly a relatively benign creature. However, with suitable seasonal conditions (usually every three to five years) a plague occurs and with it a rapid rise in the mouse's pest status.

Change in land use

A change in land use often creates a new pest. An obvious example is that of the conversion last century of the rangelands to pastoral land, particularly for lamb production. This soon put the Dingo, which had been in Australia for centuries before Europeans, at odds with the land managers (see 'Exclusion of pests: the Dingo fence', page 65). Moreover, resultant management of predators and the provision of permanent water have made the area more favourable to goats and kangaroos, which are also often regarded as pests.

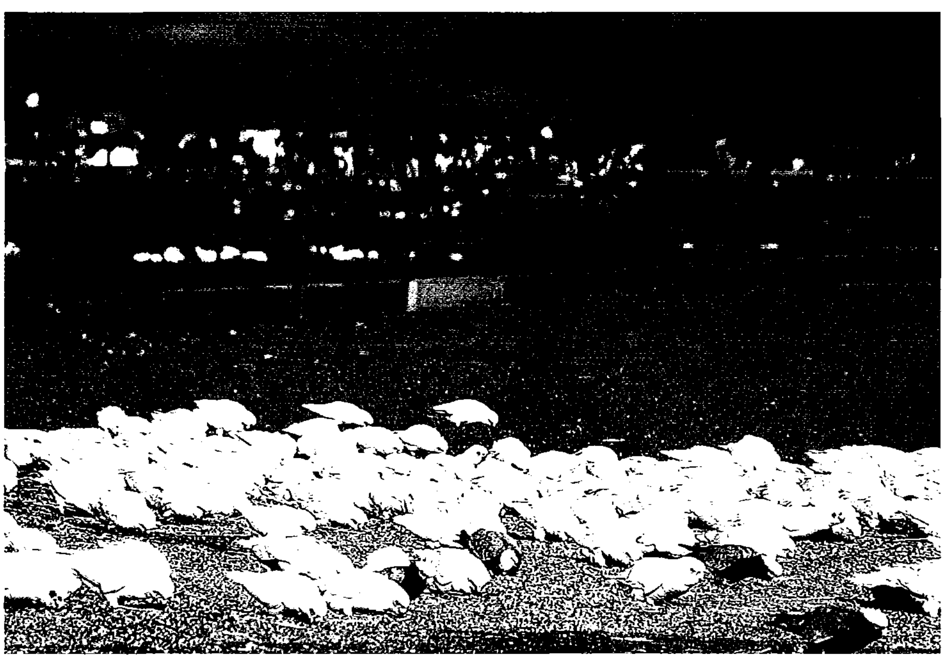
Cultivation of Bluegums for paper production is a rapidly developing industry in south-western Australia. By the mid-1990s, 40 000 hectares had been planted and another 60 000 hectares are planned (see 'Improved management to control parrot damage to Bluegums', page 73). Until the gums were cultivated, Australian Ringnecks were considered a common and attractive part of the local bird life. Now these parrots are regarded as major pests that damage about 20 per cent of the Bluegum plantation by stripping the bark from the branches, nipping off the lead shoots and causing the trees to grow deformed.

In tropical northern Australia, several native birds and two species of flying-fox are considered to be pests of crops.[119] The animals were not regarded as a problem until fruit crops such as rambutans were grown in the area. Recently, some growers have replaced rambutans with crops such as mangoes that are less susceptible to damage.

Rice and Magpie Geese

Magpie Geese were originally blamed by government and farmer alike for the failure of the ambitious Humpty Doo Rice Development Scheme. Traditionally, the geese bred and fed on the floodplains of the Adelaide River in the Top End of the Northern Territory. The Humpty Doo Rice Scheme was in the middle of one of the floodplains and the geese fed on the rice grain, ate the seedlings, and trampled the plants.

Eventually it became evident that the geese were a minor player in the failure of the Scheme. Rains and floods ruined the first crop in 1952 and drought thwarted the second attempt. Stem-boring moths, grasshoppers and rats, as well as the Magpie Geese, attacked the crops. The next decade was marked by erratic rainfall, inadequate funding, inefficient processing, poor rice yields, and high transport, labour and equipment costs, all of which contributed to its inevitable failure. The Magpie Geese are now a major tourist attraction on Fogg and Harrison dams, both built for the abandoned rice scheme.[141]



Where they conflict with human interests, native birds such as Galahs and Little Corellas can become pests. Large numbers may build up at concentrated food sources like crops and cattle feedlots.
Source: George Wilson

Pest or resource: the commercial use of pest animals

Not surprisingly, the pest status of an animal can change with its commercial worth. The value of feral goats for export, mainly to Asia, has increased significantly in recent years, to about $15 per head at the farm gate in Queensland. Many farmers see harvesting of the goats as an important supplement to their farm income, especially now that the impact of deregulated agricultural markets and other problems have eroded the return from traditional products such as wool, beef and lamb. Worth $29 million in 1991–92, the feral goat industry is growing rapidly and exporters find it difficult to keep up with demand. If the value of goats was to increase to $25 per animal, farmers would be tempted to reduce their sheep flocks and run more goats.

In New Zealand, deer were introduced as game animals late last century and seen as a recreational resource until the 1920s when their damage to native forests and competition with domestic stock led to massive, largely ineffective, government-funded control campaigns. During the 1960s a market for venison was developed in Germany and, with the advent of helicopters from which to shoot and collect deer, many hundreds of thousands of animals were killed or, more recently, captured alive to stock deer farms. Today the deer are regarded as a resource by commercial and recreational harvesters, but are viewed as a pest by conservation groups, and by some farmers concerned that the deer may infect stock with bovine tuberculosis.[173]

Commercial harvest of Australian pest animals, primarily for export, is worth more than $100 million a year.[184] Species taken include feral horses, goats and pigs, and, until the spread of rabbit calicivirus disease, rabbits. Particularly in the rangelands, many farmers now harvest such pests as a way to diversify their production base. This move has been aided by the promotion of game meat as healthy because it is lean, free of chemical residues and low in cholesterol.

Some authors suggest that commercial harvesting of pest animals such as feral horses, pigs and goats may help to manage the damage they cause.[48,67,173] However, further studies are needed to determine whether this is the case. For other pests, such as rabbits and foxes, harvesting seems to be of little value. The density of rabbits at which shooters will stop commercial harvest is thought to be well above

Before the introduction of myxomatosis, rabbits were abundant in south-eastern Australia. Government bounties and strong markets for meat and fur made rabbit trapping profitable.
Source: NSWAF (duplicated from print, circa 1948, Cowra)

that necessary to prevent significant damage.[225] Similarly, harvest of foxes for fur, even at its peak when Australia was exporting 350 000 pelts per year, had little apparent effect on their density.[198] Moreover, hunters removed animals where it was easiest, not necessarily where control was most needed.

Native animals as pests

Like exotics, native animals may also be seen as pests if they conflict with human interests. Native animals rarely cause environmental problems unless they have been transplanted to a place where they do not occur naturally, or where the environment has been altered first by other agents of change, such as vegetation clearing or the provision of water.

Native animals such as kangaroos, wallabies, wombats, parrots and fruit bats can cause damage to crops, pasture and natural ecosystems. Even some rare species, such as the Southern Hairy-nosed Wombat, and threatened species, such as the Long-billed Corella, can be pests. This was acknowledged by Australia's primary nature conservation body, the Australian and New Zealand Environment and Conservation Council (ANZECC) in its recognition of three aims for managing kangaroos:

- conservation of kangaroo species;
- reduction of the damage kangaroos cause; and
- where possible, management of kangaroos as a renewable resource.

The damage control and harvesting aims are permitted provided that they do not compromise the primary aim of conserving kangaroos.

Native animals that have been moved to new habitats can also become pests. Two Western Australian examples are Laughing Kookaburras, which were introduced as snake-killers, and Sulphur-crested Cockatoos, originally brought to the west as pets. Both have spread and compete with local species for scarce nest hollows in trees, and the cockatoo is also an agricultural pest. As a result, Western Australia has strict legislation to control the import of potential pests, including many native animals, from east of the Nullarbor.

Whereas the approach to managing native pests is similar to that for introduced animals, it is usually more complex because of public concern about the balance between conservation and control of native wildlife. The preferred strategy for native pests is to attempt to manage the damage they cause by habitat manipulation or other non-lethal techniques.[189]

Native animals, such as the Emu, can become pests through changed land use or increased numbers.
Source: Noel Preece & Penny van Oosterzee

Table 2.1 Some native animals that are sometimes considered to be pests, and examples of the damage they may cause.

Reptiles	
Saltwater Crocodile	death or injury to people, cattle
Poisonous snakes	death to people, pets, domestic animals
Birds	
Emu	damage to wheat, fences
Australian Brush-turkey	damage to potatoes, fodder oats, lucerne
Magpie Goose	damage to grain crops, fruit, flowers
Ducks, several species	damage to grain crops
Little Pied Cormorant	damage to fish hatcheries and yabbie farms
Great Cormorant	damage to fish hatcheries and yabbie farms
White-faced Heron	damage to fish hatcheries
Red-tailed Black-Cockatoo	damage to field crops, flowers
Yellow-tailed Black-Cockatoo	damage to pine plantations
Galah	damage to playing fields, fruit, nuts and grain
Long-billed Corella	damage to grain
Little Corella	damage to grain, nuts, fruit
Sulphur-crested Cockatoo	damage to grain, buildings, trees
Rainbow Lorikeet	damage to fruit, vegetables, field crops, flowers
Australian Ringneck	damage to forest plantations
Rainbow Bee-eater	damage to bees
Blue-faced Honeyeater	damage to fruit
Yellow Oriole	damage to fruit
Crows and Ravens	damage to almonds, grain, fruit
Currawongs	damage to almonds, grain, fruit
Great Bowerbird	damage to fruit, vegetables
Silvereye	damage to fruit
Figbird	damage to fruit
Mammals	
Southern Hairy-nosed Wombat	damage to fences, land
Common Wombat	damage to fences, land
Agile Wallaby	damage to pasture
Black-striped Wallaby	damage to pasture, field crops
Western Grey Kangaroo	damage to grain crops, fences, pasture
Eastern Grey Kangaroo	damage to forest plantations, fences, pasture
Whiptail Wallaby	damage to pasture
Common Wallaroo	damage to pasture
Red-necked Wallaby	damage to field crops, forest plantations
Swamp Wallaby	damage to forest plantations, seed crops
Red Kangaroo	damage to field crops, fences, pasture
Black Flying-fox	damage to orchards
Little Red Flying-fox	damage to orchards
Grassland Melomys	damage to sugarcane
Canefield Rat	damage to sugarcane
Pale Field-rat	damage to Hoop Pine plantations
Dingo	damage to livestock

Sources: 10; 18; 69; 85; 102; 119; 154; 189; 190; 191; 242.

Potential pests: exotic animals and translocated natives

Exotic animals with potential to become pests are frequently imported into Australia.[21] The Red-billed Quelea, a major pest of grain crops in Africa, is already kept in private collections in Australia.[19] Similarly, the African Rose-ringed Parakeet is already in the country, has established feral populations in other parts of the world where it is a serious pest in orchards, crops and coffee plantations,[123] and is suited to Australian conditions. There is the potential for some of these captive animals to escape and become pests in Australia. Indian Palm Squirrels have escaped from Perth and Sydney Zoos and established populations locally, although the Sydney population has been eradicated. Ferrets, long kept as pets and used to hunt rabbits, appear to have established only recently, near Launceston in Tasmania, but so far have failed to spread beyond their establishment site. Aggressive carnivores, ferrets are a major pest in New Zealand and, were they to establish in Australia, pose a risk to native fauna.[21] These mammal populations are presently small and causing little damage, but they may not remain so.

European Perch stayed in a single waterbody in the Canberra region for over 20 years before the population suddenly expanded and spread to at least four other major water bodies.[120] European Carp have been established in Australia for over 100 years. Their population and distribution were relatively small until about 30 years ago when a more vigorous strain was released allowing the fish to spread to most major waterways.[142]

Despite their potential to become pests, native animals are still moved to areas outside their normal range, usually with little consideration of the damage they may cause. For example, native fish including Golden Perch, Silver Perch, and Murray Cod, bred from fish taken in southern Australia, have been stocked in rivers and other water bodies throughout much of Queensland and New South Wales. Similarly, governments are still moving individuals of the southern race of Koala into areas once, and maybe still, occupied by more northern races of koalas. The impact that these introductions have or will have on local populations of the same species is not known.

Control over the import of animals including fish into Australia is partly through the *Quarantine Act 1908* administered by the Australian Quarantine and Inspection Service (AQIS), partly through the *Wildlife Protection (Regulation of Exports and Imports) Act 1982* administered by Environment Australia, and partly through State and Territory legislation. AQIS is mainly concerned with preventing the introduction of disease, whereas the *Wildlife Protection Act* regulates the import of potential pests. State and Territory legislation is the major mechanism for controlling the keeping, trade and movement of non-native animals once they are in Australia.

Exotic animals held in captivity have the potential to escape and become feral. Indian Palm Squirrels escaped from Perth Zoo and established a small local population.
Source: WAAPB

The national Vertebrate Pests Committee provides advice on the import and keeping of exotic animals. To assess the pest risk of species, including exotic animals proposed for import, the Committee uses criteria developed by Bomford[21] (see below 'Criteria for assessing the pest potential of an introduced animal'), who discusses a wide variety of factors that influence the chance that a wild population of exotic animals will establish and cause damage. A knowledge of some factors, such as the type of food the animals eat, their reproductive potential and their powers of dispersal, are obvious pointers to potential pest problems. Other predisposing factors are less evident; for instance, exotic animals may interact in unpredictable ways with native wildlife or may be better adapted to Australian conditions than expected. For example, it would have been difficult to predict that feral cats would do so well on sub-antarctic Macquarie Island. Because of this uncertainty, it is necessary to leave a wide margin for error when assessing the risk that exotic animals will become pests.[21] The outcome of assessment may be that certain potential pest species are found to pose too high a risk to allow import or may require high security enclosures.

Despite these controls, new species are continually being brought to Australia, often illegally.[21] Exotic birds, snakes and lizards are prime examples because they bring high prices and are relatively easily smuggled. It is not unusual for Australian Customs Service officers to discover a highly venomous snake in overseas post articles they inspect.

Ironically, Australia even has some feral animals that may need protection rather than control. For example, there are healthy populations of Banteng Cattle on the Cobourg Peninsula in the Northern Territory, but in Java, where they are native, wild Banteng are threatened.[101] In Australia, the Banteng live almost exclusively in Gurig National Park where it might be expected that they are a potential threat to habitat conservation. However, research there has shown that they do not cause significant damage to native habitat in Australia, even at high densities.[29]

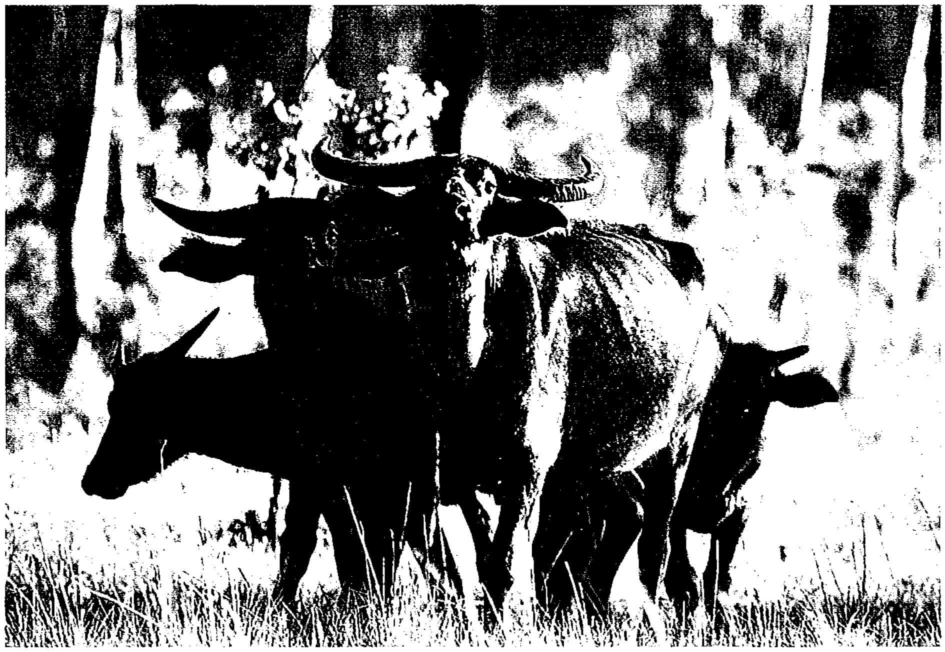
Criteria for assessing the pest potential of an introduced animal

To standardise assessment of the pest potential of species a set of criteria based on ecological principles was developed.[21] Four main issues were considered: the risk of escape; the likelihood that escapees will establish in the wild; whether eradication of the escaped pest is possible; and the likelihood of the animal causing damage to people, agriculture or the environment. When assessing a new species proposed for import, the risk of damage is balanced against any potential benefits such as agricultural potential, scientific research and education. The conservation value is also considered when a species is rare or endangered or part of an international captive breeding program. Where scientific or economic information is not adequate to assess the risk to agriculture and the environment, a conservative response is adopted.

Risk of escape from captivity

Many pets and domestic animals have estabhshed wild populations; some from escapees, others from deliberate releases. When assessing the pest potential of exotic animals it must be assumed that individuals will eventually escape or be released. Security can only minimise the risk. Events such as earthquakes, storms and accidents,

Banteng have been introduced to tropical Australia from Indonesia where they are endangered. Although they have some pest potential, their conservation is also an issue.
Source: CCNT



as well as deliberate releases through vandalism or by individuals concerned about animals being held in captivity have resulted in the escape of animals. Hippopotamuses at Tipperary Zoo in the Northern Territory were held in what was believed to be a very high security reinforced concrete and steel enclosure. However, in a major storm, flood waters broke the gate and freed the animals. They were recovered only through use of the back-up security measure of training the animals to respond to calls.

Likelihood of survival and establishment in the wild

There are no definitive rules that can be used to determine why some animals become established and survive in new environments and others do not. Nevertheless, an assessment of species that have successfully established can provide insights. Factors influencing the likelihood of survival in the wild, from Bomford,[21] include:

- timing of release in relation to factors such as weather, season, breeding season of the animal;
- number of animals released—in general, the more animals that escape, the more likely it is that a population will establish (but it should be noted that Himalayan Thar, for example, established thriving populations in New Zealand from less than 10 individuals);
- health of the released animals;
- whether or not the animal is wild-caught—individuals originally taken from the wild are more successful, as shown for rabbits in Australia where early releases of domestic breeds were unsuccessful;
- ability to adapt and pre-exposure to an Australian-like environment—animals that have the ability to adapt or that come from a climate similar to Australia have more chance of establishing; for example, the burrowing habit of rabbits enables them to cope with a range of temperature extremes;
- suitability of the site—disturbed or otherwise modified environments, such as land cleared to provide pasture, can assist some animals to establish;
- niche competition—animals that can fill niches (roles) not occupied by native species tend to be more successful; for example, Australia has relatively few

plant-eating native fish, a niche that European carp are able to exploit;
- distribution of the species—animals that have a wide distribution and have established when introduced in other parts of the world are likely to be successful colonisers;
- biology of the species—for example, animals that become sexually mature early, have a short gestation period and produce many young are at an advantage;
- diet of the species—for example, herbivorous animals are usually more successful than carnivores and omnivores;
- behaviour of the species—animals that are adapted to living with humans, or animals that are opportunists, or have a strong flocking or herding behaviour, tend to be successful colonisers; and
- heterogeneity—animals that show a high variation in behaviour, diet and nesting habits tend to be successful colonisers.

Possibility for eradication in the event of escape or release

Despite enormous effort, eradication of widely established populations of exotic animals on any continent has never been achieved.[26] It is often possible to eradicate newly escaped animals, particularly if they are conspicuous or easily approached, but timing is all-important. If they can be killed or caught immediately, then the chances of success are good. However, it is extremely difficult to detect animals at very low densities and there are few techniques to control escapees.

Potential impacts if feral populations establish

If the species causes agricultural or environmental damage elsewhere, they may do so if they become established in Australia. Some of the potential damage that exotic animals may cause if they become established include reduction of agricultural productivity, spread of disease, competition with and predation on native species, and damage to infrastructure such as fences.

Pests as disease carriers

An animal species can become a pest the moment it is discovered to harbour disease of importance to humans, livestock or wildlife. Many feral and native wild animals are potential carriers of exotic animal diseases such as foot-and-mouth disease (FMD, see Table 2.2), should the disease ever reach Australia. Pests, such as feral pigs, feral goats and feral horses, can carry the same diseases as their domesticated counterparts. Some pests, such as the European Red Fox, are a potential carrier of rabies, a viral disease which is not yet present in Australian fox or dog populations.[198]

> *Foot-and-mouth disease is probably the disease most feared in Australia by primary producers, food processors, exporters and veterinarians. Any incursion of FMD into this country would have devastating economic and social effects.*[147]

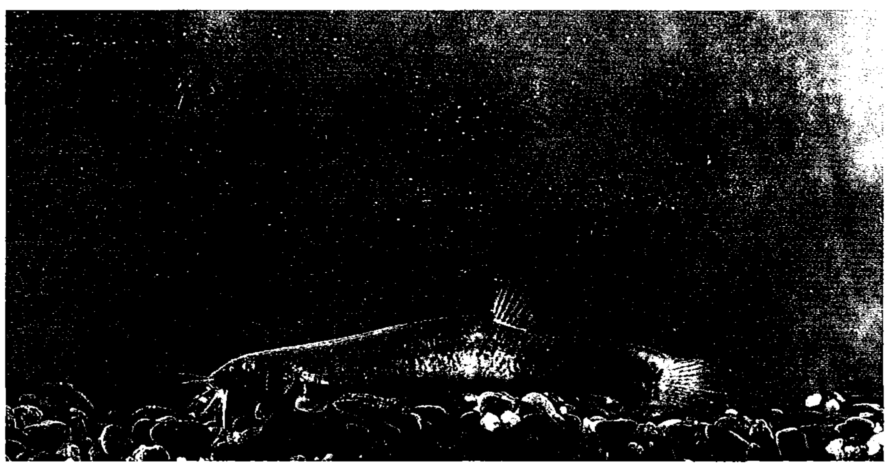
Should exotic diseases become established in feral or native animals, they could be difficult to detect and to eradicate. An outbreak of FMD in Australia could immediately close down some 90 per cent of our export market for animal products,[178] and cost Australia up to $3 billion in lost export trade, even if the disease was eradicated immediately.[228] If the outbreak persisted, continuing losses

From pets to pests

Many Australians do not realise that some of our common pets can become serious pests if they are released or escape and become established in the wild. When a pet is no longer wanted it is too often released, rather than disposed of humanely. The consequences for the environment can be dire.

Aquarium fish are a major source of aquatic pests. The pest fishes Weather Loach and Tilapia (and the aquatic weed Salvinia) are believed to have established wild populations after being released from aquariums.[36,12] Another popular aquarium fish, the Mosquito Fish, was released in the misguided belief that it would control mosquitoes.[122] Its introduction to Edgbaston Springs in central Queensland has contributed to the demise of at least one species of native fish, the endangered Red-finned Blue-eye, from two of the six springs it originally inhabited.

Common (Indian) Mynas were released deliberately in Canberra in the late 1960s because people liked them in their gardens and towns.[17, 200] They are now an established pest in the city, have begun to spread into adjacent woodland and to neighbouring towns, and are now considered impossible to eradicate. In the woodland, they compete with native species for breeding holes and in the cities they can be a nuisance when they use holes in buildings as nest sites.



The Weather Loach was a popular bottom fish in aquariums, but its sale is now prohibited because wild populations became established from fish released from aquariums.
Source: Mark Lintermans

The Common Myna was introduced to Australia from Asia in 1862. The species is still spreading and its predicted future distribution takes in much of the coastal and subcoastal east and south-east. The bird has potential to become a major pest; it damages fruit and vegetable crops, fouls public places and may spread disease. Evidence is accumulating that it competes with native birds for breeding sites.
Source: WAAPB

Table 2.2 Some exotic diseases not yet in Australia that have the potential to be introduced, spread and cause harm to humans, primary industry and native wildlife

Disease	*Some wild animal carriers*	*Some animals affected*
Foot & mouth disease	Pigs, buffalo, cattle, goats, deer	Most livestock
Screw worm fly	Most feral animals	Most livestock, native mammals
Aujesky's disease (pseudorabies)	Pigs, goats, dogs, cats, foxes	Pigs
Hog cholera (classical swine fever)	Pigs	Pigs
African swine fever	Pigs	Pigs
Swine vesicular disease	Pigs	Pigs
African horse sickness	Horse, donkey, dogs	Horses, donkeys, dogs
Jembrana disease	Cattle, buffalo	Cattle, buffalo
Rabies	Foxes, dogs, bats	Dogs, humans, cattle and many other warm-blooded animals
Rinderpest	Feral herbivores, pigs, goats	Most livestock
Rift Valley fever	Feral herbivores, pigs, rats	Most livestock
Vesicular stomatitis	Feral herbivores	Most livestock
Newcastle disease	Feral pigeons, parrots	Domestic poultry, native birds and humans
Fowl plague (virulent avian influenza)	Water birds	Poultry
Viral haemorrhagic septicaemia	Salmonids	Salmonids

Sources: 13; 80; 82; 92; 117; Exotic Disease: think the worst first, AUSVETPLAN, no date, c1994.

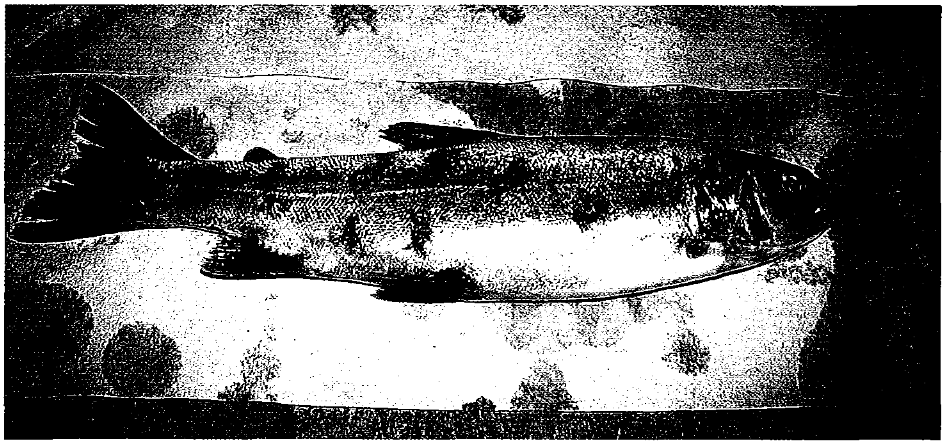
could be between $0.3 and $4 billion a year, depending on whether the trade was affected in just one State or country-wide.[15]

Feral pigs are seen as the main wild host for FMD and it has been estimated that the disease could cover 10 000 to 30 000 square kilometres before it was first detected.[96] In some ways it is fortunate that, in most parts of Australia, feral pigs are in relatively close contact with livestock, which might aid early detection of an outbreak of FMD. The difficulty in detection also has trade implications: it would be hard to demonstrate to Australia's trading partners that all feral pigs taken in the affected areas are free from FMD.[228]

Reducing feral pig density to a level where the disease could no longer survive would be difficult if not impossible. For some pig populations this may require a reduction of 95 per cent of the population;[63,176] yet in three full-scale trial programs in New South Wales, Northern Territory and Queensland, only a 40 to 80 per cent reduction was achieved. In most cases, the most practical approach to an outbreak of FMD would be to focus on managing the outbreak in domestic herds and to contain it, rather than to attempt to eradicate it in wild animal carriers.[48]

Toxoplasmosis is an example of a disease that feral animals, cats in this case, help to maintain (Table 2.3). The protozoan that causes the disease needs a feline host to complete its lifecycle. Native fauna that contract toxoplasmosis become lethargic, poorly coordinated, blind and ultimately many die. However, the extent of the damage due to toxoplasmosis nationally is not known.[66]

To help prevent the introduction of exotic diseases, Australia has strict quarantine regulations. Commonwealth, State and Territory health authorities have also developed a nationally agreed approach for managing contingency plans to control major exotic diseases such as FMD should they break out. The plans were developed and are continually updated under the Australian



The head of the green parasitic copepod Lernaea cyprinacea *bores into the flesh of fish. A heavy infestation can result in death from secondary infection. The parasite is thought to have been introduced to Australia on carp, and also affects native fish and perhaps amphibians.*
Source: Mark Lintermans

Veterinary Emergency Plan (AUSTVETPLAN). In most cases a 'stamping out' policy is used. Ideally, any disease outbreak would be contained within a small area, affected animals and those likely to have been in contact with them would be slaughtered, and the disease organism eradicated by cleaning, disinfecting and resting the land.[48] Where feral animals are likely to be involved, the contingency plans outline how these will be treated. In addition to action in the event of an outbreak and strict quarantine, exotic disease control is supported by other measures including surveillance of susceptible animals and, where appropriate, restrictions on the siting of abattoirs and other industries likely to be a source of infection.[82]

Table 2.3 Some diseases of feral animals in Australia that affect humans, domestic animals or harvested fish

Disease	*Feral and native animal carriers*	*Some animals affected*
Cattle tick & tick fever	Cattle, buffalo, horses	Cattle, buffalo, horses
Sheep liver fluke *Fasciola hepatica*	Rabbits, feral goats, kangaroos	Sheep, goats
Hydatids *Echinococcus granulosa*	Wild dogs, kangaroos	Sheep, domestic dogs, humans
Leptospirosis	Buffalo, pigs, goats	Buffalo, pigs, goats
Trichomoniasis & vibriosis	Cattle, buffalo	Cattle, buffalo
Toxoplasmosis *Toxoplasma gondii*	Cats	Many native species, livestock, humans
Q-fever (rickettsial disease)	Goats	Goats, humans
Ephemeral fever	Cattle, buffalo	Cattle, buffalo
Meliodosis	Pigs, goats	Pigs, goats
Canine distemper	Dogs, Dingoes	Domestic dogs, Dingoes
Fowl cholera	Starlings, sparrows, feral pigeons, rats	Poultry, cagebirds
Psittacosis	Feral pigeons, parrots, magpies	Poultry, humans
EHNV (epizootic haematopoietic necrosis virus)	European Perch, salmonids	Native fish including endangered Macquarie Perch; cultured fish
Lyssa virus	Bats, possums?	Native mammals, humans
Learnaea cyprinacea	European Carp, Goldfish	Native fish including River Blackfish and Murray Cod
Goldfish ulcer disease *Aeromonas salmonicida*	Japanese Goldfish	Goldfish, European Carp, salmonids

Sources: 48; 53; 80; 113; 117; 173

3 Keys to control: understanding pest biology and pest damage

Understanding pests

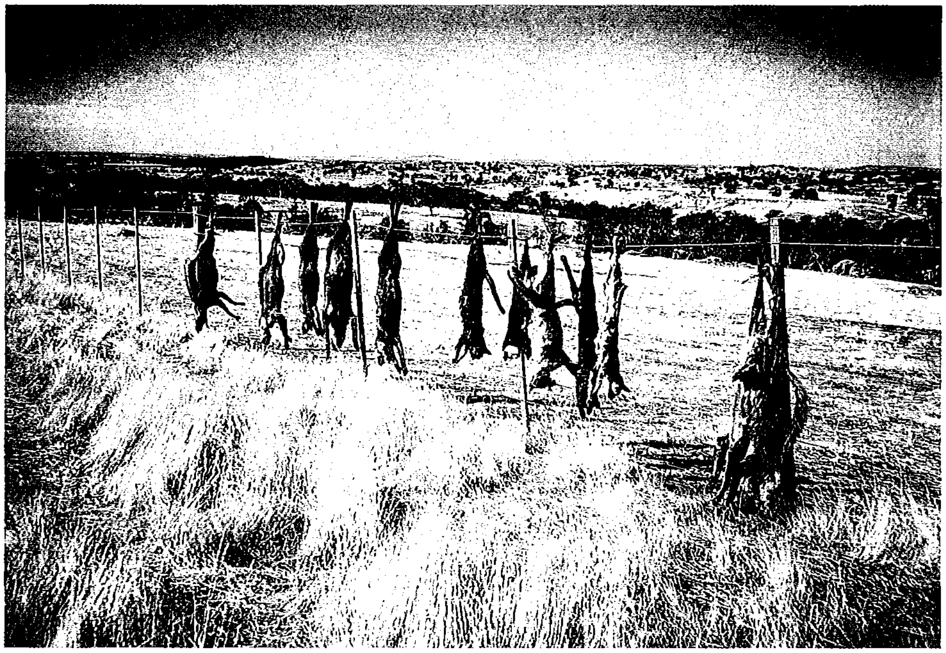
Pest animals continue to thrive despite the best efforts of humans to eradicate them. Explanations can be found not only in the fickle attitudes of people to pests, but also in pests' special characteristics. Certain aspects of their biology, combined with habitat changes that provide favourable conditions, and a scarcity of predators and diseases that might otherwise help to limit numbers, have contributed to pests' success in Australia (also see 'Criteria for assessing the pest potential of an introduced animal', pages 34–36). For example, animals that can consume a variety of different foods have great adaptability, which helps them to establish in new areas. Such adaptability may also create new, sometimes unexpected, pest problems. Foxes in the riverland area of South Australia, suffering a shortage of rabbits due to the effects of rabbit calicivirus disease, have become significant pests in avocado and fruit crops where they previously caused little damage.

In the past, little was known about the biology of pest animals and how they responded to control. Even less was understood about the relationship between pest numbers and damage. As a result, a lot of past pest management was an attempt to reduce pest numbers in the belief that any reduction would alleviate the damage pests cause. This was a simplistic but reasonable assumption given the limited knowledge at the time. With the benefit of hindsight, it is evident that simple reduction in pest numbers is rarely the best approach (also see 'Does increased pest control result in reduced pest damage?', pages 54–55).

A thorough understanding of pest biology and damage is an essential element of effective and efficient pest management. Such knowledge not only aids control directly but can also allow prediction and early management intervention to prevent pests building up their numbers and becoming a problem. For example, studies have shown that high survival of mice in winter and spring, a long breeding season, and good condition of mice at the beginning of the breeding season lead to the formation of mouse plagues. These factors are influenced by weather, which affects food quality and quantity. Thus, information on mice and climatic events can be used to make long-range forecasts of mouse eruptions.[205]

Population dynamics: high potential for increase

An important characteristic of many pest animals in Australia is their ability to rapidly increase in numbers when conditions are favourable. This helps them to establish in new areas and to recover from high losses due to control, drought or other factors. Both reproductive rate and survival rate contribute to the potential



Cats and foxes strung along a New South Wales fence reflect a farmer's concern. However, simple reduction in numbers, without regard to the pest's biology, is rarely the best solution to pest problems.
Source: NSWAF

for pests to increase. In Australia, rabbits produce on average 15 young per year, but can more than double that in good years.[84] Compare this with the one or two young produced per year for Burrowing Bettongs[97] and one to six for Bilbies,[103] both rabbit-sized native mammals.

Even pests with a relatively low rate of reproduction may increase their numbers rapidly if survival is unusually high. For example, following a one-off 80 per cent reduction in donkey numbers the increase in the donkey population was much greater than that in an uncontrolled population nearby (see Table 3.1). This was because there was more food for the reduced population, allowing more of the donkeys to breed and much higher survival of their young.

Table 3.1 Differences between donkey populations on two large properties in the Northern Territory, each with over 10 donkeys/km^2, after one population was reduced by 80 per cent.

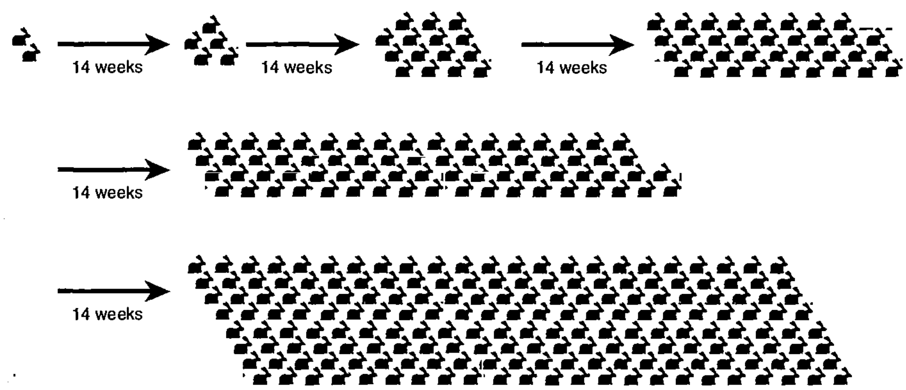
Measurement	*High-density block*	*Low-density block*
Treatment (1983)	None	80% of donkeys shot
Density three years after treatment (1986)	3.3 donkeys/km^2	1.5 donkeys/km^2
Density four years after treatment (1987)	3.2 donkeys/km^2	1.8 donkeys/km^2
Change in population 1983 to 1987	Insignificant	20% increase
% males sexually mature at 2.5 years of age	43%	100%
% females breeding at 2.5 years of age	30%	50%
% juveniles surviving at 6 months of age	38%	79%

Source: adapted from 46

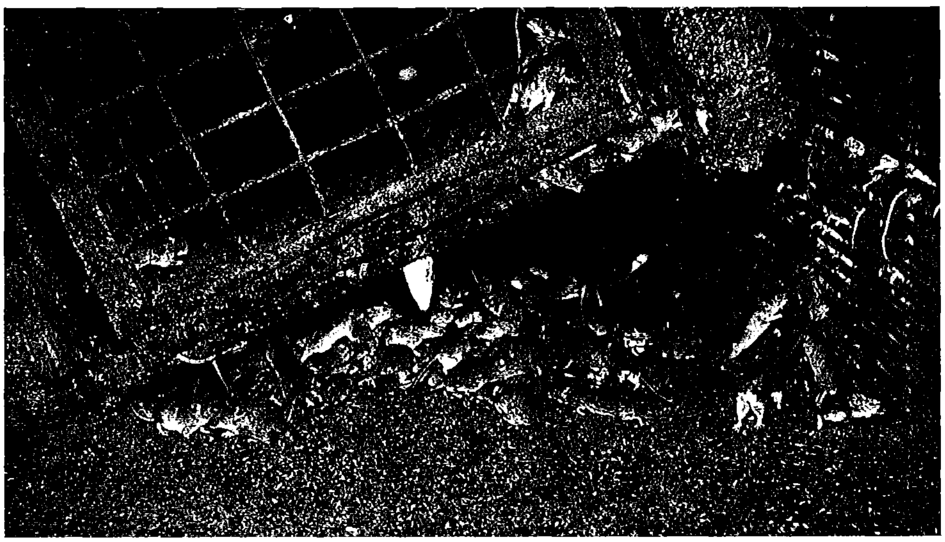
Removal of large numbers of individual pests does not necessarily lead to a significant reduction in their population size (or their damage). For example, in Western Australia, the population of feral goats increased by 18 per cent each year between 1987 and 1990, to reach 1.1 million, despite about 200 000 goats being killed annually. Clearly, the rate of increase in the goat population exceeded the rate of culling. Indeed, feral goats have the potential to double their population every 1.6 years if they are not controlled by humans, predators or other agents.[173]

The lower the density is reduced the more the population seeks to increase and this acts against the success of a control operation.[44]

Many pest management programs are carried out when pests are at high numbers and the damage they cause is obvious. Unfortunately, especially for boom or bust species such as rodents and rabbits, this is likely to be the wrong time to apply control (see below 'Understanding population dynamics'). A better strategy would be to weigh the potential of the pest population to recover and the cost of control, and determine when it would be most cost-effective to apply control (see 'When is it worth managing a pest population?', page 97).



The fabled fertility of rabbits is strongly grounded in reality. A pair of rabbits in an outside enclosure in the Australian Capital Territory, without supplementary food and water, increased to 184 individuals in 18 months (Williams et al.[226]). Such high capacity for increase is aided by large litter size, short gestation and nurturing periods, and early sexual maturity.



Mice have a particularly high potential for increase and, in good seasons, a high birth rate can lead to a dramatic increase in numbers. In south-eastern Australian grain growing areas—on average every four years—mice reach plague proportions and cause millions of dollars worth of damage.
Source: CSIRO

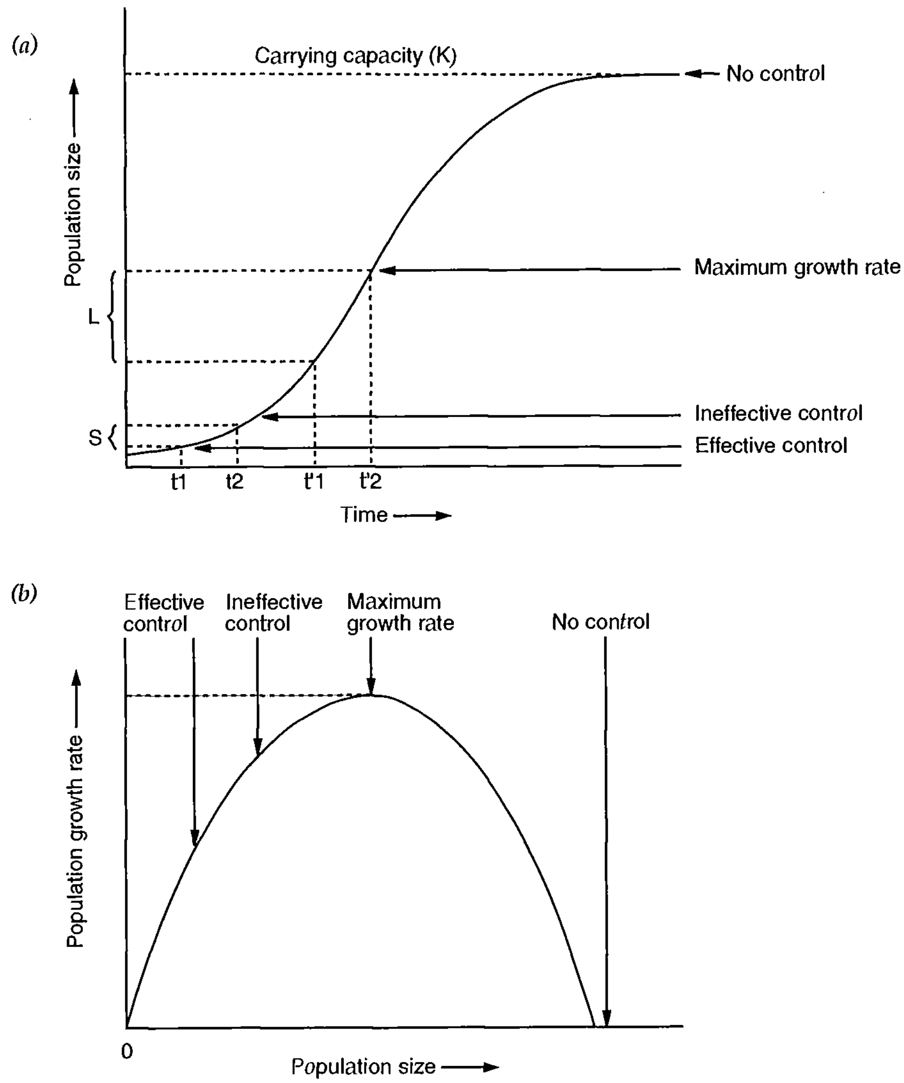
Understanding population dynamics

(Adapted from information supplied by Steve McLeod)

The density or size of a population is dependent on four main processes: natality (births); mortality (deaths); immigration (arrivals); and emigration (departures). Populations increase because of natality and immigration, and decline because of mortality and emigration. Underlying these major processes are other factors, such as age structure, genetic composition and spatial distribution, which influence population dynamics indirectly. Thus, a suite of factors, whose influence may change depending on prevailing conditions, such as weather, affects the dynamics of any population. It is the unpredictable nature of these changes that can make the result of pest management practices difficult to forecast. Nonetheless, a thorough understanding of the population dynamics of a pest species will help managers to target control at vulnerable stages in the life of a pest, and at the most effective point in the dynamics of the pest population, to maximise the benefit of any management program.[95]

A simplistic way to illustrate and predict change in abundance of an animal population over time is the logistic growth curve (see Figure 00). The population increases rapidly and begins to slow after the point of inflexion, until carrying capacity (K) is reached and the population levels off. Population growth is a function of both population size and the rate of increase in the population. This form of population growth applies to animals that are limited by resources, usually food, but sometimes nest sites or space (when crowding suppresses recruitment into the population). In reality, few pest populations follow the logistic model, in part because it assumes that rate of renewal of resources is independent of pest density. However, it helps to illustrate some of the reasons why simple removal of animals, without consideration of population dynamics, rarely achieves effective management.

The logistic curve (a) illustrates the growth of a pest animal population that is limited at K (the carrying capacity), by crowding, or lack of food or some other renewable consumable resource. Between time t1 and t2 a very small population grows by a small amount (S). When the population is larger, over the same time period it increases by a greater amount (L). For the same population, when the growth rate of the population is plotted against the population size or density the relationship forms a parabola (b). Thus, the growth rate of the population is slowest at very low densities and very high densities, and greatest at medium densities (after Krebs[109] and Williams et al.[226]). In terms of management, it is best to control such a population at low densities, when growth is slow, than at medium densities, when the population will recover its numbers quickly.



Commonly, the growth rate of a population is estimated by measuring its size or density at some time, then measuring it again after a certain period of time has elapsed. From the difference between these two estimates the population's instantaneous rate of increase can be calculated. This method has been used to estimate the rate of increase in goats,[132] rabbits,[180] pigs[47] and foxes.[177] If the rate of increase can be correlated with some other variable, such as population density or food abundance, then the population's rate of increase can be estimated for almost any situation. The estimation of instantaneous rate of increase can be a powerful tool for predicting the outcome of various management actions, such as the rate at which a population will recover after control, or the number of animals that must be removed from a population to suppress population growth.

The object of pest control is to reduce pest impact, which is often achieved through reducing the pest's population density. However, following reduction it is likely that any individuals that remain will not be limited by resources, and consequently their rate of population increase may be at the maximum rate. When resources are not limiting and birth rates are much higher than death or dispersal rates, populations can exhibit spectacular growth rates. House mice provide a prime example. Through a combination of large litter size (average litter size is six young) and a short time between conception and weaning (about 40 days), they are capable of almost exponential growth during an eruption.[45] Although some dispersal may occur in areas experiencing a mouse eruption, there are only limited areas of suitable habitat (refugia and crops) with sufficient food resources (grain) to maintain population growth. Once suitable habitats have been colonised, the mice deplete their food resources; birth rates decline and death rates increase due to starvation and reduced resistance to disease. The density of mice falls dramatically but not before they have done substantial damage to the crop.

In addition to a high rate of increase in the local population, immigrants may move into an area of low population density and abundant resources and exacerbate the rate of population increase. This effect has been noted for many pest species, for example rabbits,[168] foxes,[108] pigs[48] and goats.[173] If the goal of pest management is a sustained reduction in pest density, as opposed to a targeted or one-off reduction (see pages 98–100), then this ability of pest populations to recover is an important point to consider, and ongoing forms of control must be put into place.

How can this type of knowledge be put to use? To manage a hypothetical pest, available knowledge on birth, death, immigration and emigration, and perhaps the interactions between them, must be considered and a decision made about which process or combination of processes would best be manipulated to achieve the management goals. If the pest has a high birth rate but dispersal is not important, such as for mice in grain crops, then management targeted at reducing the birth rate will have more effect than that preventing dispersal. Alternatively, if the species is long-lived and has a low rate of increase, as is the case for the One-humped Camel, then increasing the death rate will significantly lower the long-term density of the population.

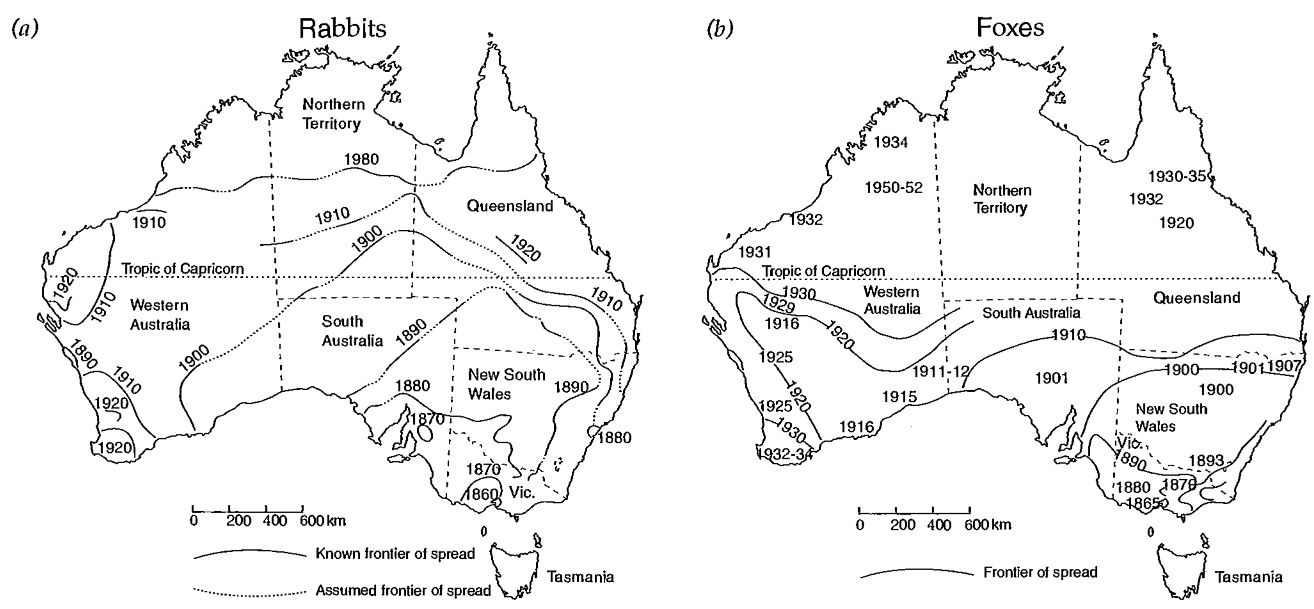
If recolonisation (immigration) is an important process for the pest species, as it appears to be for rabbits, then either preventing immigration with a fence or removing warrens and harbour so that dispersing rabbits have no place to live will reduce their rate of recolonisation. The ability of pest populations to recover is illustrated by a study of recolonisation of six areas from which all rabbits had been removed.[167] Within two years rabbit densities had returned to 26 to 81 per cent of pre-control levels. It appeared that rabbits dispersing from adjacent, uncontrolled sites quickly re-established the pest in areas from which it had been removed. Similarly, immigration of goats from areas where they were not controlled has been suggested for the failure of a goat eradication program in Western Australia.[173]

Ability to spread rapidly

The rate of spread of the rabbit in Australia was the fastest of any colonising mammal anywhere in the world.[41]

Many pests are highly mobile which makes them great dispersers and colonisers. Foxes now inhabit much of Australia and they achieved this wide distribution within 100 years of their initial introduction into southern Victoria in about 1871.[198] Their rate of spread is exceeded by that of the rabbit in Australia, which holds the record as the fastest coloniser of any mammal in the world.[41] Rabbits spread, from the original introduction of four individuals in Victoria, at a rate which varied from 10 to 15 kilometres a year in wet and forested country to 100 kilometres a year in arid rangelands.

The impressive colonising ability of many pests has major implications for pest control. A landholder conducting pest control in isolation is unlikely to be successful due to rapid reinvasion of animals from neighbouring land (see



Foxes and rabbits occur throughout Australia except in the tropical north, Tasmania and some smaller islands (after Saunders et al.[198] *and Williams et al.*[226]*). With the exception of Tasmania the distribution of the fox (b) largely mirrors that of the rabbit (a), its major prey. Rabbits arrived in Tasmania with the First Fleet in 1827, and were released on the mainland near Geelong, Victoria, in 1859; the fox was brought in as early as 1855, but probably not released successfully until 1871. The rapid spread of both was encouraged by releases into new areas.*

'Understanding population dynamics', pages 42–45). Similarly, even after massive control programs, this ability to spread often allows pests to recolonise their former distribution.

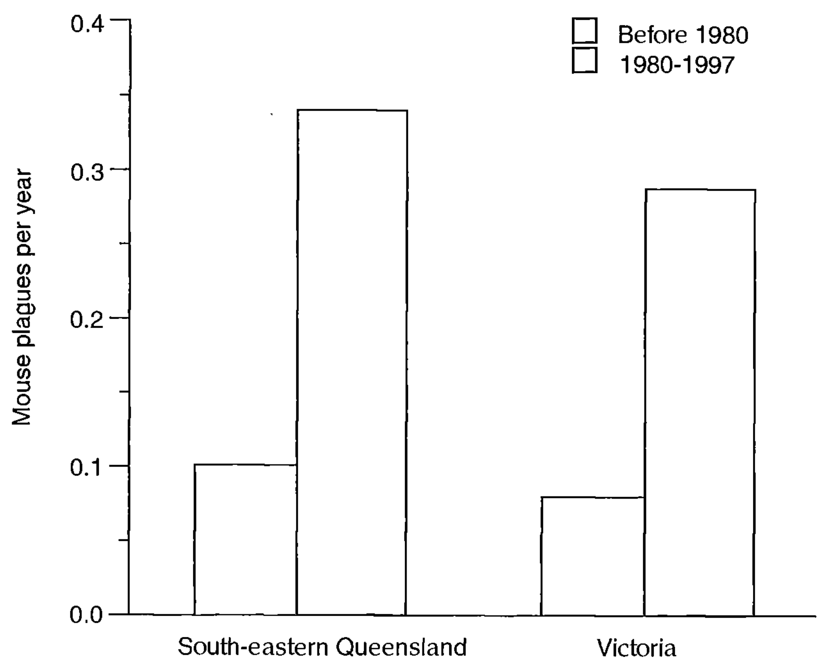
Favourable habitat changes

The successful establishment of some pest animals in Australia was almost certainly helped by the creation of disturbed habitats. Rabbits spread by moving up river systems, which were also the first areas selected for settlement by pastoralists. The farmers felled trees to increase grassland and these provided abundant harbour for rabbits. Grazing by domestic stock made the native grasses more nutritious and available to rabbits because they prefer short-cropped pasture to rank grass.[225] The introduction of more nutritious annual grasses and fertilisation of pastures also helped rabbits by providing high quality food at a time that fitted in with their breeding cycle. The rabbit in turn helped the fox to spread by providing the new invader with an abundant source of food. Similarly, the pastoral industry assisted the successful establishment of other pests such as the feral horse, donkey and goat by building dams and bores which greatly increased the availability of water.

Some of the disturbance to Australian habitats has made them less suitable for native animals and more suitable for pests. Examples are the changes in nutrient levels, salinity and water flow patterns of many inland waterways, that have benefited European Carp and adversely affected native fish such as Golden Perch and Murray Cod (also see 'European Carp: problem or scapegoat?', pages 84–86).

Successful control of pests often involves management of habitats to make them less favourable to the pest animal. For example, the House Mouse survives well in the stubble left after a rice crop is harvested. Ploughing in the stubble and heavy grazing of the levee banks to remove additional refuges for the mice may help to keep numbers low.

Mouse plagues have occurred more frequently in recent years (since 1980) than historically (before 1980). This is illustrated by data from two grain growing regions—in Victoria and south-eastern Queensland—and has been linked to new farm management practices such as greater diversity of cropping, more frequent cropping and less disturbance of stubble left after harvest. Mice now have more food for longer periods of the year and their nest sites are disturbed less often than in the past (adapted from Singleton & Brown[205]).



Bores and dams provided for stock have allowed pests such as goats to establish in semi-arid areas.
Source: Robert Henzell, APCC

The importance of burrows

The European Rabbit is the only rabbit that builds and lives in burrows.[151] This enables it to exploit open grassland habitats where the warrens provide shelter from extremes of heat and dryness, and from predators.[225] Rabbits would rather occupy other animals' burrows than dig their own.[56,166] The burrows of Bilbies, Burrowing Bettongs and several other native animals once more common and widespread than they are today, were ready-made refuges for rabbits during their colonisation of Australia. Bilbies frequently abandon their burrows when their food supply dwindles.[103] Adult rabbits, on the other hand, once they occupy a burrow, tend to stay as permanent residents.

The importance of burrows to rabbits is an aspect of their biology that can be exploited for control. Indeed, destruction of warrens is one of the most effective control techniques.

Few diseases and predators

One reason for the success of some pest animals in Australia is that there are few of their natural agents of control, such as predators, competitors and pathogens. In the days of settlement, the long voyage to Australia acted as an effective quarantine measure that weeded out diseases and parasites of stock and of other introduced animals destined to become pests. Today, one of Australia's great advantages as a major international trader in agricultural products is the lack of many common diseases and parasites of domestic stock. However, the same lack of diseases and parasites may also have helped many pest animals to prosper. It follows that the introduction of pathogens may help to control pests, and the introduction of diseases such as myxomatosis in 1951 and rabbit calicivirus disease in 1995–96 have met with some success.

Similarly, there are few predators in Australia capable of capturing the larger pest animals such as feral goats and pigs. Those predators that are here, were and still are controlled to protect livestock. Indeed, in the early days after European settlement, the persecution of native wildlife to protect introduced animals knew few bounds. For example, at Barwon Park where rabbits were first released, the shooting tally of native predators in 1866 included 448 hawks, 23 Wedge-tailed Eagles and 622 native cats.[193] In addition, potential competitors of livestock, such as kangaroos, were controlled to the indirect benefit of some pests.

Today, there are farmers who believe that by leaving Dingoes uncontrolled they have less of a problem with foxes and kangaroos. Dingoes were introduced to Townshend Island to successfully manage the large feral goat population.[4] Other attempts to use predators as a means of biological control—such as the release of introduced cats and mongooses to control rabbits and the importation of Cane Toads to control cane beetles—have been spectacular failures. Nevertheless, predators can play a role in management when pest animal density is low (see 'One-off management', page 98).

Understanding how pests fit into a complex environment

Settlers of the rangelands last century and early this century were used to farm life in the temperate and reliable climate of Europe. They found a land of fragile and infertile soils, low and unreliable rainfall, and extremes of temperature. It took a long time, but it is now known that many European farming practices are not sustainable for much of Australia. In the meantime pests were often made the scapegoats. Pest damage to the environment, to populations of native animals and to farm production can be conspicuous, but in most cases pests are not the only contributing factor.[136]

For example, it has long been believed that foxes have played a major role in the decline of certain native species. The last wild colony of Rufous Hare-wallaby (Mala) was eliminated by a fox and, if left uncontrolled, the fox could cause other species such as the Numbat and the Black-footed Rock-wallaby to become extinct. However, the decline of medium-sized species of native mammals across Austraha was probably due to a range of factors including predation, changed land use, and new fire regimes.[35,143,126,127,128]

Similarly, feral cats apparently contributed to the extinction of a subspecies of the Kakariki on Macquarie Island. However, the two species had coexisted for 70 years and it was only after another predator, the Weka, and rabbits were introduced that the parrot disappeared.[81] It is thought that the Weka preyed on the parrot's eggs and young, and rabbits reduced the parrot's habitat by grazing and provided prey for the cats, which increased in numbers. In winter, when rabbits were scarce, the cats may have turned to the parrots for food.

Although cats (and foxes) have been blamed for many of the extinctions and declines of native species, the evidence is not always clear.[66,198] It has been difficult to determine the impact of feral cats on native wildlife on the Australian mainland.[28] Dietary studies show clearly that feral cats kill many hundreds of thousands of native animals. However, it is not known whether this level of predation is a threat to the survival of native fauna populations. Cats may simply

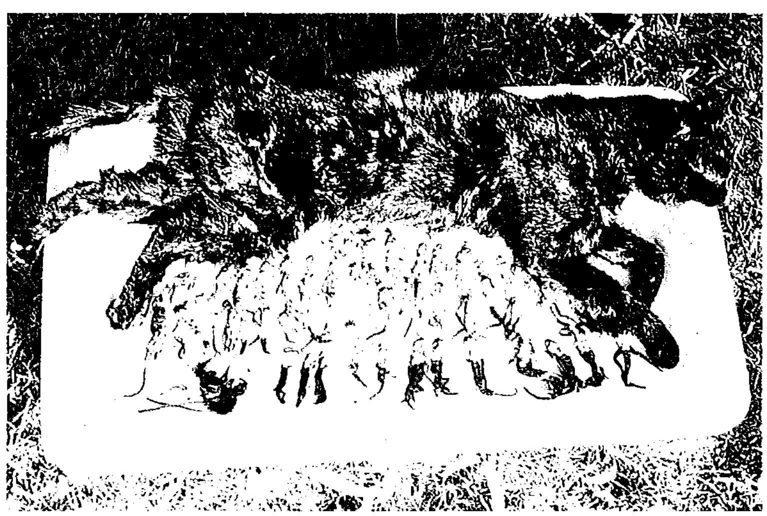
LEFT Wedge-tailed Eagles and other native predators are too often destroyed because they are perceived to be pests, yet it may be poor management to remove animals that prey on pests.
Source: Nicholas Birks

RIGHT Undeniably, several introduced predators prey on native wildlife. Here a cat has captured a rosella, yet they are not necessarily harming prey populations. Other factors, such as habitat degradation, may be more harmful.
Source: Keith Gillet, NSW NPWS ©

take a sustainable harvest of many of their prey species.[28] Most animal populations produce more young than they need to replace themselves and most of these young do not survive to become adults. Many populations can withstand a high level of predation, particularly of these doomed youngsters. For instance, hundreds of thousands of rabbits are killed by humans, and many more by other predators, without threatening the status of the rabbit in Australia. Thus, it may be considered desirable, for example, to spend resources on controlling urban cats to stop their killing of native wildlife, but it should be understood that, in doing so, little may be achieved for the conservation of native biodiversity.

Indeed, long-term environmental change, particularly habitat clearing, coupled with drought and competition, may have been the main causes of major population declines of many native species.[42,130] In the case of these very depleted populations, cat predation is likely to be a severe threat. Native animals, such as the desert-living Mala, that are slow breeding and have been confined to a few isolated pockets are most at risk.[83]

European Carp are blamed for damaging freshwater ecosystems, but one reason that carp are successful is the changes humans have made to the aquatic environment. Indeed, habitat disturbance is often a fundamental factor in the establishment and distribution of exotic fish in Australian waters. European Carp, Mosquito Fish, Goldfish and European Perch are favoured by the reduced flow conditions of dams.[12] Slow-moving waters and weedy conditions—especially



Evidence of pest damage to wildlife may be stark; this feral cat has eaten many lizards. However, unless the lizard population is already depleted or rare, predation by cats may have little effect.
Source: J. Read, FPP

Heavily disturbed river catchments with introduced weeds, such as on the Goulburn River, New South Wales, strongly favour introduced weed-tolerant fish.
Source: Noel Preece & Penny van Oosterzee

exotic weeds—strongly favour these opportunistic fish, while disadvantaging native species (see 'European Carp: problem or scapegoat?', pages 84–86). Topminnow are also tolerant of heavy metal pollution and even of the fish poison rotenone. By contrast, surveys of undisturbed natural waterways have recorded only native fishes or a predominance of native over exotic fish.[12]

Pests are often more than scapegoats but less than sole culprits

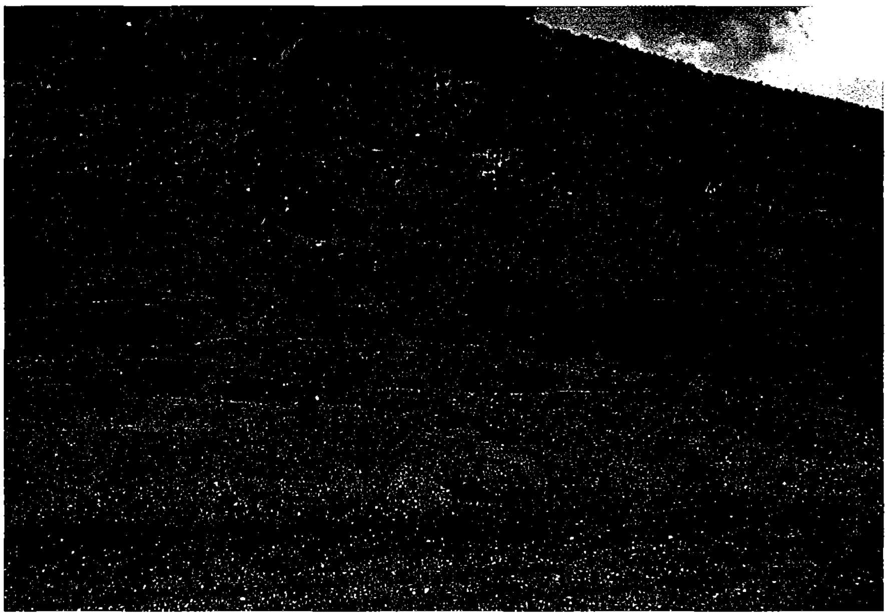
Undoubtedly, some pest species cause significant damage. However, more often than is recognised, they are just one of several contributing factors. For success, management of pests and pest damage needs to be considered in the context of all the operating factors, and incorporated into an integrated management plan.

A devastating trio: overgrazing, drought and rabbits

The Royal Commission of 1901[195] examined the economic plight of pastoralists in western New South Wales and recorded eye witness accounts of degradation of the land caused by overstocking with sheep, aided by drought, rabbits and erosion. The following sobering picture emerged. When settled around the mid-1800s and until about the last two decades of that century, the western districts had been open forest with natural grasses, forbs and shrubs thriving in the soft, absorbent soil. In less than 20 years, by the time of the Commission, many trees had been ringbarked, the ground cover was thinned and patchy, and much of the soil had already eroded, turned to dust and blown away, to cause drift, siltation and other problems elsewhere. What remained was hard, clayey ground that did not hold water and the water ran off to cause further erosion, carrying with it seeds and precious nutrients. The stocking capacity of the fragile land had been grossly overestimated.

Concern at the time was for the poor stocking rate but many native animals must also have suffered. By the turn of the century—as predicted in 1866 due to its extreme rarity and gross overstocking of its habitat with sheep[110]—the Pig-footed Bandicoot was extinct in New South Wales and soon after the last specimen was sighted, in South Australia. By then the rabbit had arrived in western New South Wales in numbers but the fox, feral cat and feral goat had not.

High wool prices in the 1870s and 1880s led to a switch from cattle to sheep and in 1891 there were 15.4 million sheep in the Western Division. Then, wool prices fell, rabbits spread across the Division and, in 1895, a seven-year drought began. The 1901 Commission tackled the major problem of overstocking and made recommendations on other issues such as rabbits, ringbarking, drought, scrub regeneration and conflicts between small and large landholders. The result was a more realistic use of the land and until 1950 the condition of the country apparently stabilised.



Grazing by rabbits and soil disturbance around their warrens contribute to degradation of the rangelands through loss of topsoil and erosion.
Source: CCNT

Rabbits are one of several factors, including grazing by stock, that cause severe erosion in the Alice Springs area.
Source: Noel Preece

However, the post-war boom of the 1950s sent wool prices soaring and new settlers to the Division. The introduction of myxomatosis reduced rabbits and allowed some recovery of pasture. But by the mid-1960s, beset by drought, extensive fires, a partial recovery of the rabbit population and falling wool prices, many properties were no longer viable. In 1980, there were less than 8 million sheep left in the Division but land clearing continued.

It wasn't until the passing of the *National Parks and Wildlife Act* 1967 and the setting aside of Sturt National Park, that wildlife was widely and seriously considered. The report of the Select Committee in 1984 noted that 52 per cent of native mammal species were believed to be extinct in the Division and a later study identified six extinct bird species and a further 103 bird species in decline in the region.[207]

The rangelands of western New South Wales are in crisis.[129] Their long-term sustainable use, including conservation of biodiversity, will be a complex process involving property restructuring, land use that is based on principles of ecologically sustainable development (see 'Ecologically Sustainable Development', page 76), and appropriate management of dwindling water resources.[129,144]

Better land management, of which pest management is just one element, is also essential for land restoration in the Western Division. Recovery of the fauna and flora will be one measure of the success of restoration efforts.

Pest damage

Management needs to focus on reducing damage and not just pest numbers.[30]

Pest animals such as the goat, rabbit, fox and pig cause extensive damage to Australia's natural resources and agricultural production. Together, these introduced animals cost Australia hundreds of millions of dollars annually in lost agricultural production and conservation expenses.[23,76,161,229]

Rare mammals such as the Numbat have been reduced in range and number due to the combined effects of grazing by rabbits, cattle and sheep, changed land use, reduced natural vegetation cover, and introduced predators.
Source: Noel Preece & Penny van Oosterzee

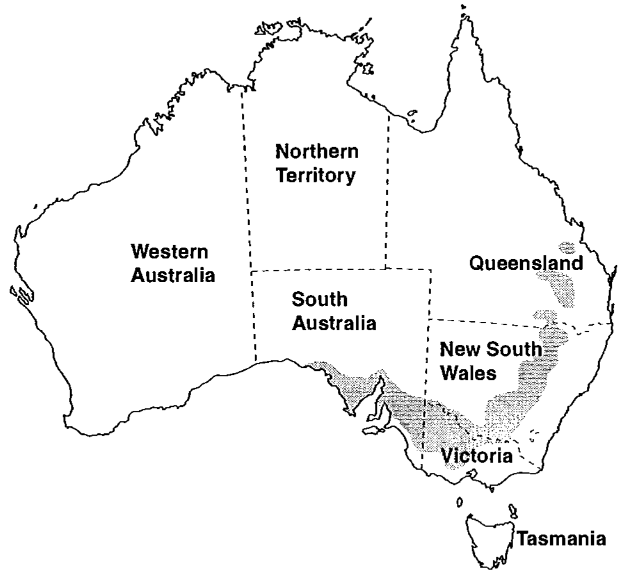
Many of Australia's unique species, such as the Eastern Barred Bandicoot, are threatened by foxes and cats. Where habitat remains, management of the two predators can allow Bandicoot populations to recover.
Source: Clive Marks, DNRE

Some of the most compelling evidence that pests can cause significant damage comes from experiments where pests have been controlled or excluded. Foxes were removed from some Black-footed Rock-wallaby colonies in Western Australia, but not others. At the colonies subject to predator control rock-wallaby numbers increased five-fold; in the untreated areas they showed a slight decline.[108]

Damage caused by introduced pests is often at its most obvious on islands, where habitat and movement of native species are restricted.[125] Rabbits introduced to Laysan Island in the Pacific Ocean, in 1903, caused the local extinction of three endemic bird species and 22 of the 26 native plant species within about 30 years.[223] National parks or uncleared patches of native vegetation in a sea of agricultural land can also be considered islands vulnerable to the impact of pests.[35]

Foxes and cats, in particular, pose problems for captive breeding and release programs aimed at conservation of threatened species.[28] The captive-bred stock are often liberated into habitat islands where they are particularly vulnerable to predation. For example, despite baiting to remove foxes, reintroduction of the Numbat into a Western Australian nature reserve was not the success that it had been in wheatbelt areas. It appeared that feral cats had increased in numbers in the absence of foxes and were limiting the increase of the Numbat population.[79] Cat predation is also threatening the now very restricted population of the endangered Eastern Barred Bandicoot near Hamilton, Victoria.[202]

Of all the animals introduced to Australia, rabbits have probably caused the most damage. They compete with native wildlife for food and shelter, and contribute to the decline in the numbers of many native plants and animals. In particular they have been closely implicated in the disappearance, late last century and earlier this century, of many medium-sized ground-dwelling native mammals. At this time, the combined effect of sheep, rabbits and drought seriously reduced the carrying capacity of the land, and brought about a wave of extinctions and severe population declines. Burrowing Bettongs, Brush-tailed Bettongs, Eastern Hare-wallabies and Bridled Nailtail Wallabies disappeared from much of the mainland before the end of the nineteenth century [10]



The main mouse plague prone areas in Australia: grain growing country in the semi-arid zone (Grant Singleton, CSIRO).

Pests may also damage native vegetation. Lack of plant regeneration, in part due to grazing of seedlings by rabbits, is likely to result in some native plant communities dying of old age.[13,144,225]

Rabbits are also believed to compete with livestock for the most nutritious plants and seedlings and annual production losses to rabbits in the pastoral zone of South Australia alone are estimated to be $17 million[89] (see below 'Does increased pest control result in reduced pest damage?'). Throughout most of Australia, the introduced field or House Mouse is usually a relatively harmless part of the environment. However, in the south-east Australian grain belt, every four years or so mice reach plague proportions and cause tens to hundreds of millions of dollars of damage.[45]

Native species also cause damage. Canefield Rats, and to a lesser extent the Grassland Melomys, cause severe damage to sugarcane and cost farmers about $2–4 million each year. In other parts of northern Australia these native rats are considered a valuable part of the fauna. Likewise the Pale Field-rat, a valuable component of natural tropical ecosystems, is poisoned in eastern Australian Hoop Pine plantations because it kills trees by ringbarking the roots and stems.[45]

Whereas there is abundant evidence that pests can severely damage the environment and cause major losses to agriculture, only rarely is there a simple relationship between pest numbers and the amount of damage they cause (see below 'Does increased pest control result in reduced pest damage?'). Ideally, the focus of effective pest control should be on reduction of damage. However, much remains to be learned about quantifying pest damage and relating it to pest density so that informed management decisions are possible.

Does increased pest control result in reduced pest damage?

Often little is known about the relationship between pest density and the level of damage caused. Usually, it is assumed that by reducing the numbers of the pest, the degree of damage will also decline. However, this is not necessarily so.

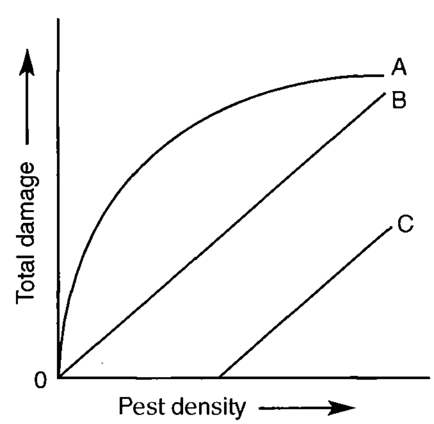
Some hypothetical relationships between pest animal density and the level of damage are illustrated in Figure 00 below. The relationships shown are only three of many possibilities. 'A' represents a situation where pest damage remains high even at relatively low pest densities. An example might be pig predation of winter lambs in some areas where damage is due to a few rogue boars.[175] These are often the wily older animals that have learned to avoid traps and shooters. Reducing overall pig density may fail to take most of the rogue boars, so damage remains high even at low pig densities. Another example of 'A' might be rabbit browsing of regenerating native shrubs; even at densities of less than one per hectare rabbits can prevent regeneration of some native plants such as wattles in the rangelands.[114] Thus, reducing rabbits to low numbers may make little difference to regeneration.

'B' represents a direct relationship between pest density and damage. An example might be the competition for pasture that is assumed to occur between sheep and rabbits. Based on the average food consumption of wild rabbits it is estimated that 16 rabbits are equivalent to one sheep.[204] Therefore, reducing rabbit density should enable X/16 more sheep to be run where X is the number of rabbits removed from the property. However, this is simplistic. There is evidence that, in the rangelands of New South Wales, competition between sheep and rabbits occurs only when the amount of pasture is less than 250 kilograms per hectare.[204]

An example of a 'C' type density–damage relationship might occur when feral pigs at low densities eat only still-born lambs, but when pigs are at higher densities they begin to kill increasing numbers of healthy lambs.[48] With this type of relationship, at high densities reduction of pig numbers should decrease lamb predation.

The aim of pest control is to reduce and maintain pest density at a level where the manager can maximise the benefits compared to the costs of control (see 'When is it worth managing a pest population?', page 97). In other words, a farmer or nature reserve manager wants to know the expected return from a given investment of financial and other resources into pest control. The return may be in increased profits, greater flexibility of farm management and/or protection of native plants and animals. However, since the level of damage and the relationship between pest density and damage are rarely accurately known, there is a degree of guesswork, albeit based on some good scientific information, when deciding what level of pest control is sensible.

Three of several possible relationships between pest density and pest damage (after Choquenot et al.[48]). 'A' represents a situation where pest damage remains high even at relatively low pest densities; 'B' shows a direct relationship between pest density and damage; and in a 'C' type relationship damage is negligible at low pest density but increasingly severe at high density.



4 Pest control techniques

Choosing a control technique

The armory of techniques available for managing pest animals is surprisingly limited. This has a lot to do with some of the common characteristics of pests. It is technically difficult and usually expensive to develop and apply techniques against populations of animals that have great powers of recovery disperse readily and are highly adaptable (see Chapter 3). Other concerns such as animal welfare, harm to non-target animals or other resources, and contamination of soil or agricultural crops, further limit the number of techniques that can be used.

Currently, there are five approaches that are useful for the control of pest animal damage:

- killing or removing by poisoning, shooting, trapping or mustering;
- exclusion;
- biological control;
- habitat manipulation; and
- other management practices.

Despite the relatively small range of suitable techniques, there are many examples of successful control of pest animal damage. Typically, these have relied on strategic application of techniques at the most critical time in the agricultural production cycle and/or when pests are most vulnerable to control, such as after their numbers have been reduced by drought.

It is essential to choose the appropriate control technique or combination of techniques to suit the management strategy. While a number of techniques may be possible, some may not be practical in certain circumstances. Certain techniques are effective largely regardless of pest density, while the success of others depends on density. For example, ground shooting at water points may be effective for goat control when water is scarce, but only after other techniques such as mustering or aerial shooting, which are effective at higher pest densities, have reduced the population to a low density. Some techniques are suitable for frequent application whereas others are not.

For example, repeated warren ripping (destruction), to treat new warrens as they appear, will not reduce the technique's effectiveness for rabbit control, whereas rabbits may begin to avoid 1080 baits (see page 00) if they are applied too often. Similarly, trapping feral pigs may can be effective when first used in an area, but the pigs quickly learn to avoid the traps especially if they are poorly set and animals can escape.

A decision matrix can help managers determine which alternative techniques, or combinations of techniques, are most workable and acceptable (see Table 4.1).

Table 4.1 A hypothetical decision matrix to assess 10 possible options for controlling fox damage on a sheep property. A 'yes' indicates that that the control method meets the criterion and a question mark appears where there is insufficient information on which to base a decision. The desirable option, in this case poisoning, is that which meets the most criteria.

Fox control options possible?	*Technically acceptable?*	*Will it work?*	*Economically desirable?*	*Environmentally acceptable?*	*Politically acceptable?*	*Socially acceptable?*
Killing						
Shooting	Yes	No?	Yes?	Yes	Yes	Yes
Trapping	Yes	No	No	No?	No	No
Poisoning	Yes	Yes	Yes?	Yes?	Yes?	Yes?
Fertility control	No	?	Yes	Yes	Yes	Yes
Habitat manipulation						
Destroy dens	Yes	?	?	Yes	Yes	?
Exclusion						
Electric fence	Yes	No?	No	Yes?	Yes	Yes
Guard dogs	Yes	?	Yes	Yes	Yes	Yes
Other management practices						
Switch to cattle	Yes	Yes	No?	Yes	Yes	Yes
Lambing in a shed	Yes	Yes	No?	Yes	Yes	Yes
Coordinate lambing with neighbours	Yes	Yes?	Yes	Yes	Yes	Yes

Source: After Norton [159]

Killing or removal

There are four means commonly used for killing or removing animals: poisoning, shooting, trapping and mustering.

Poisoning

Poisons were one of the first techniques used to control pests in Australia and they remain a primary method. A variety of poisons have been used including arsenic, cyanide, strychnine, yellow phosphorus (CSSP), anticoagulants such as warfarin, bromodialone and pindone, and sodium monofluroacetate or compound 1080. Similarly, poison has been delivered in baits ranging from chicken heads and meat to apples, cereal grains, thistle roots and even sandalwood twigs (laced with strychnine). Adding poison to water was also a common pest control practice.

Past methods were often indiscriminate and resulted in substantial losses of native wildlife and considerable risk to humans and livestock. Refinements have now made poisoning much more effective and pest specific. These include studies of animal behaviour to determine how and when to poison, development of poisons that target certain animal groups, and modifying the way poisons are delivered, such as the use of more target-specific baits or bait stations.

Compound 1080 is an example of a relatively new poison that is used to control a variety of pest animals. It is an acute metabolic poison that blocks the energy production pathway of animals usually resulting in death from heart or lung failure. There is considerable variation in the susceptibility of animals to the poison: dogs and foxes are extremely susceptible; rabbits, sheep, cattle and humans are moderately susceptible; and birds and reptiles are relatively tolerant.[225]

The active ingredient of 1080, fluroacetate, occurs naturally in some native vegetation, especially in Western Australia, and some native animals have a high natural resistance to the poison.[107] This has enabled wider use of 1080 in that State with little risk to native non-target animals. The poison has the added advantage that it is broken down rapidly by soil bacteria and fungi to non-toxic compounds.[68] However, a major drawback to its use is that there is no known antidote. This has led to the search for alternatives for use in areas where there is concern about non-target poisoning of pet dogs and cats, particularly in semi-arid country where the compound breaks down relatively slowly. Pindone, for which vitamin K is an antidote, is now the poison of choice in these areas.

Table 4.2 A comparison of the commonly used rabbit poisons 1080 and Pindone and a potential new poison, cholecalciferol

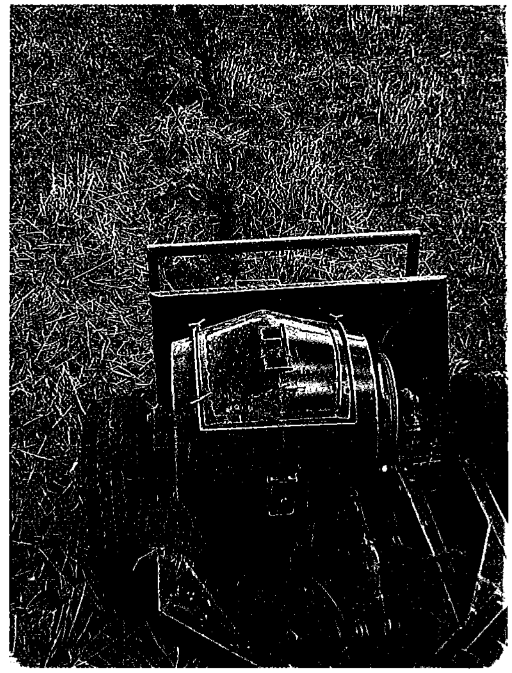
Desirable property	*1080*	*Pindone*	*Cholecalciferol*
High toxicity to rabbits	Yes	Yes	Yes
Low toxicity to other mammals	No	Yes	Probably
Low toxicity to birds	Yes	Yes	Probably
Causes painless death	Probably	No	Probably
Slow-acting*	No	Yes	Yes
Has an effective antidote	No	Yes	?
Odourless and tasteless	Yes	Yes	Probably
Does not require pre-baiting	No	Yes	Yes
Reaccepted readily	Yes	Yes	Yes
Cumulative	No	Yes	?
In baits—has a long shelf-life	Yes	Yes	?
In baits—resists rain and dew	No	Yes	Probably
Does not persist in livestock	Yes	No	?
Degrades rapidly in dead rabbits	Sometimes	No	Yes
Degrades rapidly in the field	Yes	No	?
Low cost	Yes	No	Yes

Source: adapted from Williams et al. [225]
*slow-acting can be a desirable characteristic because it leaves time to apply an antidote if the poison is ingested by operators or non-target animals, for example, pets

The selectivity of a poisoning campaign can sometimes be enhanced by:

- prebaiting with unpoisoned bait and checking tracks and other signs to ensure that only the target animal is taking the bait;
- using a bait that is most attractive to the target animal—for example, feral pigs are poisoned using a fermented wheat bait, which is not attractive to many other animals;
- using the minimum concentration of poison sufficient to kill the target animal;
- placing the bait so that only the target animal is likely to take it—for example, in the prime feeding area of rabbits, by burying baits for foxes and feral pigs, or by using bait stations for rodents that other animals cannot enter; and
- if practicable, collecting poisoned carcasses and burying any exposed bait at the end of the campaign.

A variation of poisoning is the use of fumigants to kill rabbits and foxes in their dens. Chloropicrin and phostoxin are commonly used fumigants. They are usually applied using a pressure fumigator and kerosene is added to produce white smoke that can help to locate all warren entrances so that they can be



Baits, covered with a layer of soil to reduce the risk of poisoning non-target animals, can reduce rabbit numbers prior to warren ripping or other control techniques. A small baitlayer attached to a four-wheel motorbike allows access to difficult areas.
Source: Bathurst RLPB

blocked. However, chloropicrin is considered to be inhumane[225] and there are similar doubts about phostoxin. Attention has recently turned to the use of carbon monoxide as a more humane alternative fumigant.[236]

Shooting

Pest animals can be shot either from the ground or from the air. Although common, ground shooting of pests is not considered to be a highly effective technique for most pest animals because it is time consuming and shooters can cover only a relatively small area. It has been used successfully to control feral goats in New Zealand and to mop up goats that remain after mustering and helicopter shooting in the Gammon Ranges in South Australia. Local hunting groups have been co-opted to shoot goats as they come to watering points.[173] Welfare concerns make shooting unacceptable in areas where it is not possible to follow-up and dispose of injured animals.

Shooting from helicopters is used to manage a range of feral animals including horses, donkeys, goats and pigs. Most often it is employed after the population has already been reduced by other methods such as mustering and trapping. The efficiency of helicopter shooting can be improved by employing a spotter aircraft to locate groups of pests and, using a Global Positioning System, to accurately pinpoint their position and relay it to the helicopter. The National Consultative Committee on Animal Welfare reluctantly accepts helicopter shooting as an efficient control technique provided that it is done by trained shooters using weapons of a suitable calibre, and that there is immediate follow-up to dispose of wounded animals.

The 'Judas animal' technique has been used to locate small groups of animals that remain after the majority have been removed. The Judas is a wild pest animal that is trapped, fitted with a radio-collar and released to join others of its kind. The group is located from the air or sometimes the ground and shot, leaving the Judas animal to join and betray another group. The technique works most effectively with animals that are strongly social, such as feral goats and donkeys.

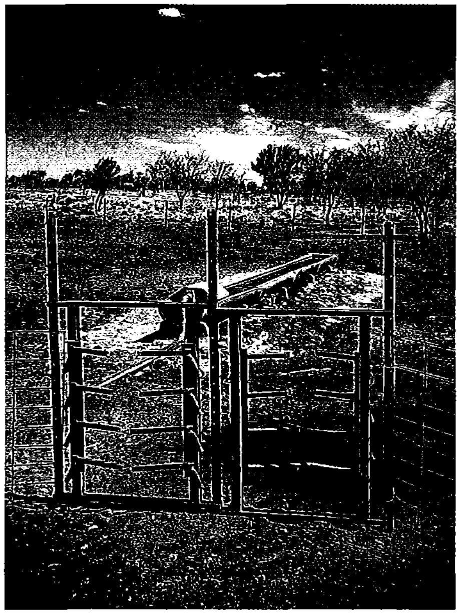
Shooting from helicopters has been used to manage several feral pest species, from horses to pigs.
Source: DFAT

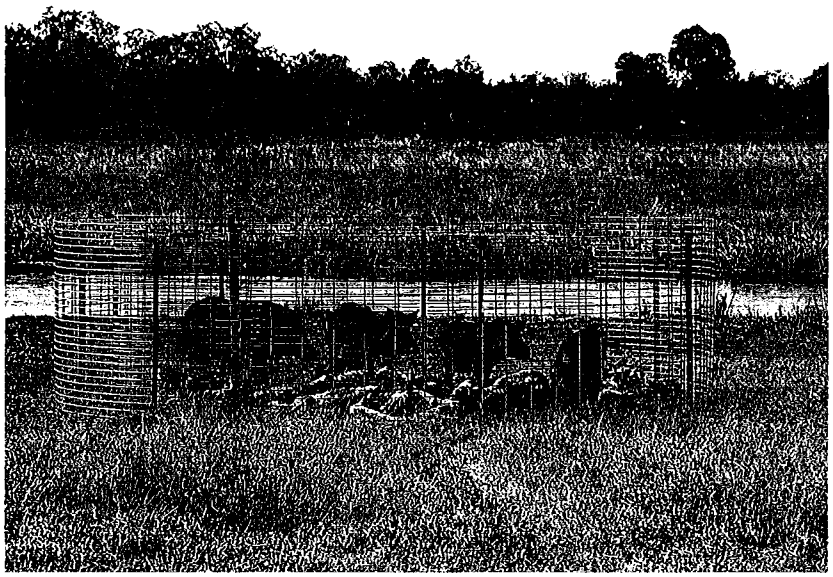
After goat numbers have been reduced by mustering and shooting, Judas goats, trapped and fitted with a collar containing a radio-transmitter, can be released to join remaining goats and reveal their location to managers.
Source: Robert Henzell, APCC

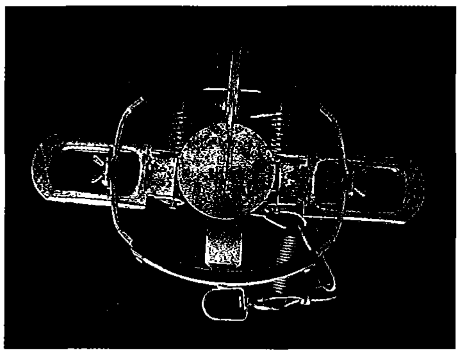
Trapping

A variety of traps has been used on pest animals, from small break-back, leg-hold or mesh cage traps to larger silo traps and fences around watering points.

Due to concerns about animal welfare, steel-jawed (gin traps) traps for rabbits and foxes are now banned throughout most of Australia. They are still used for Dingo control although this is declining; in Victoria soft-catch traps are now used for wild dog control. Small traps are not usually recommended for pest control. This is mainly because they are expensive and time consuming to distribute and have not been shown to reduce damage by pests unless only a few individuals are causing the pest problem.







ABOVE LEFT *Particularly in drier areas, one-way gates at watering points can be an effective way to trap goats and horses.* Source: Quentin Hart, BRS

LEFT *Small, softcatch traps are an improvement on the cruel and indiscriminate steel-jawed version, but are rarely an effective or economic way to manage pests.* Source: Queensland RLPB

ABOVE RIGHT *Cage trapping is an effective way to manage feral pigs, particularly where baiting is impractical. The cage must be robust and have an efficient, one-way door. The trap is set where pigs are active, such as at watering points. It is left open and baited with meat, pellets or fruit and vegetables, so that pigs can feed freely for the first night or two before the trap is set.* Source: Peter Fleming, NSW Agriculture

Larger, baited traps have been used for feral pigs, and self-mustering traps set at water points are commonly used for feral goat control. The increasing popularity of large traps is partly due to land managers being able to see what they have caught and it also allows them to supplement their income by selling the animals. In 1995, a 45 kilogram dressed-weight feral pig was worth approximately $100 at the chiller. Trapping can be carried out by the land manager and timed to fit in with routine property activities. Self-mustering traps have been found to be very effective in semi-arid country, especially in dry times when the animals are forced to enter to drink. The traps are also useful for mustering sheep.

In spite of these benefits large traps can be time consuming and expensive to construct and maintain. Animals quickly become trap-shy, especially if they enter and manage to escape from a poorly set trap. For pest animals such as feral pigs, poisoning is usually much more cost-effective.[48]

Mustering

Like trapping, mustering large pest animals such as feral horses and goats has the advantage that the animals can be sold. The muster can be carried out from horseback, motorbike or helicopter or, as is often the case, by a combination of aerial and ground work. It is usually effective only when the pest is reasonably common—above one animal per square kilometre for feral goats.[90,91] The efficiency

Dogs can aid in the mustering of feral goats, for management and harvest.
Source: Jim Thompson

of mustering varies and in Western Australia an average muster yielded only 30 to 40 per cent of the feral goats. By contrast, in the Flinders Ranges of South Australia, approximately 80 per cent of the population is taken in an average muster. Other control methods are used if the pest animal population needs to be reduced further.

Mustering must be planned carefully, using skilled operators to direct the animals into appropriately located yards. Tame mares released amongst feral horses can help to attract lead stallions and to settle the herd. Electric fencing to exclude animals from all but a few watering points can help to concentrate the herds and improve the effectiveness of the muster.

Exclusion

Since the early days of European settlement, fencing has been the most common method used to exclude pests from an area. Probably the best known fence in the world is the Dingo fence that stretches from Queensland through New South Wales and across South Australia to the Great Australian Bight—at 5614 kilometres, it is 3374 kilometres longer than the Great Wall of China. The fence divides the southern and eastern sheep grazing lands from cattle and Dingo country.

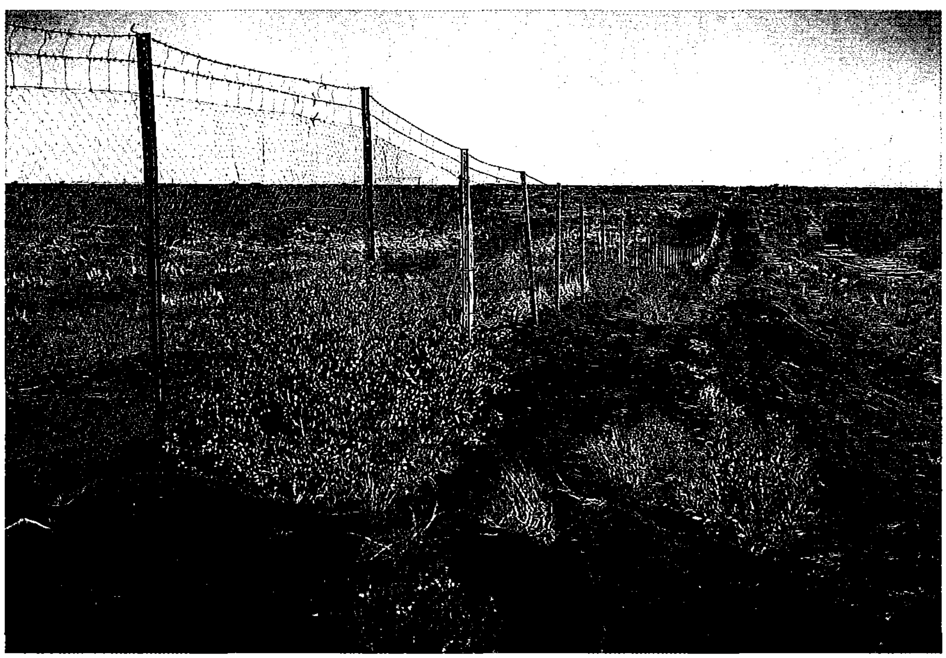
There are many types of fence used to exclude pests.[42,48,173,198] They include conventional stock fencing, electric fencing and purpose built fences to protect native animals in private zoos. Electric fencing is relatively cheap compared with conventional stock fencing. It is particularly useful for short-term exclusion of pests, such as the protection of a ripening melon crop against feral pigs.[48] Conventional fencing is expensive; it cost NZ$18 000 per kilometre to exclude feral goats from an extensive area of native forest on Arapawa Island, New Zealand.[174] Eventually, the goats broke through, highlighting the need to be sure that the purpose and likely effectiveness of the fence is clear before committing resources to it.

Nevertheless, fences can be an important component of effective pest control. They have been used to used to break up areas into manageable blocks for control

The Dingo fence stretches for a total of 5614 kilometres, from Queensland through New South Wales, and across South Australia to the Great Australian Bight (after Breckwoldt[32]).

of feral goats in Hawaii, and have also been used to exclude feral animals from some watering points and so concentrate them at water where traps are set.[14,172] They can also slow dispersal, making control on the protected side more feasible and economic.

Foxes are agile and adaptable animals that are difficult to exclude with fences. They have been known to raise a litter within a fenced enclosure, and to regularly scale a formidable electrified fence to hunt and return with food for their young.[198] Nevertheless, fencing has been used successfully to exclude foxes and feral cats from zoos and private wildlife parks. The fence design usually incorporates several electric wires and a roof or overhang. Warrawong Sanctuary in South Australia



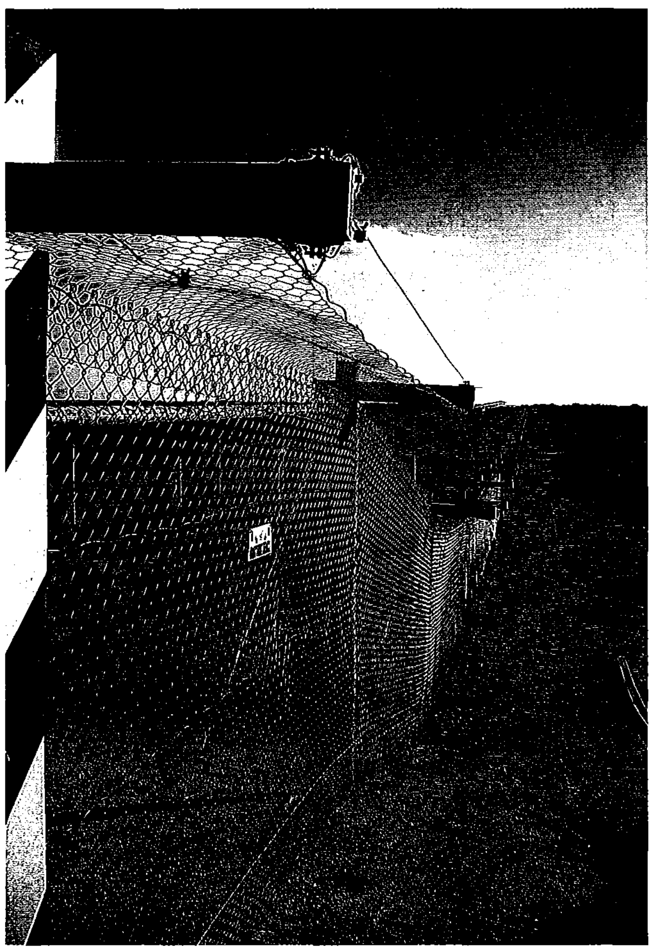
The Dingo fence helps to exclude Dingoes from the southern and eastern sheep grazing lands.
Source: CSIRO

has successfully excluded foxes using high netting fences with unstrained overhanging tops. Apparently the floppy nature of the upper section of the fence prevents foxes from climbing it.

The success of a good fence depends on appropriate construction, regular maintenance, frequent monitoring for breaches and quick action to remove any animals that break through. This is particularly important where fences are used to exclude predators such as foxes from valuable collections of native animals—a fox can kill many animals in a very short period.

Good quality, long-lasting netting, to exclude birds, is the most effective protection of grapes in vineyards.[242] It must be correctly applied, draped over the vines and gathered under them, or with a skirt that may be covered with soil, to prevent birds entering from under the net. The mesh should be 20 millimetres or less in diameter to prevent birds from becoming entangled, not only because of animal welfare considerations but also because foxes may tear the dead birds from the nets. Depending on the quality of the grapes and the previous level of damage, costs can be recovered in as little as a year. For low-value grapes, nets may not be economic.

Another method used to exclude pests from an area is guard dogs. In the Mediterranean, guard dogs are used successfully to protect domestic goats from predators.[241] Some lamb and goat producers in Australia are experimenting with guard dogs and even Alpacas.



A well-built fence successfully excludes predators from the Peron Peninsula, Western Australia, and protects several rare native mammals which are being reintroduced to the Peninsula.
Source: Noel Preece & Penny van Oosterzee

Exclusion of pests: the Dingo fence

The story of the Dingo fence that crosses southern Queensland, north-western New South Wales and South Australia is a fascinating insight into the lengths farmers and governments go to in their attempts to control pest animal damage.[32] Three State Dingo barriers link to form the 5614 kilometre fence which, until 1980 when the original Queensland barrier fence was re-routed, spanned an incredible 8614 kilometres.

The fence started life as series of barriers, completed in 1890, designed to halt the spread of rabbits. They were failures for a number of reasons, not least because they were built too late, and eventually fell into disrepair. By the early 1900s, the Dingo had become as important a pest to the pastoral industry as was the rabbit and it was apparent that the flourishing wool industry would not survive without protection. The *Wild Dogs Act* of 1912 set the land rate for fenced land at half that for unfenced land and successfully encouraged construction of vermin barriers. The rabbit fences were repaired and thousands of kilometres of private barriers erected—54 646 kilometres in South Australia alone by the early 1930s. By then the Dingo had become increasingly scarce in the south and east and a single barrier seemed the most economical way to prevent movement from the Central Australian cattle areas.

The Dingo fence helps to exclude Dingoes from sheep country. However, it is expensive to monitor and maintain and is frequently breeched, washed away or covered by sand drifts. On top of this, properties that border the fence need to conduct periodic wild dog control to remove those animals that break through. Nevertheless, the barrier is probably the only solution if sheep farming is to continue east of the fence.

Another complication is that inside the fence kangaroos and emus abound, whereas outside they are much less common. Some pastoralists wonder whether sheep losses due to wild dogs may be preferable to pasture damage caused by high numbers of kangaroos and emus. By restricting movement, the fence probably also has a significant negative impact on some other native animals.

Biological control and anti-fertility agents

Biological control is the use of one organism, such as an agent of disease, to control another. The release of disease and fertility control are often suggested to be the ultimate answers to pest problems. Many see them as low cost, long term and, in some cases, humane alternatives to conventional pest control.[20] However, these hopes are seldom realised. In reality, the release of diseases to control pests is rarely the full solution and, at least in the short term, the development of effective fertility control agents for broadscale pest control appears unlikely.

The rabbit-specific myxoma virus, which causes myxomatosis, was introduced to Australia to control rabbits. When wild rabbits were first exposed to the virus in 1951, 99 per cent of individuals that contracted the disease died.[73,225] In the second year, 85 per cent died and in recent years the death rate of rabbits that contract myxomatosis has often been less than 50 per cent. Nevertheless, it is estimated that Australia's rabbit population is now about half that before the release of myxomatosis and, in conjunction with other techniques, the disease remains a valuable control agent. The recently introduced rabbit calicivirus disease (RCD) has caused some initial reduction in the rabbit population, but like myxomatosis will not replace the need for ongoing rabbit management[34,8] (see below 'RCD, a potential biological control agent for rabbits').

Unfortunately, diseases such as myxomatosis and RCD are the exception rather than the rule.[72] Many other diseases that could be used to help control feral animals such as feral pigs and goats also affect important domestic stock of the same species.[173] Domestic animals could be vaccinated against some diseases, but this is likely to be expensive and may have unforeseen implications for overseas trade. Another consideration is that some animals such as the fox and rabbit may be pests in Australia, but an important component of the fauna in their native countries.[220] Biological control techniques being developed for introduced Common Brush-tailed Possums in New Zealand, for example, if released in New Zealand, may spread to Australia where they could have devastating effects on these and other native possums.

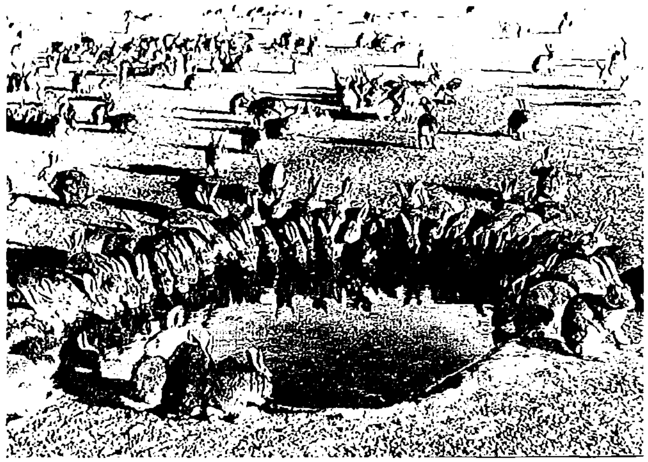
RCD, a potential biological control agent for rabbits

Rabbit calicivirus disease was first recognised in China in 1984. It spread throughout Europe and Asia and by 1992 had reached Britain. Typically, RCD causes blood to clot in rabbits' heart, lungs and kidneys and within a few days of infection they die from heart or lung failure. Overseas studies show that in the laboratory the disease can kill over 99 per cent of infected adult rabbits.[116]

Australia and New Zealand began research into the potential for cahcivirus disease to control rabbits in 1989.[34] Results of laboratory studies into the virus' effectiveness and species specificity were promising and field trials commenced in 1995, on Wardang Island off the South Australian coast. By October of that year, the virus had escaped and was killing rabbits on the mainland. Initially, the virus spread fast, sweeping north-east from the Flinders Ranges, Yunta and Point Pearce through the arid zone, leap-frogging large distances and leaving areas with almost no rabbits. By early 1997, aided by deliberate releases, it had spread patchily across the entire distribution of the rabbit. Its performance appears to have been greater in arid and semi-arid areas than in wetter areas.

Before deciding to deliberately release RCD, Commonwealth, State and Territory governments made thorough assessments. Public submissions were invited and the main concerns raised were the possibility that animals other than rabbits might be infected, the potential threat to native animals when introduced predators were deprived of rabbits, and the likelihood of harm to native predators, mainly birds of prey that eat rabbits. It was decided that RCD was specific to rabbits and effective in that it killed rabbits, and release was authorised.[34]

The virus has not behaved as predicted based on European experience and there is much to learn about RCD. The rate of spread in Australia, about 50 kilometres per week eastwards and northwards from its original outbreak, was much faster than the few hundred metres a month reported for Britain.[54] Although it is not known with certainty, the main agents for the spread in



Rabbits gather to drink at a denuded dam during an early trial of myxomatosis, on Wardang Island in the 1930s.
Source: CSIRO

Australia are thought to be flies. New techniques for effective delivery of the disease, such as a virus-laced bait, are being tested. Some of the other aspects under investigation include determining how the virus spreads and identifying the vectors (transmitting organisms), how it interacts with other control methods such as myxomatosis, and whether it persists under Australian conditions.

Comparisons with the myxoma virus, which is spread by rabbit fleas and mosquitoes, are inevitable.[8] Myxomatosis, imported to Wardang Island for testing in the 1930s, escaped from test sites in the Murray Valley in 1950. Initially, 99 per cent of infected animals died and rabbit populations were greatly reduced. However, by the late 1950s resistance in rabbits and changes in the virus had lessened the virus' impact. Rabbit numbers increased again, but did not return to former numbers.

Anti-fertility agents aim to limit the reproductive success of pests and hence reduce their numbers. Effective fertility control of wild pests is hindered by high cost, failure to treat enough animals, accidental treatment of non-target animals and inability to administer repeat doses. These difficulties can be overcome for a relatively small and confined population of pests where control costs are not a major consideration, such as the Eastern Grey Kangaroos on the grounds of Government House in Canberra, the males of which were castrated surgically. However, it would not be feasible to treat, for example, 300 000 feral horses spread across Australia.[67]

To be effective, fertility control needs to overcome the following difficulties:[28]

- Lack of an effective delivery mechanism.
  There is no practical method known to deliver a sterilising agent to a high proportion of a wild pest population. Most tests that have achieved fertility control relied on hand or dart gun injection or administration of frequent doses of the sterilising agent through food or drink.
- Behavioural and biological flexibility in the pest.
  There are a number of biological and behavioural mechanisms by which pests can modify the effectiveness of an infertility agent. For example, pests may simply avoid the bait or any other mechanism used to deliver the agent. Compensatory changes in a population subject to fertility control may also limit any reduction in pest density by the fertility agent. These include increased

survival of young animals, increased immigration, and increased birth rate in the remaining fertile animals. Young animals may also reach sexual maturity earlier and so produce more young. All these responses have been seen in animal populations subject to control and could compensate for reduced fertility.

- Humaneness of fertility drugs.
  Many fertility drugs are humane, but some have undesirable side-effects or are poisonous at high doses.
- Specificity to the target animal.
  Unfortunately, few fertility control drugs are specific to the target pest species. The genetically engineered sterility agents being developed may overcome this problem for some pests, but are unlikely to do so for feral animals such as goats, pigs and horses that are also kept as livestock. Similarly, fertility control agents are unlikely to be suitable for wild dogs and feral cats because of the risk to pets.
- Environmental acceptability.
  Fertility drugs usually have low environmental risks, but residues in baits could enter the food chain and affect native wildlife, livestock and people.
- Cost effectiveness.
  Compared with other pest control techniques, fertility control using currently available technology is extremely expensive for widespread and abundant pests.

At present, chemical fertility control techniques, such as administration of synthetic oestrogen to cause temporary sterility or steroid hormones to induce abortion, appear to have little chance of success as pest control agents.[28]

Genetically manipulated viruses that cause sterility have some potential for pest control, but research is still at an early stage (see below 'Immunosterility to control foxes, rabbits and house mice'). Even if a virus or other suitable agent can be found, it will be many years before it will be fully developed and ready for field trials. First, the technological difficulties associated with developing a genetically engineered immunocontraceptive agent must be overcome. Then it must be demonstrated that the agent has the desired effect and only affects the target pest. The possibility that the pest will develop genetic resistance, and social and ethical implications are some of the other issues that have to be addressed.

Immunosterility to control foxes, rabbits and house mice

The Cooperative Research Centre for the Biological Control of Vertebrate Pest Populations is attempting to develop genetically engineered viruses to control pests by immunosterilisation.[28,218,219,220] Immunosterilisation is a captivating idea. The aim is to use a virus, or some other vector, to carry an agent that stimulates an auto-immune response in the pest animal and renders it sterile. The agent can be a protein from the pest animal's reproductive system, which is introduced into the virus' genetic material. When the virus infects the pest animal and multiplies, it also replicates the protein. The immune system identifies the virus, and protein, as foreign and attacks the protein even where it occurs in the animal's own reproductive system, making the animal sterile. The hope is that reduced fertility of the infected population will result in lower pest density and reduced pest damage. There are several components to this research.

- Locating a suitable vector.

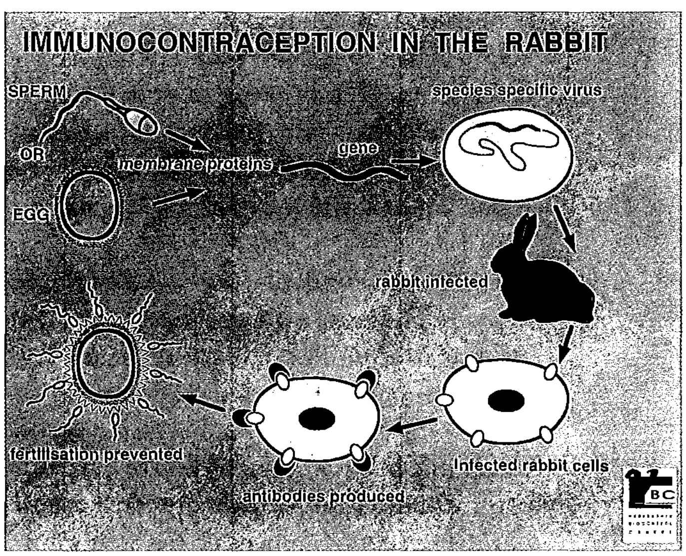
If the sterilising agent is to be spread by a virus, one must be found that is specific to the target animal. For House Mice, the mousepox or *Ectromelia* virus is being used for initial development of the technique, but it is not specific to mice and will never be used in the field. Mouse megalovirus, already present in the wild mouse population, may prove to be more suitable. The myxoma virus, which only affects rabbits, has been chosen as a possible vector for rabbits. To date a virus specific to foxes has not been found as promising candidates also infect dogs. Thus, for foxes, the possibility of distributing a non-viral antifertility agent through baits, rather than through a self-spreading virus, is being researched. Once a suitable virus has been identified, some of its genetic sequence must be determined and a site located into which the antifertility protein can be inserted.

- Locating a suitable anti-fertility protein and conducting laboratory trials.

A search is being made for a protein on sperm or in the female reproductive tract of the pest animal that can be used to stimulate an antibody attack. Several likely candidates have been located and some have been shown to cause an immune response and infertility when injected into the pest animal. Recent laboratory trials with altered *Ectromelia* virus have dramatically lowered fertility in female laboratory mice and are the first indication that virally vectored immunocontraception could work.

- Investigating the biological effects of sterility and behaviour of the virus in the wild.

The aim of this component of the research is to test the effects of sterility on pest animal populations. To achieve this, immunosterility is mimicked by tying the fallopian tubes of females. This sterilises the female but does not inhibit normal hormone function and hence, hopefully, normal social behaviour. The response of the pest animal population to different levels of sterility is being tested. Preliminary results indicate that 50 per cent or more



Source: G. O'Neill.

of the sexually mature females in the rabbit population may need to be sterilised before the population will fall significantly.[217] Other aspects of this research include monitoring changes in the behaviour of the sterilised animals and estimating the likely reduction in damage due to any reduced densities of the pest animal. Transmission and survival of the virus in an effective form in the wild will also need to be researched.

Habitat manipulation

Habitat manipulation can be an effective way to lessen pest damage. The principle is to modify the habitat so that it is less favourable for the pest or more favourable for the threatened native plant or animal.

Habitat manipulation is a common technique in rabbit control. Rabbits require nutritious, short-cropped grass both for food and so that they can see potential ground predators such as foxes and cats. They also rely on cover, whether it be a warren or surface logs and vegetation clumps, for protection from temperature extremes and from predators. Rabbit density can be reduced by removing surface harbour and destroying warrens by ripping or blasting.

Recovery of a rabbit population after control can be inhibited by allowing the height of vegetation to increase. This may not be a practical solution for a grazing property but may be possible on a nature reserve. It was used to virtually eliminate rabbits from a high swamp in Namadgi National Park in the Australian Capital Territory.[233] Habitat change, including warren collapse and vegetation changes, following the initial spread of myxomatosis is believed to be the major reason for the virtual disappearance of rabbits from large areas of the Riverina District of New South Wales.[148,150]

Australia is considered to be the driest inhabited continent. Provision of water through artesian bores has been essential to opening up the interior to pastoralism. In western New South Wales and south-western Queensland there are very few areas that are more than 1 kilometre from a water source.[232] Many of the bores are not capped and provide water across extensive areas. The water has not only benefited stock but also native grazers, such as kangaroos, and feral animals, such as goats, pigs, horses and donkeys. The States and the Commonwealth are cooperating to close or cap most of the bores in the Great Artesian Basin both to conserve water and to better control grazing pressure on the already degraded native pastures. One other major benefit from this exercise is likely to be a major reduction in the density of feral animals, most of which depend on water for survival.

Habitat manipulation is also a useful means to reduce pest damage to native animals. Foxes are a major predator of native wildlife in south-western Western Australia, including the Western Ringtail Possum.[198] Usually these possums move from tree to tree through the canopy. However, where tracks and logging have opened the canopy they come to the ground where they are vulnerable to fox predation. Long-term protection of the Western Ringtail can be assisted by initial control of foxes until the canopy can be closed by revegetation. Fox predation of normally arboreal animals occurs across much of Australia. Habitat modification,

Habitat modification to reduce native rat damage to sugarcane

The Canefield Rat and Grassland Melomys are native rats that cause extensive damage to sugarcane crops in north Queensland. Both rats live in grassy areas such as drain and creek lines, along fences and in pasture paddocks. These grassy areas provide them with essential protein and cover and protection from predators. Grassland rats breed prolifically when there is an abundance of weeds and only invade cane crops when their preferred cover can no longer support the growing population. However, the rats will not stay and colonise the cane if there are no grass and weeds in the crop.

The key to managing grassland rats is to manage their preferred habitat and also make the canefields less attractive. Effective weed control in cane, by slashing and herbicides, robs the rats of their essential source of protein.[37] Where herbicides were used to exclude weeds, crop damage by rats was reduced by as much as 60 per cent.[192] Revegetation of the creek lines is also proving effective. The natural vegetation in the region before it was cleared for sugar cane was tropical rainforest and pockets of forest still exist next to the cane crops. Studies showed that replacing cane grass with rainforest greatly reduced the density of the rats, by as much as 75 per cent within one year of planting.[192] The habitat modification is supported by strategic poisoning of rats in seasons when necessary, early in the breeding cycle, before their numbers build up.

Not only has habitat manipulation reduced damage to cane, it has also benefited the local fauna by providing creek-line corridors linking blocks of rainforest, and the local drop in sales of rodenticide may lessen the risk of poisoning non-target animals.

including closing and revegetating unnecessary tracks and roads, may have an important role in helping to conserve many of these animals.

Rock-wallabies are believed to be particularly at risk from fox and feral cat predation. Many remaining colonies of rock-wallabies are now confined to rock stacks where they are safer from fox predation. However, these areas are considered to be marginal habitat for the wallabies which are mainly grazers. There is good evidence that in the past they were much more widely dispersed and grazed on pastures away from the rock stacks.[108] Predator removal enables the wallabies to use the more favoured grazing sites and increase their numbers.

The ultimate in habitat manipulation to protect native animals from pest animals is the establishment of populations on pest-free islands. Both Australia and New Zealand have used this method to help conserve many representatives of their endangered and threatened fauna. An example is the Black-footed Rock-wallaby, which was once abundant and widespread over much of central and western Australia. The wallaby declined dramatically on the mainland, where it is now found only in small numbers at isolated locations. In the 1970s, it was introduced to fox-free Thistle and Wedge Islands in South Australia, where it is apparently thriving.[208]

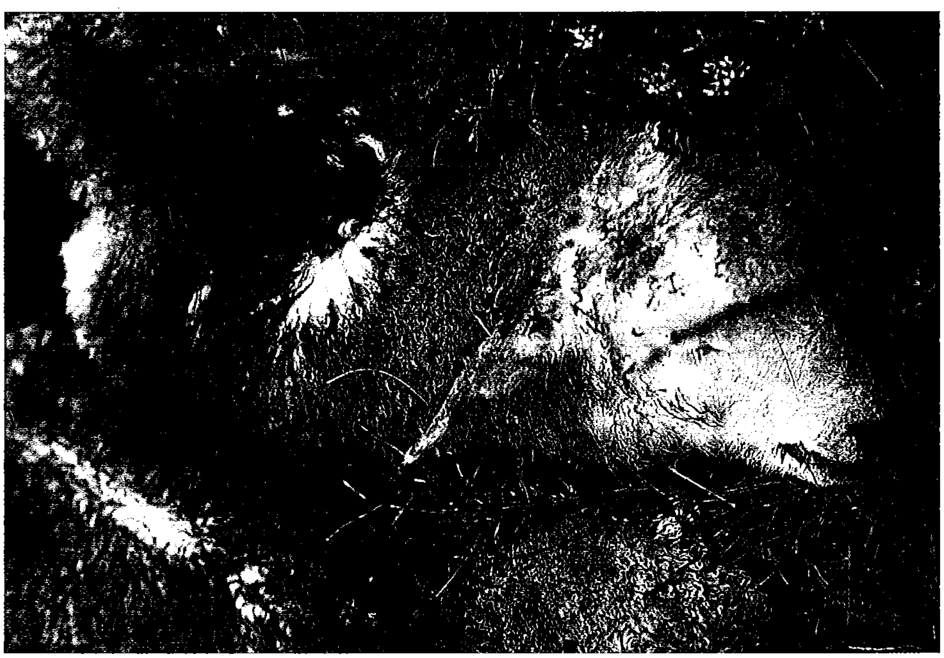
Other management practices

As well as pest removal and exclusion, and habitat manipulation, many land managers are beginning to use other management practices to reduce the damage caused by pest animals. Lamb producers have been especially effective in this area;[198] some have used smaller lambing paddocks placed close to the house to make it easier to monitor the flock and to reduce the chance of young lambs being left unattended by the mother. The ultimate in this approach is shed-lambing, although this is likely to be economically sensible only to protect high-value stock such as the young of stud animals.

Most predators of lambs only kill lambs up to few weeks of age. The availability of lambs to the predator can be reduced by concentrating lambing to a short period. The effectiveness of this strategy can be improved by coordinating lambing with neighbours so that predators such as feral pigs and foxes are saturated with potential prey. Timing of lambing can also be critical; lamb losses could be reduced by lambing in early spring when the density of foxes is lowest, young foxes have stopped dispersing and breeding has not yet started. Selection of flocks or sheep breeds with more protective ewes can also help. Merino and Merino-cross sheep are usually much poorer mothers than other breeds and may be better replaced by other breeds when lamb production is the main objective.

Another management technique is to switch to an alternative product or farming technique that is less susceptible to pest animal damage. For example, lamb producers can switch to cattle and grain growers can plant their seed more deeply when a mouse plague is likely. Some Queensland sorghum producers pick the crop early and shed-ripen the crop when mice are plaguing.[45] However, the capacity to switch crops or the type of stock is limited and, usually, there is a significant cost (for example, planting cereal seed deeper can reduce yield).

All management practices involve risk. Managers need to weigh up the costs and benefits of switching crops or changing practices that are likely to affect their returns.



Severe wounds to the neck of a slaughtered adult sheep are typical of attack by a Dingo or wild dog. Where such losses are great, the landholder may have to consider farming cattle rather than sheep.
Source: NSW Agriculture

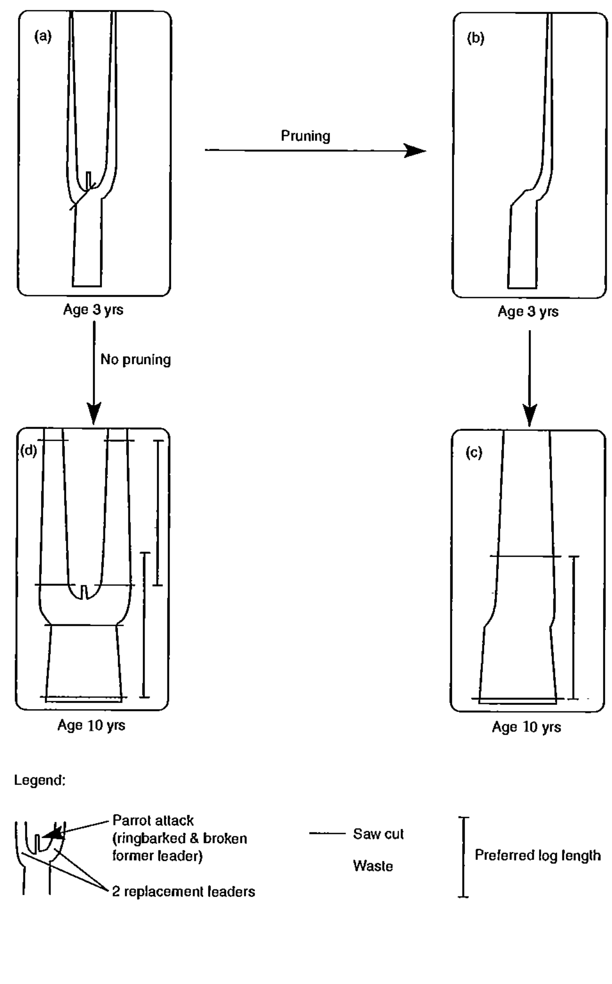
Improved management to control parrot damage to Bluegums

Cultivating Bluegums for wood for the production of paper is a new and rapidly developing industry in south-western Australia. Bluegums grow rapidly and can be harvested on rotation about every 10 years. Much of the planting is on farmland where the trees help reduce salinity, waterlogging, and erosion, are an excellent shelter belt for stock and crops, and provide an additional supplement to farm income. Approximately 40 000 hectares of Bluegums had been planted by 1995. The estimated gross annual value to producers from a projected planting of 100 000 hectares is $40 million.[189,190,191]

Australian Ringnecks cause significant damage to the crop; it is estimated these parrots will cause major damage to an area of trees covering about 20 per cent of the land suitable for Bluegum plantings. The birds strip the bark from the branches and cut the lead shoots, deforming trees. Losses occur in total wood volume, loss of log quality, increased debarking and other handling costs for deformed trees, and increased costs from harvesting highly forked trees. The trees are most susceptible to parrot damage during about the first 18 months, after which losses are relatively small.

Several solutions were proposed to reduce the damage. They included killing the birds, using repellents, planting decoy crops to attract the birds away from the main crop and silviculture practices to rectify the damage after it has occurred. Of these only silviculture and a decoy crop of sorghum and soya bean planted near the plantation under threat seem to be successful. Shooting did not reduce the damage.[239] Indeed, indiscriminate shooting can increase the damage in some crops, as has been found with sunflower crops.[75] Parrots feeding on the crop will drop the sunflower head in response to the gunshot and pick off a new head when they return.

Silvicultural techniques for recovering losses include thinning deformed trees to give remaining trees more room to grow, and pruning the multiple leaders caused by parrots back to one. Trials showed that the benefit gained from silviculture was 2.5 to 5 times the cost.[242]



The use of silviculture to lessen parrot damage to Bluegums grown for timber production (after Ritson[189]). If the gums are pruned at three years of age (b), so that they are left with one main stem and no leader which parrots can damage, by 10 years they produce a log of preferred length (c) which can be logged with only one saw cut and leaves little waste. By contrast, the unpruned trees require three cuts (d), and if the base log does not meet minimum log length specifications it is wasted along with the fork crutch.

5 Introducing the strategic approach

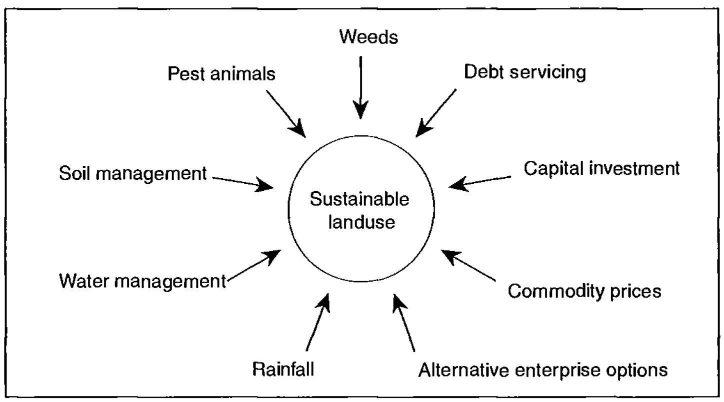
A whole system approach to land management

Pest management is much more complicated than simply reducing pest numbers. It is just one element of a complex ecological, economic and social system that farmers and land managers operate within. Thus, pest management is best approached as part of the whole system of land management.

Pest animal management cannot be fully effective without considering other factors that influence sustainable use of the land. For a farmer these might include choosing the right type and variety of crop, level of fertiliser and marketing strategy, or the need for a better water distribution system. A high lamb marking percentage, an aim of a profitable fat lamb enterprise, might depend on ram fertility, climatic conditions, food quality, disease status of the ewes and cover for newborn lambs, as well as the level of predation by foxes. For a nature reserve manager, factors that affect the conservation of native wildlife in the reserve include the size and effectiveness of the buffer zone between the reserve and undesirable outside influences such as pests and stock, disturbance by visitors,

Pests are just one of many factors that may influence sustainable land use that must be considered by land managers, whether on the farm or the nature reserve (a). Similarly, pest problems must be viewed in the context of all the significant adversities hampering conservation of endangered species or communities (b).

(a)



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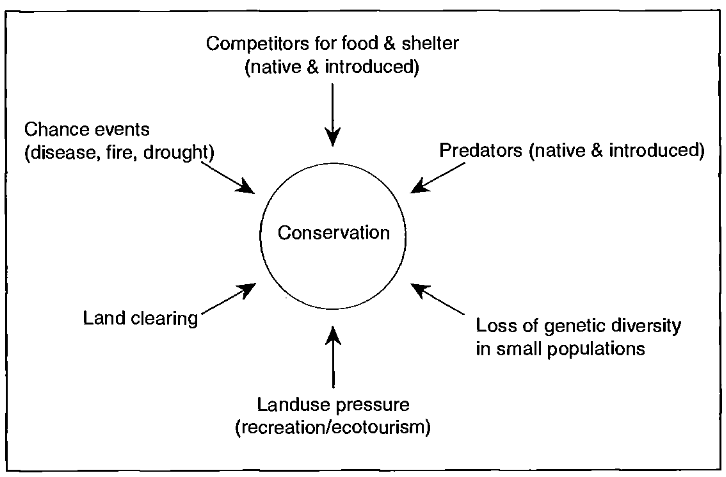


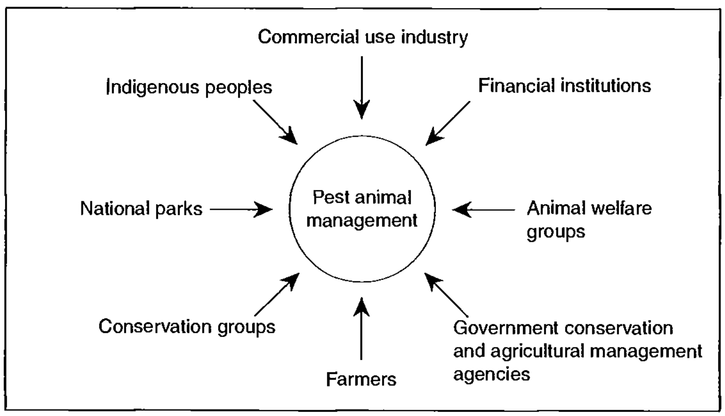
the fire management regime, weeds, the effectiveness of wildlife dispersal corridors, the size of the breeding populations of the animals to be conserved, as well as the effectiveness of pest control programs.

Too often, costly but inappropriate control strategies are adopted in managing both for production and conservation.[30]

For effective, sustainable land management three major elements should be considered which greatly influence the approach to and effectiveness of pest animal management:

- Ecological—pest management that takes into account the relationship between organisms and their environment, specifically, the interrelationship between communities of animals and plants, soil and water resources, and other factors;
- Economic—relating to the costs and benefits of various pest management strategies;
- Social—covering a multitude of factors, from the attitude of neighbours to cooperative pest control and the attitude of individuals to pest animals (for example, 'I just want to get rid of them') to the impact of community groups through restrictions on techniques and practices due to concerns about animal welfare, as well as any political considerations.

Many individuals and groups have an interest in pest animal management. They include farmers, nature reserve managers, government agencies, banks, animal welfare and nature conservation groups. Failure to adequately consult and take into account the views of all major players when determining the best approach to pest animal management, may hinder effective management of pest damage. For example, if a neighbour has little interest or is opposed to some forms of pest animal control, they are unlikely to cooperate.



Just some of the range of players that may have an interest in a pest management project that are best involved from the outset.

An integrated planning system such as a Nature Reserve Management Plan or a Property Management Plan is a good way to analyse the interrelationship between the factors that determine the profitability of an enterprise. The Property Management Planning program is a joint initiative between the Commonwealth and State and Territory governments. It aims to assist farmers and their advisors to improve their business and natural resource management skills, including short- and long-term planning, risk assessment, and drought and pest management. Increasingly, individual farm management plans are being linked through Total Catchment Management Plans or Regional Management Plans. Advice on farm and regional management planning can be obtained from local Landcare or Total Catchment Management coordinators.

Key principles of pest management

Several key principles underpin sustainable pest animal management. Since the main aim of most pest control is to reduce pest animal damage and promote sustainable production or the conservation of biodiversity (the preservation of the natural variety of native flora, fauna and habitats), it is not surprising that many of the principles are the same as those for Ecologically Sustainable Development (ESD, see below).

The main aim of ESD is to provide future generations with an environment that is at least as healthy, diverse and productive as that experienced by the present generation.

Ecologically Sustainable Development

The idea of sustainable development was crystallised in the 1987 report of the World Commission on Environment and Development, the Brundtland Report. This report defined sustainable development as that which 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. In 1990–91 the Commonwealth, in cooperation with the States and Territories, business, farmers and the community developed an Ecologically Sustainable Development (ESD) strategy for Australia.

There are a number of principles that guide ESD.[1] Those that are of major concern to sustainable land management and pest animal control in particular are:

- ensuring that the next generation is left with an environment that is as least as healthy and productive as that experienced by the present generation;
- protecting the diversity of our native plants and animals and maintaining the ecological process and life support systems. An example is ensuring that our waterways are not degraded;
- taking into account the real value of environmental and natural resources. As far as possible, the price placed on natural resources should reflect the full social and environmental costs of their use. However, there is no simple formula for valuing natural resources that are not normally bought and sold. Economists have developed techniques such as Hedonic Pricing and Contingent Valuation in an attempt to value these natural assets.[209,224] They are based mainly on estimates of how much people would be willing to pay to protect or improve the environment. The fear is that our natural assets will be lost or irreversibly damaged before they can be accurately valued;
- applying the precautionary principle to land management practices. This requires that risk and uncertainty are dealt with cautiously and care is taken with actions that have irreversible consequences. An example would be to err on the side of caution when considering whether to allow the import into Australia of a new animal that could become a pest.

Other key principles that underpin the new approach to managing pest animals include taking account of animal welfare concerns (see 'Attitudes to animal welfare', pages 22–24), adopting a whole system approach to management (see pages 74–75) and involving all major interest groups in dealing with the pest management issue (see Chapter 8). Three additional principles are important: beneficiary-pays, the role of legislation, and the management of total grazing pressure.

Beneficiary-pays

The Commonwealth, States and Territories have endorsed the principle of beneficiary-pays.[100] For land management, the trend is to ensure that the full costs of pest animal control are identified and, where appropriate, assigned to the individual or group of individuals that benefit from the pest control. Benefits are not only financial gains, but can also be non-market benefits, such as improved protection for a threatened native plant or animal.

The identification of beneficiaries and true costs of management have implications for all areas of land management, not least for conserving Australia's natural heritage. Formal nature reserves and national parks alone will never be adequate to conserve biological diversity because many species are not represented on reserves.[71,196] Several reserve systems are fragmented by other land management practices such as urban development and farming. This is especially true of the southwestern slopes of eastern Australia and the wheat belts of South and Western Australia. Protection of natural biodiversity should be an objective for non-protected areas such as agricultural and forestry land that contains important natural habitat.[70,71,134]

Many landholders are willing to pay for some of the additional management costs involved in controlling predators such as the fox to a greater extent than is necessary to protect agricultural production. However, where the cost is likely to be significant and the landholder is not the main beneficiary (it may be the community in general), mechanisms should be developed to identify the major beneficiaries and ensure that they contribute to the management costs. For example, a grazier might control rabbits to protect the land resource base and to limit damage to production. However, to ensure successful regeneration of native vegetation, rabbits may need to be kept at much lower densities. Protection of native plants has a community benefit, and in principle, the community should contribute to the additional control costs. Ideally managers need to know how much damage a pest is causing, and the cost of controlling the damage, so that the community contribution can be determined. However, this information is rarely available (also see 'Pest damage', pages 52–55).

The role of legislation

Legislation and its enforcement are important components of pest animal management, especially where they apply to responsibilities such as the control of access to and appropriate use of poisons. However, legislation that directs land managers to carry out certain actions, such as rabbit control, is being replaced with legislation that assists rather than requires appropriate management action. The older form of legislation, often called the command-and-control legislation, is applied increasingly by governments only as a last resort. For example, it has been used to encourage farmers who for one reason or another refuse to undertake pest control and cooperate with their neighbours, to meet agreed community objectives for managing pest animal damage.

The major role of legislation should be to encourage appropriate management.[70] It should state the overall management philosophy and the resource values to be protected. The *South Australian Pastoral and Land Management Act 1989* is an example of the new approach to legislation. The Act and associated policy documents establish objectives for managing leasehold and pastoral land, and provide for negotiated property plans that aim for sustainable land management. This includes control of excessive grazing by both domestic and wild animals. As a backup, penalties can be used against those who fail to abide by property agreements to protect the land.

Managing total grazing pressure

One of the most important elements in any grazing system is the stocking rate.[227] Excessive grazing pressure can cause severe land degradation through loss of vegetation and subsequent soil erosion. Degradation occurs in the improved pasture lands, which are located mainly in higher rainfall areas, and the unimproved or native pastures of the rangeland, located mainly in semi-arid and arid areas. Damage due to excessive grazing can be treated more readily in improved pastures than in the rangeland, consequently, further discussion is concentrated on the rangeland.

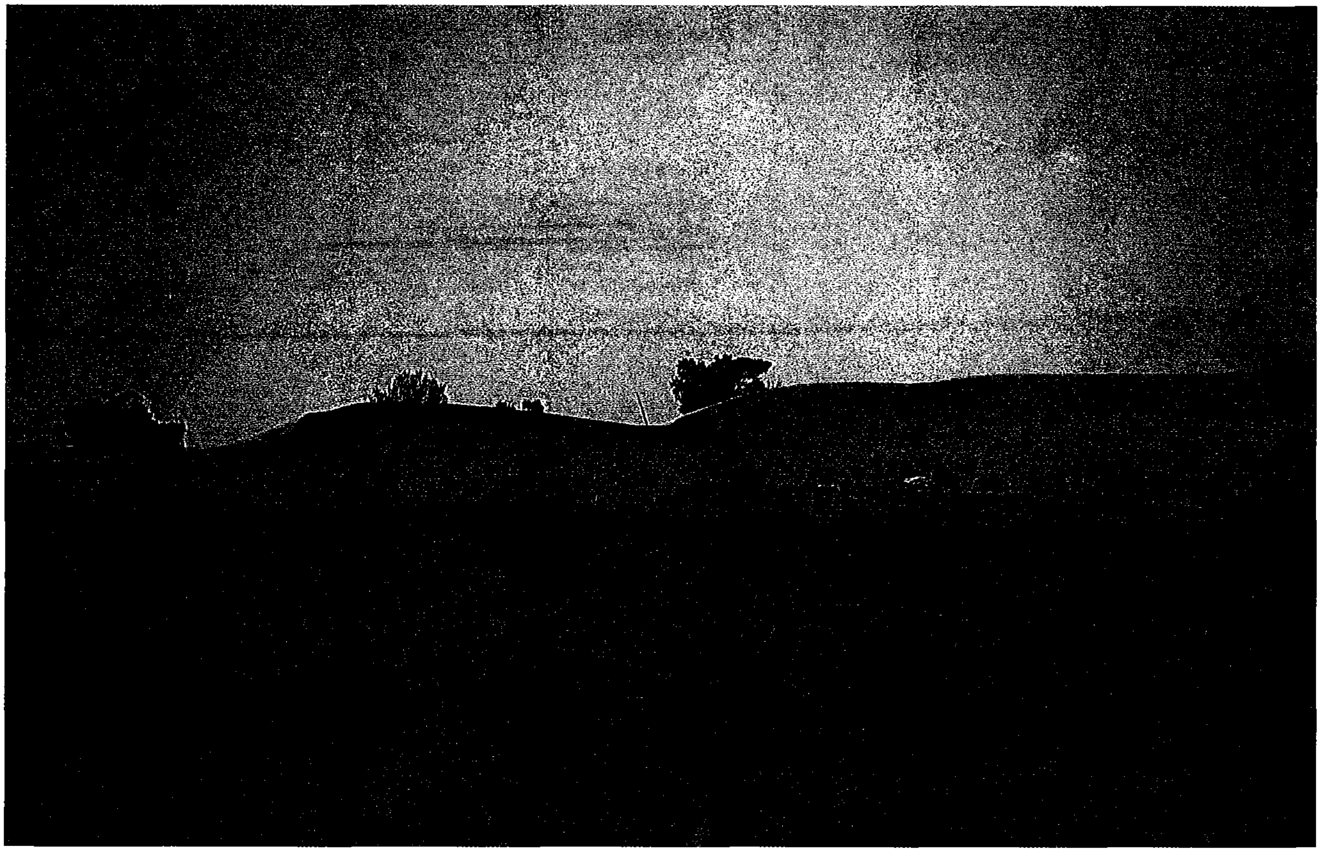
Almost 75 per cent of Australia is rangeland, most of which is in the arid interior.[59] The majority is controlled by pastoralists or is Aboriginal land. It has a rich assemblage of native flora and fauna including what is believed to be the world's most diverse reptile fauna.[60] Across the rangeland, especially where it has been used for pastoralism, many native species, particularly native mammals, have become extinct or been reduced to small isolated populations.[142] While some States and Territories have reserved significant sections of rangeland, survival of native plants and animals also depends on appropriate management of native plants and animals on privately managed rangeland.[145]

Much of Australia's rangeland is degraded, due mainly to grazing pressure from domestic animals.[94,111,112,227] Much of this damage was unintentional. Past management practices, adopted from those used for more stable systems in Europe, are now known to be unsuitable for fragile, infertile rangeland that is also subject to extended droughts and intermittent periods of high rainfall.

Continued overstocking of rangelands leads to destabilisation of natural pastures, mainly grasses in the north, and shrubs in the winter rainfall areas.[94] Natural pastures help to stabilise the grazing system and are essential habitat for much of the rangeland's native ground animals. Grazing pastures more heavily than they can sustain, especially during drought, can cause them to be replaced with less stable annual plants, most of which are weeds.

To maintain native pastures, total grazing pressure, including that of stock, feral animals and native grazers, must be limited. Indeed, such control is essential if the three recommended primary management goals for the rangeland are to be achieved:

- protection of the vegetation base and soil resource;
- maintenance of natural biodiversity; and
- sustainable pastoral production[59].



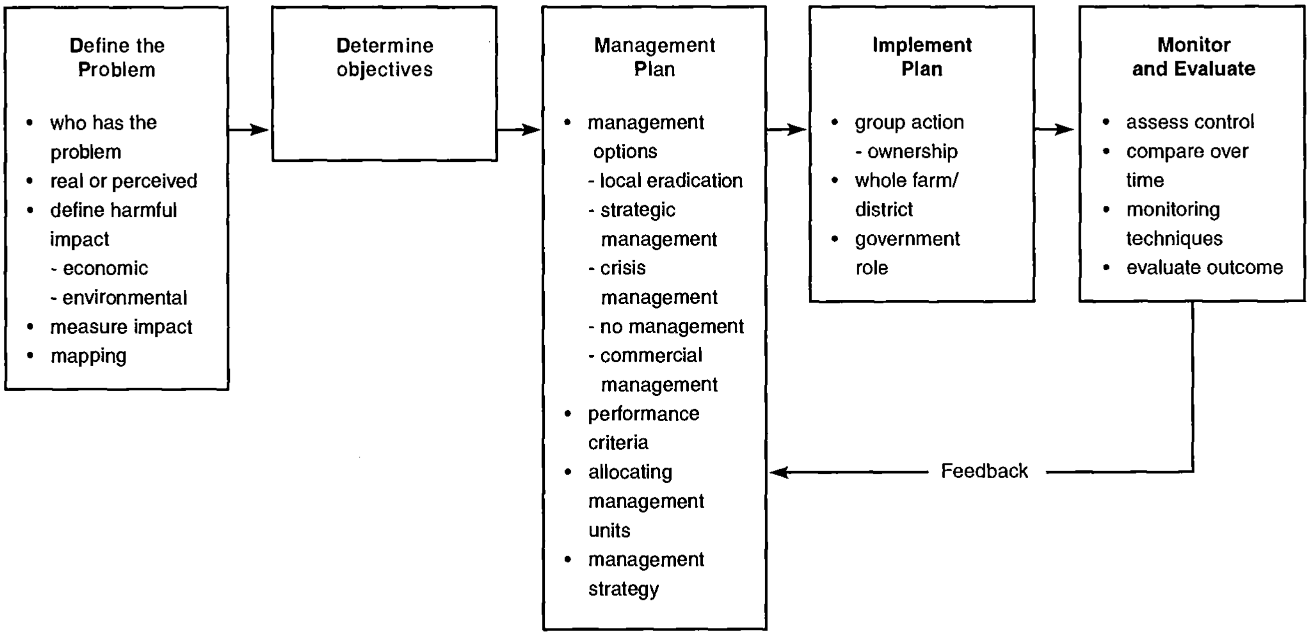
Near Ouyen, South Australia, clearing and overgrazing have stripped the land of vegetation, leaving wind-blown dunes. In such degraded landscapes, native animals struggle to survive. Both production and the conservation of biodiversity depend on sustainable land management practices, including the control of total grazing pressure.
Source: Noel Preece

The strategic approach to pest management

The strategic approach is a process of planning, action and evaluation, developed to help land managers address pest management problems. It was developed by the Bureau of Resource Sciences in cooperation with States, Territories, CSIRO and national farmer and nature conservation groups.[30] The basic steps in the approach are:

- define the problem in terms of alleviating the damage caused by the pest (see Chapter 6, pages 81–93);
- determine the objectives of the pest management plan (Chapter 7, pages 94–95);
- identify and evaluate the management options and develop the management plan (see Chapter 7, pages 95–107);
- implement the management plan (see Chapter 8, pages 108–117); and
- monitor progress and evaluate the results against the stated objectives (see Chapter 8, pages 117–118). If necessary, return to the first step and redefine the problem.

For most management situations, best practice management will develop as the knowledge gained by experience is incorporated into the management strategy. Using the management system in this way, to refine pest management strategies is called adaptive management or 'learning by doing'. Land managers learn from their past successes and mistakes, and those of others in similar situations, and combine them with research findings and technical information to continually improve management and care for their land in a more sustainable and cost-effective way.



The five-step strategic approach to pest management (adapted from Braysher[30]).

6 Defining the problem

Defining the pest problem

The first step in the strategic approach is to define the problem and identify the causes. This requires an assessment of the available information to determine whether pests are the real culprit or just perceived to cause damage and, when pests are a problem, whether other factors are also involved. Assessing the extent of the damage—deciding when and where it occurs and how severe it is—and identifying who is affected or has an interest, are also part of this process. It is also advisable to investigate the economics of the pest problem at this stage (see 'When is it worth managing a pest population?', page 97).

From the management perspective, the pest animal problem is best stated in terms of the desired outcome sought from pest damage control; in other words, the expected conservation or production benefit. To illustrate, from a reduction in rabbit damage a sheep grazier might expect any of the following outcomes or a combination of these:

- increased wool production;
- reduced soil erosion;
- protection of native vegetation;
- better management of the effects of drought;
- assisting neighbours to control their rabbits;
- ridding their farm of a pest that they do not like.

Is there a problem?

In many cases pests are of real concern (see case studies, pages 119–139). For instance, feral pigs take as many as 40 per cent of lambs born in the lamb production areas of western New South Wales,[164] and rabbits, even at densities of less than 1 per hectare, can prevent the regeneration of some native plants.[225]

Nevertheless, in some situations there may not be a problem or pest animals may not be the main cause of damage. Predation by rats has contributed to the decline of several bird populations on islands and seemed to be the obvious cause of the extreme rarity of the Lord Howe Woodhen, which is found only on Lord Howe Island, New South Wales.[43] However, careful assessment of the situation showed that feral pigs were to blame. Reduction in pig numbers eventually led to an increase in woodhens, from about 10 to 60 breeding pairs. A situation where a pest animal may be incorrectly blamed for production losses is that of poor lambing success attributed mainly to fox predation, when other factors such as poor ram management, ram infertility or infertile pasture are the major causes. For example, in a recent study at Boorowa on the Southern Tablelands of New

South Wales, fox predation of lambs accounted for less than 2 per cent of lambs born. Foxes took a number of lambs, but most of these died or would have died from other causes such as difficult birth, exposure to cold, poor mothering or low birth weight.[240] In this case, the farmer is likely to obtain a greater gain in lamb production from treating these other causes of lamb loss rather than from fox control. In other lamb production areas, primary predation by foxes may be more important and deserve a higher management priority. Each case must be assessed individually.

Rat damage to Hawaiian macadamia nuts: a perceived rather than a real problem

Hawaii has substantial macadamia nut plantations. Farmers noticed that the introduced Black Rat damaged many of the nuts and this was confirmed by studies which showed that up to 15 per cent of the nuts were damaged by rats. Expensive annual rat removal successfully reduced nut damage. In order to better understand the problem, the United States Department of Agriculture set up experiments to measure the nut yield from macadamia trees in crops where most of the rats were removed compared with trees where there was no rat control.[216] Rat removal greatly reduced damage to the developing nuts. However, when the yield of macadamia nuts from the protected trees was compared with that from the unprotected trees, there was virtually no difference.

In the next stage of the experiment, rat damage to developing macadamia nuts was mimicked by artificially removing nuts at various stages of development. It was discovered that trees could fully recover loss of individual nuts in the developing crop up to 150 days after seed set. This is not surprising, as most fruit trees produce a similar weight of fruit, and often larger and better quality fruit, when excess developing fruit are removed. Thus, although rats were damaging developing nuts, they were not affecting the yield, rather they were pruning the excess fruit.

Rat damage to macadamia nuts is an example of a perceived rather than a real pest problem. Resources devoted to rat control would have been better spent on improving other aspects of the production and marketing of macadamia nuts.

Cane Toads: a real or perceived pest problem?

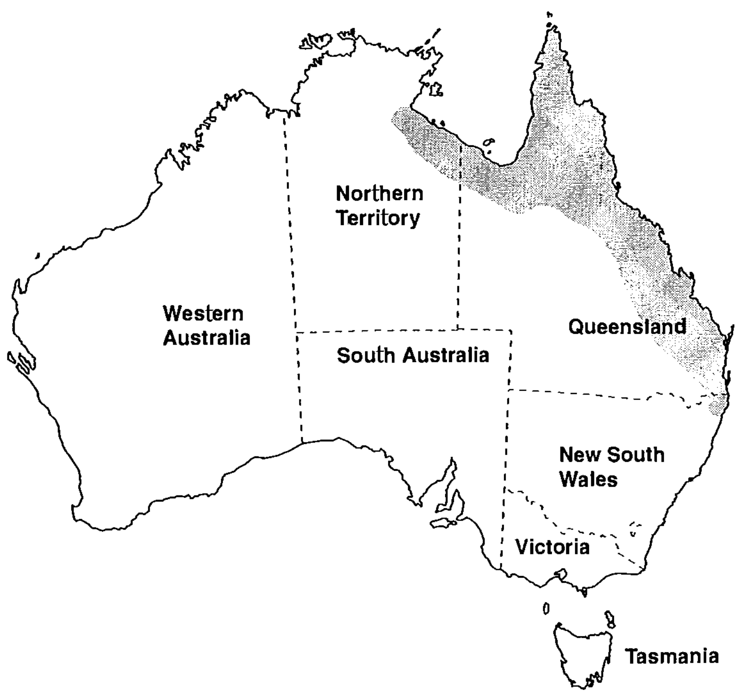
The South American Cane Toad was introduced to Queensland to help control cane beetles, which damage sugar cane. In 1935, 62 000 captive-bred toadlets were released.[135] They took to their new home with enthusiasm and are now common across a large part of eastern Queensland, have extended into northern New South Wales and are invading the Northern Territory at the rate of about 30 kilometres per year.[61] However, they do little to control cane beetles.

The toads are predators of native invertebrates, such as aquatic insects and tadpoles of native frogs. When alarmed, they produce a toxic poison from glands in their shoulders, and their tadpoles are also poisonous. Cats and other pets and some native animals such as goannas and native quolls can die if they eat Cane Toads.[78,115] For this reason the toads are considered a major pest and blamed for contributing to the decline of some native animals. Undoubtedly the cause of the Cane Toad has not been helped by their unattractive appearance. As a result of these concerns, extensive funds have been spent developing methods to control the toads, a task that so far has proved unsuccessful.

However, after Cane Toads invaded the habitat of four species of native frog, no damage could be detected.[78] Indeed, when the researchers artificially reduced the numbers of one common species of native frog, their numbers recovered despite the presence of Cane Toads. In another study, invading Cane Toads caused an initial decline in the numbers of goannas and predatory snakes. However, a few years later populations of both species had recovered to the levels they were at before the toads invaded.[237]

One of the problems in assuming that Cane Toads have caused the decline of some native animals, and in focussing a considerable proportion of available resources on attempts at control, is that the real cause of the decline may be overlooked. For example, loss of suitable habitat rather than Cane Toads has probably been a major cause of the decline of the Spotted-tailed Quoll in Queensland.[201]

This is not to say that no action should be taken to control the spread of Cane Toads. Consistent with adopting the precautionary principle (see 'Ecologically Sustainable Development', page 76), where practical, the toad should be prevented from invading new habitat. However, unless studies can show that it is a significant pest in areas where it is well established, attempts at control are likely to be futile and of little value to conservation.



Distribution of the Cane Toad in Australia in 1996, thirty-one years after it was introduced in the futile hope that it would control cane beetles (after CSIRO[61]).

Cane toads are unsuccessful agents of biological control, introduced to Australia to control cane beetle. Their continuing spread and the defensive poison they exude from glands on their shoulders—which can kill wildlife and household pets—cause concern.
Source: Queensland RLPB

If Cane Toads are not a conservation problem, how should community concerns be addressed? An extensive public awareness and information campaign may be needed. If, after this, the community still wishes to support research and action to control Cane Toads, then at least they are more aware of the likely costs and benefits.

European Carp: problem or scapegoat?

European Carp are common in many of Australia's river systems. In the Murray and Murrumbidgee River systems they have been blamed for the reduction in the numbers of trout and native fish such as Murray Cod, Golden Perch and Silver Perch. There is increasing pressure to control carp and, if possible, eradicate them. However, it is highly unlikely that they can be eliminated or indeed even that suitable control methods can be identified. More importantly, closer examination indicates that carp may not be a major problem to native fish, at least compared to other modifications of the Murray/Murrumbidgee System.

The Murray and Murrumbidgee Rivers form southern Australia's major river system. The river basin, the Murray Darling Basin, produces around 40 per cent of Australia's primary production. As might be expected for such an important production area, there have been extensive changes to the environment which include:

Water diversion

Seventy per cent of the available water in the system is regulated; 90 per cent of this is diverted for irrigation. Water use has increased rapidly and, as a result, between 1988 and 1994 alone there was a 12 per cent reduction in the amount of water that reached the sea.[138] Consequently, there is less water to flush impurities from the system and floods are less frequent and usually smaller. This in turn reduces the capacity of native fish to breed since many rely on floods to provide the stimulus and the correct environment for breeding.

Salinity

Salination is a major problem in the basin. Between Yarrawonga in Victoria and Morgan in South Australia salinity in the Murray River increases 12-

fold and salt levels are so high that lower parts of the river can no longer be used to irrigate certain crops such as apricots.[138] Carp are relatively tolerant of salinity but most native fish are not well adapted to saline water.

Nutrients

Nutrient inflow to the system is unnaturally high, for example, there has been a 250 per cent increase on the phosphate level of the river between Albury in New South Wales and Morgan in South Australia.[138] Frequently, nutrients are discharged from town sewage treatment plants and carried in run-off from farms into the rivers. The increased nutrient level has led to algal blooms which decay and cause low oxygen levels in the water. Unlike native fish, European Carp have a high tolerance to water with a low oxygen level. High nutrient levels can also increase vegetation on which carp feed, but which most native species do not eat.

Pesticides and herbicides

The level of persistent pesticides and herbicides and their breakdown products in the rivers of the basin has risen significantly as the level of irrigation along the rivers has increased.[138] While the impact on fish and other aquatic fauna is not clear, it is likely to have reduced the health of the system. For example, some of the organochlorine pesticides may cause feminisation of fish and reptiles,[183] that is, they may cause males to take on feminine characteristics or change sex.

Dams and weirs

Many dams and weirs have been constructed along the system and this has affected native fish in two main ways. First, it prevents their up-river migration, which is considered important for the long-term survival of species such as Golden Perch.[187] Second, water is usually released from the bottom of dams where it is cold and usually low in oxygen. The temperature of the water for a considerable distance below dams is too cold to stimulate native fish to breed, but European Carp can breed at much lower water temperatures than can native fish.

Removal of trees and snags

There has been extensive clearing of vegetation along the riverbanks, as well as removal of trees from the river beds to improve river flow. Tree removal, combined with the access of stock to the river, has led to extensive slumping of the banks. The effect on many native fish has been to reduce the amount of habitat available to lay their eggs. For example, unlike European Carp, Murray Cod must attach their eggs to underwater objects such as the roots of trees and underwater snags.

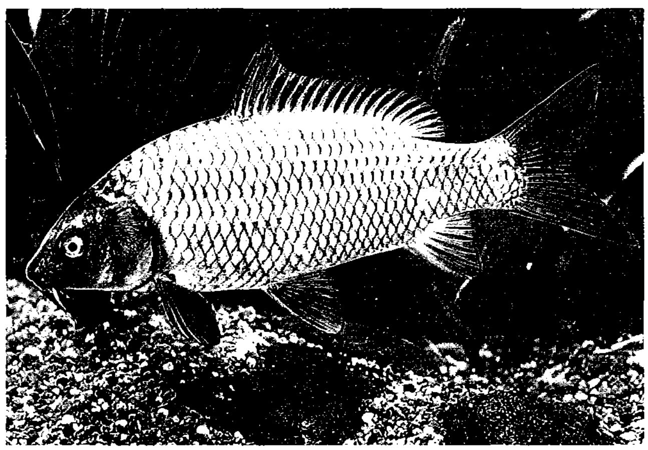
Other introduced fish

Beside European Carp, several other species of fish have been introduced to the rivers. These include trout, European (Redfin) Perch and Topminnow (Mosquito Fish). Both trout and perch are voracious predators and there is good evidence that trout have caused declines in populations of several species of native fish.[38]

Commercial and recreational fishing

Although the catch of native fish has declined considerably in recent years due to the decline in stocks, both native and introduced fish are still commercially harvested from the system, putting further pressure on native fish populations.

These are just some of the profound changes that have occurred in the Murrumbidgee and Murray Rivers as the result of human activities. Many of the alterations have been highly detrimental to native fish. While carp may cause some problems, such as increased turbidity and removal of bottom vegetation, these impacts need to be considered in comparison with the other major changes that have been wrought on the system. Viewed in context of these wider problems, carp may not be a major problem for the survival of native fish. Even though carp constitute an average of 80 per cent of fish biomass over the entire Murray Darling Basin,[244] it is likely that they are simply taking advantage of an altered river system to which they are better suited than are native species. Unless the other impacts can be reduced, native fish stocks are unlikely to improve even if European Carp can be controlled. Thus carp are likely to be a symptom of a degraded river system, not a major cause of declining native fish stocks.



European Carp are now one of the most common fish in many Australian river systems. They are blamed for declines in populations of several native fish.
Source: E. Beaton

Disturbance of catchments, such as on the Crookwell River, New South Wales, probably contributes more to declines of native fish than do introduced Carp.
Source: Noel Preece & Penny van Oosterzee

Clearly, it is important to determine the importance of pest damage compared with other factors so that available resources can be used to maximum benefit. It must also be kept in mind that situations often change. For example, feral pigs cause a significant reduction in cattle production in the Mary River catchment (see below). However, many other factors also contribute to cattle losses, and changing land-use will affect the future dynamics of pest management in the area.

Feral pig damage in the Mary River catchment

In the Mary River catchment, about 100 kilometres south of Darwin in the Northern Territory, cattle producers are concerned about feral pig damage to fences and pasture. Pastoralists claim that feral pigs root up pasture and break fences, causing them to lose about 10 cattle per property per year. The Northern Territory Parks and Wildlife Commission is also concerned about the damage pigs cause to local wetlands. Discussions with farmers and the local Landcare group indicated that the problem is much more complex than simple damage caused by the pigs. The following are just some of the important issues that were raised:

1. The aquatic weed *Mimosa pigra* has established in local waterways and begun to invade properties, reducing the availability of productive land;
2. Salt water has intruded far up the Mary River, killing large areas of native pasture and threatening native plants. Damage to coastal barriers by buffalo is believed to have been a major cause;
3. Wild dogs take and injure many calves;
4. Salt-water crocodiles in the Mary River are a major tourist attraction but they also take several head of stock each year from properties bordering the river;
5. Recreational feral pig hunters cause loss of stock when they cut fences to gain access to feral pigs;
6. Although considered a pest, feral pigs are also the basis of a growing commercial game industry and an important source of alternative income to pastoralists;
7. Returns for pastoralists that rely on free-range Hereford cattle are poor because of declining beef prices. There is pressure to upgrade their herds to Brahman-cross cattle for the live export trade but the capital investment to change is very high;
8. Large tracts of neighbouring land are being developed for nut and tropical fruit crops. The managers of these lands are likely to have different problems with feral pigs and other pests than do the pastoralists.

Effective control of feral pigs is unlikely, without careful planning to determine how it relates to other land uses in the area and to the future of the local cattle industry. All the key players, including pastoralists, the tourist industry, national parks, horticulturists and commercial pig hunters need to be consulted. Future trends in land use also need to be considered: if pastoralists change to higher value Brahman cattle, calf losses to wild dogs may become a much more significant problem than pig damage.

Damage by feral pigs in Mary River catchment, Northern Territory, affects cattle production. However, it is just one of several pest and land management problems, and changes in land-use are altering pest management priorities. Source: DFAT

Assessing the scope of the problem

It is important to obtain a broad perspective of the pest management problem. Once the problem is defined, its scope should be clarified. Key questions that assist this process include:

- Who has the problem?
- Where is the problem?
- How severe is the problem?
- Will the problem change with time? For example, is it likely to continue at its present level, increase, or decrease?

A definition of the scope of the pest problem should put it in its economic, environmental and social context. Some environmental contexts were discussed in the previous section ('Is there a problem?'). Consideration should be given to whether it is economically desirable to manage the pest problem and, if so, at what point it is most economical to proceed (see 'When is it worth managing a pest population?', page 97). To place the problem in its social context, the most important players should be identified and involved. Some, such as farmers and nature reserve managers, are easy to identify because they stand to benefit most from effective pest control. But others, such as policy regulators, animal welfare groups, commercial harvesters, hunters and conservation groups can also influence pest management. In this process it is useful to determine the importance of these groups, how they are involved, and to recognise any inconsistencies between them. Misunderstanding or inefficient or conflicting management of a resource may result when the main objectives of the groups do not coincide. Discussions with the key players can also help put the problem into its proper context (see 'Feral pig damage in the Mary River catchment', pages 87–88). Where they exist, regional or Catchment Management Plans are a great aid to planning.

Who has the problem?

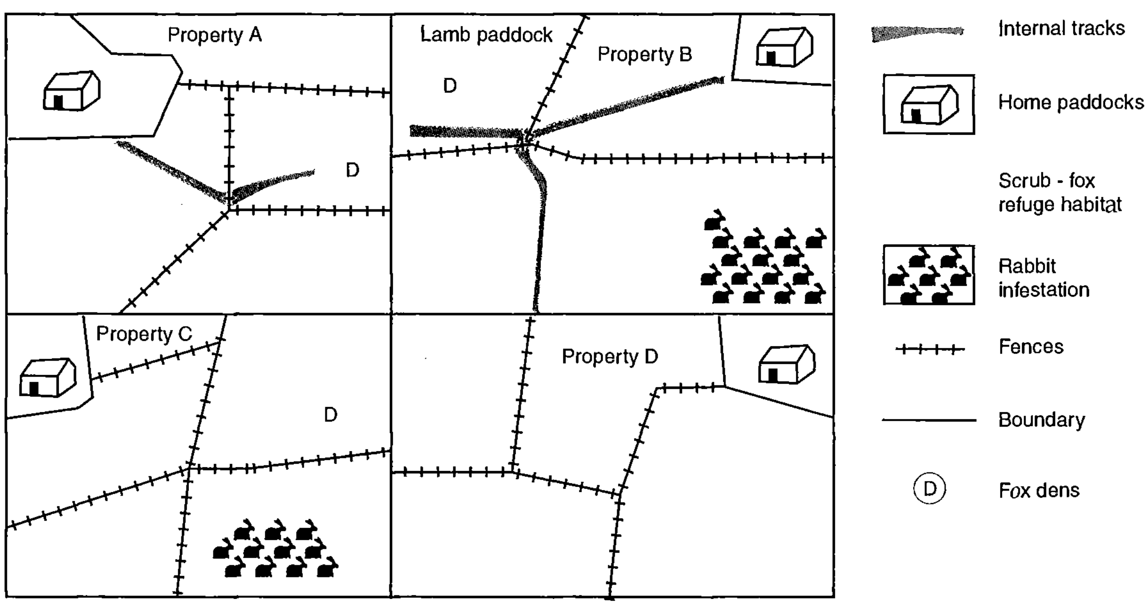
All major interest groups should be involved in defining the extent of the pest problem. Pests rarely respect property boundaries (unless a pest-proof fence is erected) and, in general, successful control requires a coordinated approach across a wide area. For effective pest management, land and nature reserve managers need to talk to and work cooperatively with their neighbours and other interest groups. Stakeholders include all those affected by the pest either through the damage caused or because they must pay for the pest control. These may include other farmers, hobby or absentee farmers, national park managers, foresters, water catchment managers, miners or semi-urban dwellers. The different groups are likely to have widely differing attitudes, approaches and levels of resources. Consequently, it is important that all stakeholders meet and discuss openly the various aspects of the problem, and contribute to the plan of action and its implementation.

Community-based groups, such as Landcare, and Total Catchment Management groups can help, especially if there is an effective coordinator/facilitator in the group. Meetings do not have to be highly structured. An informal meeting in a work shed or a kitchen can be very effective. On the other hand, a more structured meeting may be the appropriate way to discuss pest animal management when it concerns many players from a wide area (see 'A coordinated group approach to management', page 109–110).

Where is the problem?

Maps show the extent of problems and may help to indicate solutions.[225]

Maps help to define the scope of the problem and pinpoint priority areas. They can be of various types, from simple hand-drawn charts to topographic maps, land system or land unit maps, aerial photographs and sophisticated interactive computerised geographic information systems. The choice depends on resources, scale of the treatment and the type and extent of the problem.



A simple map of four hypothetical farms, showing some of the the key factors that landholders could record to plan fox management (after Saunders et al.[198]*).*

For example, when planning fox control, the map may record tracks, trails, fence lines, lambing paddocks, refuge habitats for important native animals, property boundaries, natural boundaries, areas infested with rabbits, fox corridors and dens and fox refuges. Mapping the relationship between pest animal damage and landuse, perhaps using overlays, may help determine where management should be targeted. In the fox example, mapping may indicate where lambing paddocks coincide with areas where fox damage is greatest and thus where control is best focussed.

Measuring the problem

Once it is established that the pest is the real cause of the problem, the amount of damage it causes, such as the percentage of lamb production lost to foxes or the reduction in production due to rabbits, needs to be determined. However, this is rarely easy even when there are good records of farm production, and it is still more difficult when assessing the level of damage caused to native plants and animals.

Designing experiments to quantify pest animal damage is also often difficult (see 'The logic and function of experiments: an example', pages 91–93). Large experimental units and several replicates of each treatment are often required to ensure that chance events such as fire and disease do not complicate interpretation of the results. Even if suitable experiments can be conducted, it may be a long time before the results of pest control become clear. For example, it may take many years for a rock-wallaby population to recover once the loss from fox predation is halted. Moreover, other factors may complicate interpretation of the information. One example is that of Malleefowl which were believed to be threatened by fox predation.[181,182] In a study designed to demonstrate the damage foxes cause to Malleefowl, there was little recovery in Malleefowl numbers following predator control. Later research showed that, although foxes were important, Malleefowl did not increase because the necessary food for chick survival was not available. Thus, as well as the essential control of foxes, management of grazing by domestic stock, feral goats and rabbits was also necessary.

Although fox predation is an important contributor to declines in Malleefowl numbers, experiments showed that fox control alone was not sufficient to enable recovery. Low chick survival due to starvation indicated that management of grazing by domestic stock, feral goats and rabbits was also necessary.
Source: Applied Biotechnologies

The logic and function of experiments: an example

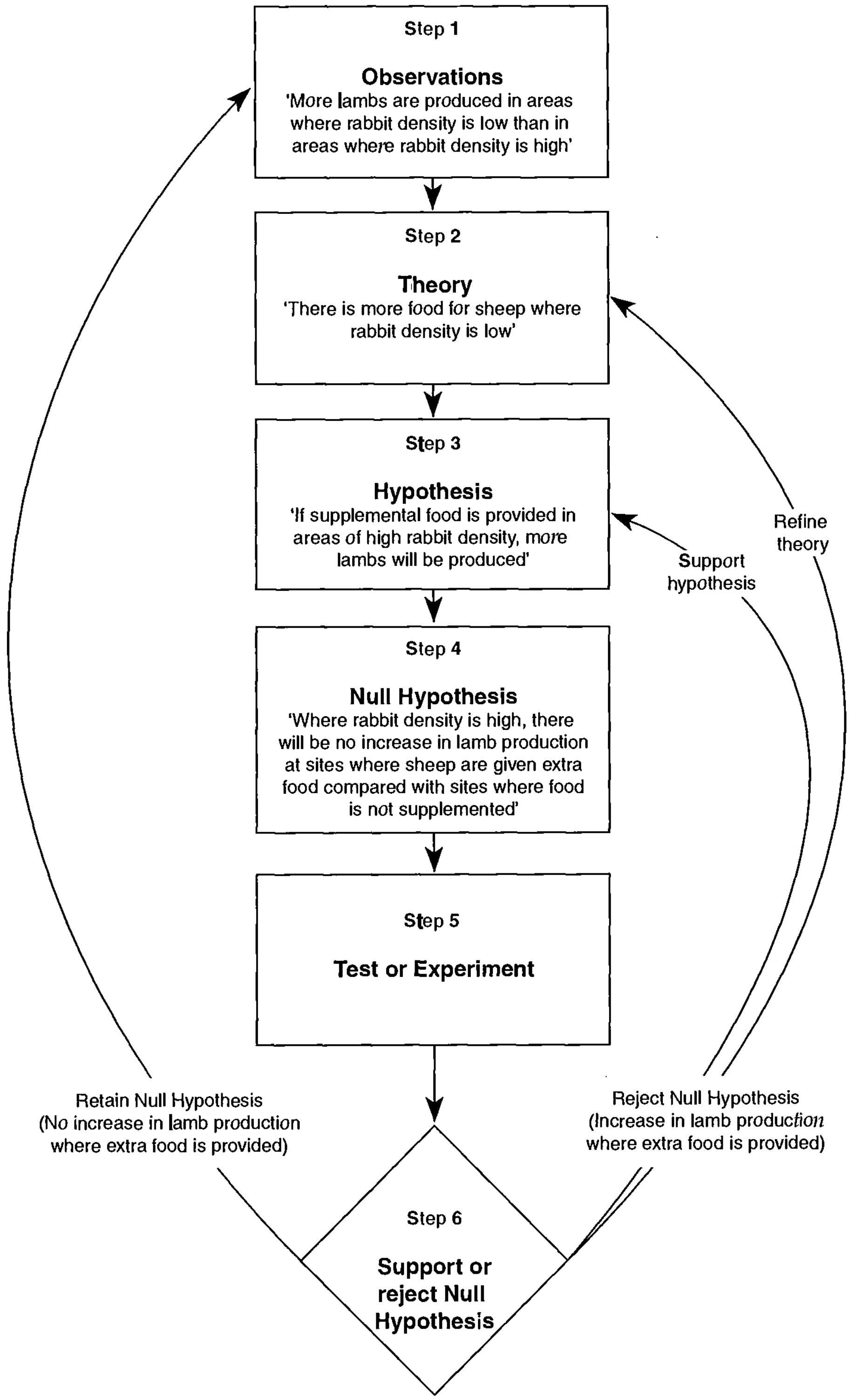
(Based on a draft by Steve McLeod)

To gain better knowledge of pest biology or evaluate the effectiveness of management techniques, experiments are often required. Well designed experiments follow a logical procedure (see figure overleaf). The first step involves making an observation of a pattern or a departure from a pattern. An observation could be as simple as 'More lambs are produced in areas where rabbit density is low than in areas where density is high' (Step 1). Once the observation has been clearly defined, the experimenter attempts to explain the observation with theories, which can be simple or complex and must always support the original observation. Several different theories can be put forward, each equally capable of explaining the observation, but differing fundamentally from the next. One theory that could explain the observed difference in lamb production is that 'Rabbits affect the food that limits successful lambing' (see Step 2). Another theory might be 'There are fewer foxes in areas where rabbit density is low than in areas where density is high'. The two distinct theories concern food and predation. At this stage both theories are regarded as valid.

During the third step, hypothesis building, specific predictions are made from the competing theories. The experimenter predicts some new and unexamined set of observations (Step 3), and then sets out to prove the value of the theory by showing that its predictions are true. If the predictions are not true, then the theory was in some way incorrect. From the theory that lamb production is limited by rabbits' effect on food, the prediction would be that if supplemental food were given to ewes in areas with high rabbit density, more lambs would be born. It is important to note that if lamb production is largely dependent on the rate of fox predation, then simply manipulating the amount of food is unlikely to have any effect. Most hypotheses are constructed in the positive form, that is they make the prediction that there will be a difference between treatments. However, before the hypothesis can be tested statistically it is usually restated in a negative form, called the null hypothesis (Step 4), which usually states that there will be no difference between experimental treatments.

Once the null hypothesis has been clearly stated it can be tested by an experiment (Step 5). At this stage the experimenter must consider such things as replication, experimental treatments and controls, allocation of experimental units, what data need to be collected, sampling intensity, and appropriate statistical analyses. The data needed to test the null hypothesis are then collected. If the data do not support the null hypothesis then the hypothesis is upheld and, if the hypothesis was logically constructed, the theory is supported (Step 6). However, even if the null hypothesis is rejected, that is, the theory that relates to food is shown to be correct, the other theory cannot be dismissed. Lamb production may be poor where rabbit density is high both because there is less food and foxes kill lambs.

The next step is to refine the original theory, making it better able to predict nature, either at a more complex scale, or by making it more general and able to predict at a broader scale. This can be done by experiments designed



The logical steps in the design of an experiment (from Underwood[221]). The example shows the design of an experiment to determine why more lambs are produced in areas where rabbit density is low than in areas where density is high; in particular, to test the theory that rabbits affect the food that limits lamb production.

to establish whether predation is important and whether food and predation interact. Further, rabbits may affect the food of sheep by competition for food and/or by the habitat degradation they cause, and it may be useful to explore these theories. Alternatively, if the null hypothesis is not rejected then there is evidence that the original theory was wrong. Whatever the outcome, the researcher goes back toward the start of the procedure: to the theory (Step 2) if the null hypothesis was rejected, or to the observation stage (Step 1) if the null hypothesis was retained. Thus, experimentation is a process of continual refinement, evolution and, occasionally, revolution.

Most problems in interpreting experimental results stem from the hypothesis stage (Step 3) or the testing stage (Step 5). If hypotheses were ambiguously stated there is a chance that more than one theory could be supported by the experiment. However, more typically, inconclusive experimental results are a consequence of problems during the testing stage, most commonly: 1) lack of experimental controls (the word control is used here in the experimental sense, to mean an untreated site); 2) inadequate replication; 3) lack of interspersion of treatments and controls; 4) overall lack of statistical power; or 5) errors in statistical analysis and interpretation.[99] In this experiment the control is a set of untreated sites with high rabbit density, similar to those where food supplementation takes place. The use of control areas lessens the risk of obtaining a misleading result if, for example, there are good rains and lamb production increases regardless of the provision of extra food.

There are many excellent guides to the correct design and interpretation of experiments (for general texts see Cochran and Cox;[50] Winer et al.;[230] Manly;[133] for texts with an ecological slant see Caughley and Sinclair;[44] Scheiner and Gurevitch[199]).

Appropriate monitoring of the effectiveness of the pest control will assist land managers to determine whether their estimate of pest damage was correct or whether the problem needs to be reassessed. It can also indicate whether the pest problem changes over time. The National Pest Animal Guidelines explain techniques that can be used to determine the extent of pest animal damage (see listing inside front cover). State and Territory nature conservation and agriculture agencies may also be able to help. Estimates of the level of damage, based on the best available information, will need to be used when there are no reliable measures. However, if damage estimates are not available, the only useful guide to the likely level of pest damage may be an estimate of pest density.

7 The management plan: objectives and options

Developing a management plan

Once the pest management problem has been identified and the social, economic and environmental boundaries determined (see Chapter 6, pages 81–93), the next step is to plan how best to address the problem. For larger scale problems, this should be a joint exercise with key interest groups and is best based on cooperative action at the local or regional level. Developing the pest management plan involves several steps:

- setting clear objectives;
- identifying the appropriate management option or combination of options;
- selecting control technique(s);
- establishing criteria to measure effectiveness of control and designing a monitoring program;
- deciding which regions form management units (see 'Defining management units', page 102); and
- bringing all the elements together to complete the management plan.

Once objectives are set, and the management option and the technique or combination of techniques (see Chapter 4, pages 56–73) has been selected, the manager in consultation with other key players can put the management plan together. This requires deciding when, where and how the management program will be conducted. However, the management plan is not complete without a monitoring and evaluation component (see the section on 'Monitoring and evaluation', pages 117–118), which establishes criteria to measure the effectiveness of control and sets out a monitoring program.

Setting objectives

Effective pest animal management should have clear objectives aimed at reducing pest animal damage to an acceptable level. Where practicable, the objectives should also be measurable and time-limited. The level of reduction sought will be determined mainly by the value of the resource affected by the pest, and the cost of pest control.

For a high value crop, such as a pine plantation, the objective may be to reduce losses caused by rabbits to less than 2 per cent of the total crop value within one year. Meeting this objective will be expensive but the value of the product may justify the high cost of control. An objective for a fox management program might be to improve lamb marking by 20 per cent after two years of fox control. For a nature reserve, the manager may aim to increase the population of rock-wallabies by 200 per cent after four years of fox control.

However, often the level of pest animal damage is not known or poorly known and land managers need to make some assumptions. They might assume that the level of damage is directly related to pest density, as is sometimes the case (see 'Does increased pest control result in reduced pest damage?', pages 54–55). The objective of pest animal control can then be stated in the form of reduced density of the pest. An example for rabbit control to enable mulga regeneration in semi-arid areas may be the objective of a 90 per cent reduction, within one year, of rabbits seen on a spotlight transect. However, it is important to bear in mind that, unless the relationship between pest density and the level of damage is known, the objective of a reduction in numbers is only an indicator of the desired outcome—a reduction in rabbit *damage*. It is possible that even a 90 per cent reduction in rabbit numbers may fail to significantly reduce mulga losses.

Management options

There are three main options for pest control: eradication, short- or long-term management or no action. With the exception of islands or isolated populations of pests, complete eradication is rarely feasible or economically sensible. Usually land managers opt either for short-term control at a critical time such as at lambing or for longer term sustained pest control. The most appropriate option will depend on local circumstances, including the resource under threat, the nature of the land, available techniques, the attitude of neighbours and the availability of financial and other resources (also see 'When is it worth managing a pest population?', page 97). To protect a valuable vegetable crop from rabbits, a farmer may choose intensive control using a combination of poisoning, warren ripping and fumigation followed by the erection of a rabbit-proof fence to prevent reinvasion. By contrast, the manager of a pastoral lease in the far north-west of New South Wales may only be able to afford warren destruction on the most productive parts of the property and decide to leave rabbits uncontrolled in the harsher limestone outcrops.

More specifically, the options for addressing pest animal damage include the following:

- local eradication;
- strategic management: one-off management, sustained management, and targeted management;
- crisis management;
- commercial management; and
- no management.

When determining the appropriate management option or combination of options, the following factors need to be considered:

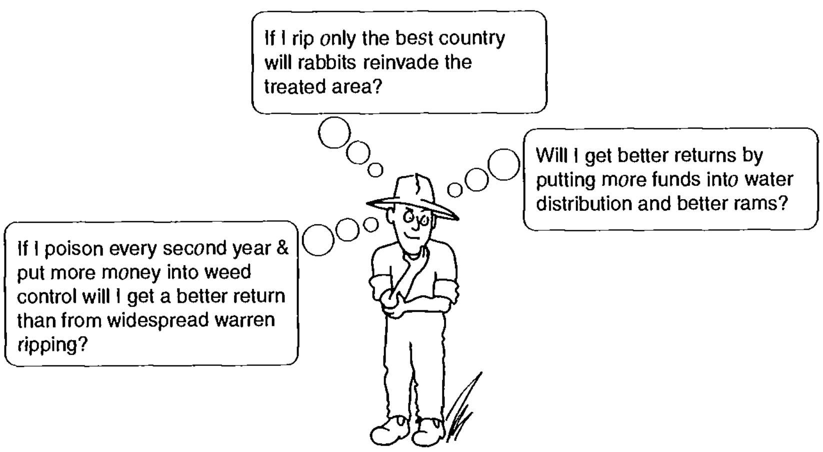
- the level of current and future resources available for pest control;
- the reduction required in the pest population to achieve the desired reduction in damage; and
- the availability and practicability of control techniques.

From the range of possible management options, a manager of a pastoral lease in the far north-west of New South Wales may make a decision to manage rabbit damage by ripping warrens on the most productive parts of the property and leaving rabbits uncontrolled in the harsher limestone outcrops.
Source: Quentin Hart, BRS

Depending on the dynamics of the situation and restrictions on the use of certain control techniques, a land manager may choose only one or a combination of techniques (see Chapter 4 pages 56–73). For example, because of the risk of killing domestic pets, 1080 poisoning of rabbits is rarely possible near towns and an alternative poison such as pindone, that has an antidote, may need to be used in locations where pets are at risk.

Each situation needs to be assessed individually and the appropriate management option or combination of options identified. Too often, costly but inappropriate strategies are adopted in managing pest animal damage to production and wildlife conservation values.

To help managers decide how to allocate scarce resources, the Department of Conservation in New Zealand uses a process which ranks areas according to their priority for pest management (see Appendix 1). The process may seem complex but is basically simple: given a finite level of resources allocated to pest management, how is it best spent on a farm or nature reserve? In essence, it is a mapping exercise (also see 'Where is the problem?', page 89–90) that considers the following:



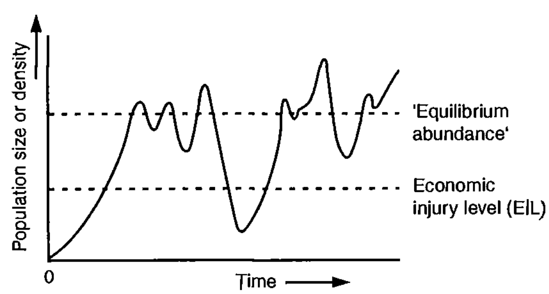
A farmer has many options to weigh up before deciding which, if any, pest management option is best under the circumstances.

When is it worth managing a pest population?

The aim of economic pest management is to reduce the pest population to a level below which further reductions give no additional cost-effective benefit, that is, below which any extra benefits do not exceed the extra costs of control. This is often called the economic injury level (EIL).[16] The costs are the cost of the initial reduction to the required population density and the cost of maintaining that density. The costs of short term, targeted management, such as baiting of foxes just before lambing, are likely to differ from those for sustained management to, say, protect an endangered bettong population from foxes. The relationship between pest numbers and pest damage is also important (see 'Does increased pest control result in reduced pest damage', page 54–55); there may need to be a greater reduction in a fox population to conserve bettongs than to protect lambs. Thus, for the same pest, in this case the fox, the EIL may differ according to the resource being damaged and the management strategy adopted. The cost of the same management strategy may also vary according to conditions. For example, management may be less costly and more effective when applied in droughts compared to good seasons and when disease or predation is having an impact on the pest population compared with when the population is unaffected by these.

The Figure illustrates the concept of EIL for a hypothetical pest. The EIL is greater than zero density (eradication) and because the pest animal population often exceeds this level it is regarded as a pest. In theory, any attempt at eradication or control when the pest density is lower than the EIL generally will not be profitable.

However, although it is a useful way to view pest problems, the EIL concept has several shortcomings. In particular, if the population is to be kept below the EIL then action must be taken at some lower pest density because it takes time for control actions to have an effect. It is this lower level—the pest density at which action should be taken to avoid an impending pest problem by preventing the population from exceeding its EIL—that is often most important for practical pest management.



The population fluctuations of a hypothetical pest animal over time (after Begon et al.[16]). Abundance increases rapidly when the population size is small and reaches an equilibrium abundance set by the pest's interactions with its food, predators and so forth. The population then fluctuates about this equilibrium. Intuitively, it makes economic sense to manage the pest when its abundance exceeds the economic injury level (EIL), below which further reductions in the pest population give no additional benefit. However, due to rapid fluctuations in the population size of many pests and delays in the effects of control, management may need to start before the population reaches the EIL.

- where are the pests?
- where are the most important resources being damaged by pests?
- where is the worst pest damage?
- how much money or other resources are available for pest management?
- what does pest management cost per hectare to be effective?
- how many hectares can be treated?

Local eradication

Complete and permanent removal of a pest from a region is rarely possible except on a local scale, and usually at high cost (see 'Eradication is rarely possible', pages 104–107). Nevertheless, it has been used successfully in Austraha to eradicate rabbits and goats from several small offshore islands.[173,225] On Townshend Island, Queensland, a small herd of milking goats left behind when the sole grazier moved from the island grew to about 2000 in number and was having a large impact on the native vegetation. In 1993, 16 Dingoes were introduced and within 15 months they had reduced the goat population to 200 and the vegetation had begun to recover.[4] After 21 months, 21 goats remained. Six months later only four survived on a rugged part of the island and these were shot.[5] The Dingoes were then removed.

Before attempting local eradication of a pest, managers should critically assess whether the criteria for eradication can be met (see 'Criteria for local eradication', pages 104–106). For mainland Australia, local eradication is likely to be successful only where there is a permanent barrier to reinvasion, such as a wide band of unsuitable habitat between the potential invaders and the treated area, or a fence.

The Western Australian Government for example, has successfully eradicated Starlings from the State. Pockets of Starlings were shot and trapped, and a team established to regularly patrol caves and other potential roosts sites on the Nullarbor Plain, thereby maintaining an effective barrier to potential immigrants from eastern Australia.

Strategic management

When local eradication is not practicable, strategic management is the most popular option. There are three possible forms: one-off management; targeted management; and sustained management.

One-off management

Long-term or permanent reduction in the damage caused by some pests may be possible with one action or set of actions, such as some biological control, erecting appropriate fencing, or modifying habitat so that it is less suitable for pests. For example, in some areas it appears that the release of myxomatosis severely reduced rabbit numbers and the habitat subsequently became much less suitable for rabbits, hmiting reinvasion.[73] Three 160 square kilometre properties in the eastern Riverina district of New South Wales were surveyed for rabbits before the release of myxomatosis in 1950–51 and after release in 1975. Despite little other control the estimates of rabbit infestation on the three sites dropped from 38, 26 and 52 per cent to 0.26, 0.04 and 13 per cent, respectively. Habitat changes between the early and later surveys included collapse of established warrens and taller vegetation that no longer provided suitable food and blocked vigilance for approaching predators.

Sustained management

Ideally, sustained management is when pest animal density is reduced and then maintained at, or near, a threshold density at which there is no increase in benefit (damage reduction) from additional control. This option usually involves two steps: an initial knockdown aimed at removing a high proportion of the population; followed by periodic maintenance control to slow or prevent recovery. The threshold density for a pest is likely to vary according to many factors including the relationship between pest damage and density, the region, climate and land use (also see 'Does increased pest control result in reduced pest damage?', pages 54–55 and 'When is it worth managing a pest population?', page 97). It is therefore complex and often difficult to implement, not least because the relationship between pest animal density and the level of damage is rarely known. Alternatively, a manager may choose an arbitrary level of pest damage or pest density that they find acceptable and manage the pest to maintain damage or density at, or below, that level.

Maintenance is an important element of sustained control. For example, between 1979 and 1988, 5892 goats were shot in Mount Pirongia Forest Park, New Zealand, to protect native plants, at a cost of $500 000. Most of this was wasted as goats were not held at a sufficiently low level, long enough to allow regeneration of the native plants and animals being damaged.[170,173]

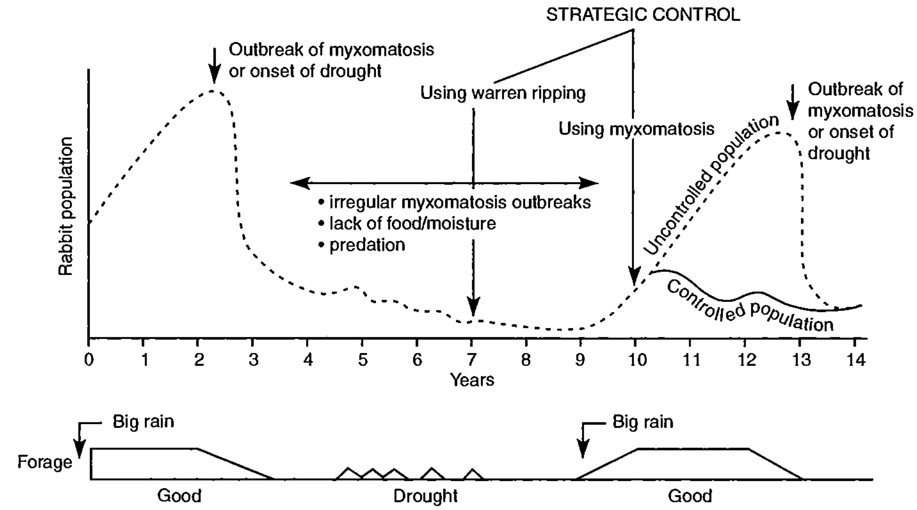
How often maintenance control is needed depends on how quickly the pests recover and cause unacceptable damage. A variation of sustained control, intermittent control, is used periodically to reduce a pest population to low levels to enable other factors to come into play. For example, it has been suggested that some animal species may be kept at low numbers by a predator, in what is known as a 'predator pit'.[179] It may be possible to control rabbits or feral pigs by reducing their density to a level where their primary predators, foxes and wild dogs respectively, could slow or prevent their return to former densities.

This approach can also be considered in the reverse to protect native animals. In the case of Numbats threatened by fox predation, if the fox population is reduced for a sufficient period, Numbats may be able to build up their numbers to such an extent that they can withstand further predation. This may reduce the need for more fox control, unless the population of Numbats again drops to low levels due to chance factors such as large-scale fires.[179]

Targeted management

Targeted management is where action is directed at the individuals or group of individuals that cause the majority of the damage, or applied at that time when damage is most critical. For example, in the sheep country of Western Australia, it appears that most sheep kills are caused by younger, dispersing feral dogs.[210] It is also believed that the older, more wily foxes are the primary predators of Malleefowl chicks near nest mounds.[198] Control targeted at these problem animals may be more effective than aiming to reduce the overall density of the pest population.

However, a targeted approach is not always practicable. Usually it requires a good understanding of the behaviour and biology of the pest to determine which individuals are the key animals to target. In addition, it is often the problem animals that are more experienced and avoid conventional control techniques.



Hypothetical model of an Australian rabbit population and suggested application of control techniques for sustained management beginning at seven years (after Williams et al.[225]). Initially, when rabbit numbers are low during drought, warrens are ripped, followed by further warren destruction and/or fumigation where necessary. Then, after good rains in year 10, myxomatosis is introduced. As this is a costly management strategy it would be appropriate only for highly productive country.

A variation of targeted management is to conduct control only at critical times, such as baiting (poisoning) foxes just before lambing. Similarly, some pests such as House Mice cause little damage until seasonal conditions become favourable and they build to plague levels. Models can now help to predict when a plague is likely and assist farmers to target mouse control just prior to the major population build-up.[205]

Crisis management

All too often farmers and reserve managers undertake pest control only when the pest animals or their damage become too obvious to ignore; this is crisis management. There is no clear objective for the control other than to kill pests and control efforts are largely wasted because the damage has already been done. Crisis management is not a desirable management strategy. The poisoning of mice at the height of an outbreak, when the mice are at high density, have spread widely and caused massive damage, is an example of crisis management.

Pest managers can target control at critical times, for example, by laying manufactured 1080 baits for foxes just before lambing.
Source: Applied Biotechnologies

Commercial management

Many pests are harvested either by recreational hunters or for commercial gain[184] and it is argued that they should be seen as a resource as well as a pest.[185,213,214,215] Commercial pest harvesting industries in Australia are estimated to earn in excess of $100 million a year, mostly from export products, and are growing rapidly.

The value of commercial harvesting of pest animals as a means to control pest damage has been questioned. Commercial use is likely to play little or no role in the management of some species such as rabbits and wild dogs. However, it has potential for other species such as feral horses, goats and pigs. For example, harvesting in the form of mustering and selling the animals is a component of

Commercial harvesting of pest animals such as feral goats can add to farm incomes and assist in the effective management of pest damage. Source: Quentin Hart, BRS

some control programs for feral goats and horses and any profit can be used to offset the cost of follow-up control. Nevertheless, commercial harvesting is rarely built into pest management plans. Indeed commercial harvesting is quite often carried out independently of other control action, as is the case for most feral pig harvesting in Queensland and New South Wales. The effectiveness of this type of control in reducing pest impact has rarely been determined, and should be assessed for more situations.[173]

Commercial harvesting as it is currently practiced is usually concentrated relatively close to processing plants in areas where the pest is abundant, and these may not be the areas where control is most needed. Nevertheless, there are advances which may make the commercial harvesting of species such as feral goats and other large feral animals more effective as a management option. These include the development of larger and more reliable overseas and domestic product markets which add stability to the industry, and large portable chillers which enable harvesters to work in more remote areas.[238]

No management

Many pest animals, including feral cats, foxes, camels, starlings and feral pigs, are not managed over much of their range, especially in conservation areas. This situation is likely to continue due to limited resources. A consequence is that in some areas certain land uses are not possible, such as wool production outside wild dog fences or re-establishment of small endangered native mammals.

Reserve managers may not have the resources to control pests over the whole reserve or they may not regard pests as a major problem. Nevertheless, when assessing the costs and benefits of pest control, they have a responsibility to consider the impact of pests dispersing onto neighbouring land. A compromise may be that pest management is carried out in the buffer zone where the reserve adjoins farming land.

Defining management units

Maps and a process of ranking according to pest management priority, such as that used by the Department of Conservation in New Zealand[48,155,156] can be used to identify practical units for pest animal management. In the past, a lot of pest animal management has been based on inappropriate management units. Too often, fox control was carried out on individual properties or nature reserves with little coordination between neighbours, and was of limited success due mainly to reinvasion by foxes.

Around Mildura, bird damage to sultana grapes is generally insignificant because they are grown over a vast area and ripen at the same time. By comparison, the scattered vineyards in the Barossa Valley, adjoining scrub or other timbered areas, suffer more damage. The greatest losses occur in the Riverland of South Australia where vineyards, mixed orchards and horticultural areas border croplands, offering pest birds a year-round smorgasbord. Clearly, the scale of the management units will differ for each of the areas.

The size of the management unit can also be influenced by the time-frame over which control is required. For example, protecting a lambing paddock for one month just before and after lambing would be a much smaller operation than ensuring the survival of an endangered species that was under constant threat of predation in a large nature reserve. In the case of the reserve, it is likely that control of dispersing foxes in a buffer zone between the reserve and neighbouring farmland, as well as action in the reserve itself, would be necessary. This would require coordinated management involving several land managers and greatly increase the size of the pest management unit.

Incomplete knowledge: dealing with risk

There is often little good information about the amount of damage pests cause and the likely benefits from a given level of pest control. As a result there is considerable risk involved in deciding the level of resources that should be allocated to pest control. Most land managers, but especially farmers, understand the concept of risk because it is a daily part of management; a farmer may weigh up the risks and benefits of planting canola instead of wheat or of delaying winter planting if the season is late. Comparing the risks and benefits of various levels of pest control against diverting the resources to other aspects of a farm operation is a similar assessment process.

The attitude of the land manager to risk will affect how they are likely to approach pest control. If farmers are risk-averse, they are likely to choose a pest management option that offers them the least losses due to pest animals even in the worst situation, or, alternatively, by deciding not to spend money on control until the problem becomes very obvious (crisis management). By choosing a safe option they usually reduce their chances of achieving a much more economical and beneficial outcome.

A conservation example of the impact of risk on pest management is the control of fox predation on native animals. Studies in Western Australia have shown that intensive fox control over large areas often allows an increase in threatened native mammals such as Numbats and Brush-tail Bettongs. Intensive fox control is expensive, but it may be possible to lower costs by reducing the frequency of fox baiting when the native animal population reaches a higher level. The theory is that a larger Numbat or bettong population will produce more young and be able to withstand an increased level of fox predation. A risk-averse reserve manager would not risk any increased losses of Numbats and bettongs and would continue intensive fox control.

However, the potential benefits from choosing the more risky option of reducing the frequency of fox baiting is that resources saved on fox control in one area could be directed to controlling foxes or other pests in other reserves. The possible losses from adopting the more risky approach can be reduced by appropriate monitoring of changes in the bettong and Numbat populations in response to the changed frequency of fox baiting. If the decline is too great, fox baiting can be increased again.

Management options for feral pig impact on lamb production: considering risk

Feral pig predation can cause an economically significant loss of winter lambs in western New South Wales.[163,164,175] To reduce lamb predation, several possible actions are available, either alone or in combination, and each has economic costs and associated risks. A manager's objective is to maximise benefit while taking appropriate account of associated risks. For pig control, some of the possible actions and associated risks a manager might consider are:

- *Action:* poison or trap pigs in late summer to early autumn to reduce winter density.
  Risks: pigs can be difficult to poison or trap outside winter, a few rogue boars that take the majority of lambs may not be removed,[175] and motivation to act early, before the problem becomes evident, may be lacking.
- *Action:* coordinate lambing with neighbours to spread losses.
  Risks: neighbours may not cooperate because feral pig distribution is patchy, and chance weather fluctuations may devastate all district lamb production.
- *Action:* change lambing to spring when alternative foods are available to pigs.
  Risks: poorer lamb prices, and more lambs may die or be stunted because rainfall in spring is less reliable than in winter.
- *Action:* erect electric fence around lamb paddock to exclude pigs.
  Risks: a short-term break at a critical time could result in high loss of lambs, and the fence may not exclude rogue boars.
- *Action:* implement control only when damage occurs.
  Risks: losses may be unacceptable before action is taken and by then the range of control options is reduced.
- *Action*: no control.
  Risks: losses may be unacceptably high.

Managers must identify and evaluate potential actions or combinations of actions, and weigh the associated risks and benefits to determine which actions are most suitable. A decision matrix to determine if options are practicable, feasible and economically desirable can help.[159]

Eradication is rarely possible

The hope behind most pest animal control campaigns has been eradication—the complete and permanent removal of a pest. Pests have been destroyed by shooting, poisoning or trapping, by fencing them in or out, or, in the case of rabbits, by encouraging the spread of disease, and cats and other predators such as mongoose. The methods were often applied with little concern about non-target effects. For example, chemicals such as carbon disulphide and yellow phosphorus were spread indiscriminately to control rabbits, but often killed many non-target native animals. They were also very dangerous to the user.[225]

Eradication is appealing because it requires no understanding of the relationship between pest density and the level of damage. Also there are no ongoing costs. The results of eradication are always assumed to be beneficial, but this is not necessarily so. Rabbits were eradicated from Bowen Island, a 100 hectare island in Jervis Bay, New South Wales, primarily to increase the amount of nesting burrow habitat available to Little Penguins and nesting shearwaters. After rabbit removal, kikuyu grass, an introduced weed formerly grazed by rabbits, spread and prevented some penguins from reaching their burrows and feeding their chicks. Expensive kikuyu control had to be conducted to correct the imbalance.[233]

It is sobering to note that, despite years of effort no widely established, common pest animal has been eradicated from Australia. Given that most established pests are widespread and common, and that there are relatively few techniques to control them, usually the best management goal is to reduce the level of damage to an acceptable level rather than to attempt eradication. Killing more pests than is needed to achieve this goal is expensive and wasteful when budgets are limited.

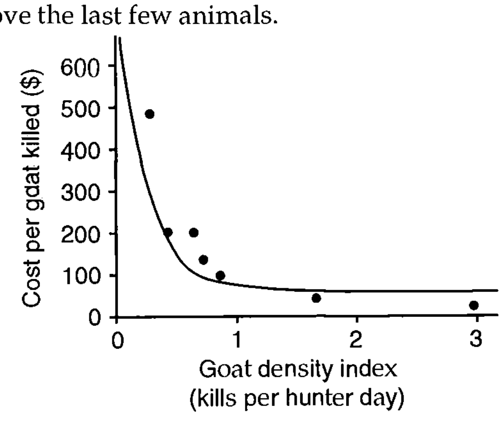
Criteria for local eradication

Eradication of established pest animals is possible only on a local scale. To determine whether eradication is likely to be successful, six criteria can be applied: three essential for the achievement of eradication and three to indicate whether eradication is preferable to ongoing control.[26]

Essential

Pests can be killed at a faster rate than they can replace themselves.

This seems obvious but it is difficult to achieve in practice. There are two main reasons. First, many pest populations have a high natural rate of increase. Second, as the density of a pest declines, it takes progressively more time and more expense to locate and remove the last few animals.



The cost per goat killed at different densities of feral goats in the Kaimai Range, New Zealand (after Parkes[171]). At low goat densities culling a goat is much more costly than at high densities.

Immigration can be prevented.

If animals can recolonise an area from nearby populations or by escape from captive populations such as domestic herds of goats and pigs, elimination of the pest will at best be temporary. This criterion can be met for islands, but is often difficult to achieve on the mainland.

Immigration to a local area may be prevented where fencing and control, at ongoing cost, creates a perfect barrier. An example is the successful campaign to prevent the Common Starling from crossing the Nullarbor Plain to south-western Australia. However, this does not come cheap. It costs the Western Australian Government about $350 000 each year to kill the 1000 or so starlings annually that attempt to migrate into the south-west. Given the damage Starlings could cause to crops and native species this is probably money well spent.

All reproductive individuals are at risk from the available techniques.

It is not necessary to remove all pest animals at the first attempt. However, all reproductive or potentially reproductive members of the pest population must be able to be taken by the techniques available. This is rarely possible in part because there is only a limited armory of techniques. If, for example, some animals become trap-shy or avoid poisoned baits then those animals cannot be removed and eradication will not be achieved. Trap-shyness, bait-avoidance and resistance to poisons, are common among pest animals.

Desirable

The pest can be monitored at very low densities.

If the animal cannot be detected at very low densities, then there is no way of knowing whether all animals have been eliminated. However, most population assessment techniques cannot detect animals at very low densities. The difficulty in meeting this criterion is illustrated by the attempts to remove rabbits from Phillip Island; a small population of rabbits was found on the island two years after it was thought that all of them had been removed (see 'Eradication of rabbits on Phillip Island', page 106).

The socio-political environment supports eradication.

Even when all the technical problems can be met, social and political factors may prevent successful eradication. Community attitudes may oppose killing large numbers of animals on moral, emotional or cultural grounds (refer to Chapter 1, pages 18–27). Also, eradication is expensive. Political factors may withdraw funds from the program before eradication is achieved.

The high costs of eradication can be justified.

It is appealing to think that the value of perpetual freedom from a pest is very high, but this may not be so. Future benefits such as those obtained from eradicating pests have a lower economic value than benefits that are available immediately. This is because the value of future benefits is discounted. Calculating discount rates involves the reverse of the equation to calculate interest rates on invested money. Using a hypothetical model of the costs and benefits of eradication it was shown that when the discount rate was set at zero, eradication became cost effective after 28 years.[26] Setting a very low discount rate of 3.5 per cent made eradication cost effective after 47 years, but, at 10 per cent, eradication never became cost effective.

The practice of discounting the value of future benefits assumes that land managers act in an economically rational manner. However, pests seem to evoke strong emotional responses to the extent that management aims and expenditure are often far from rational. The resource being protected also has to have a monetary value allocated to it in order to determine whether eradication is economic. Yet the monetary value of conservation and biodiversity is difficult to assess. There are methods to do so, such as contingent valuation, but their usefulness is debatable.[30,31]

Eradication of rabbits on Phillip Island

The combined impact of rabbits, goats and pigs caused almost complete elimination of the vegetation on Phillip Island in the tiny Norfolk Island Group, an Australian territory in the south-west Pacific. During the 1800s the islands' dense forest was logged for timber and the animals were introduced as food for the convicts and sport for the officers of the penal settlement on Norfolk Island. At their peak, the pigs alone were said to number 4000–5000 on the 190 hectare island.[104] By 1912, when the pigs had gone and only the rabbit survived in numbers, they had created a bizarrely beautiful, barren landscape.

The original vegetation and fauna was poorly documented, so the full extent of the loss will never be known. At least one plant species is extinct, 11 have been lost from the island and only single specimens remain of several others.[104] Since settlement, two of the Island group's 14 endemic land birds have become rare and one has not been seen for several years despite considerable efforts to find it. Six bird species have become extinct and of these a parrot, the Norfolk Island Kaka, was last seen on Phillip Island in 1851. Convicts and settlers probably hunted the parrot and a pigeon to extinction, but habitat destruction through clearing and the impacts of introduced animals may have contributed to their demise and that of the other species.[81]

The island has significant natural values and in the 1980s it was considered economically, socially and politically desirable to eradicate the rabbits. A rabbit flea carrying a virulent strain of myxomatosis was released and reduced the population for a time; when numbers began to build up again, poisoned baits were laid, and the remainder of the rabbits were shot. Rabbits even lived on ledges on sea cliffs on the rugged island, thus it was not surprising that the 'last rabbit' was eliminated twice—once in 1986 and again in 1988. The effort required to remove the rabbits from this 190 hectare island was high: in human resources alone it took the equivalent of seven people each working for 100 days.

During the century when pest animals were present, it is estimated that over 4 metres of soil was eroded from the island. Nevertheless, since rabbits were eliminated, revegetation has begun, mainly in the gullies and crevices where soil remains. The Phillip Island Hibiscus, formerly on the brink of extinction,[57] has started to re-establish itself and another plant, the Norfolk Island Abutilon, not seen since 1912, has also recolonised several patches on the island.[33]

Even on small islands such as Phillip Island, stripped to a dramatic moonscape by goats, pigs and rabbits released for food and sport, eradication of pests can be a major task.
Source: Penny Olsen

8 Implementing and evaluating the management plan

Putting the plan into practice

Once a management plan has been completed the individual land manager may simply put it into practice. Most often, however, some cooperation is needed. This may merely involve informing the neighbours where and when baits are to be laid, but for most pest animal problems group action is essential to the development and implementation of an effective management plan. Ideally, groups are made up of representatives of stakeholders with a key interest in natural resource management and the impact of pest animals within a region. They include local landholders, government land managers such as national park and forest reserve managers, animal welfare groups and conservationists. Such partnerships encourage identification and understanding of the issues and ownership of the management plan.

The successful implementation of any plan depends largely on the enthusiasm and commitment of the stakeholders and the availability of adequate technical and financial resources. Additional support may be needed with coordination and facilitation to help stakeholders manage their own problems and develop solutions. State agencies often have extension officers to assist with group problems and provide information and advice on best practice pest management. The agencies sometimes run coordinated programs for pest animal management. National agencies have a role to play on Commonwealth land, such as national parks and defence force land, and where the national interest is at stake.

New South Wales reviewed its approach to pest animal management in 1992 and one outcome was to establish a Pest Animal Council made up of representatives from key government and community groups with an interest in pest animal management. A diversity of interest groups are represented: New South Wales Agriculture; National Parks and Wildlife Service; Land and Water Conservation; Environment Protection Authority; State Forests; Rural Lands Protection Boards; Landcare Australia; CSIRO; New South Wales Farmers' Association; Royal Society for the Prevention of Cruelty to Animals; and Nature Conservation Council of New South Wales. The Council is an important means for liaison between relevant Ministers and key interest groups concerned with pest animal management. The Council provides high level policy advice, and representative groups, working at the local level are responsible for planning and carrying out pest control programs.

A coordinated group approach to management

Successful pest management programs are based on an understanding of the nature and extent of the problem and identification of clear shared goals.[173]

It is often stated that coordinated management of pest animals will result in more effective control. However, in some cases coordinated action is unnecessary. For example, individual land managers can apply techniques such as silviculture (tree management, including thinning) to minimise parrot damage to Bluegum crops, or netting to protect grapes from birds. Nevertheless, in most cases a broad-scale cooperative approach is more effective than individual action. Some of the reasons for this concern the characteristics of pest animals—such as their high mobility and high reproductive potential—or relate to the economics of scale. To illustrate, feral pigs have large home ranges and will readily move considerable distances when food or water is scarce, or if continually disturbed. Therefore, an effective management program must be directed at an area at least the size of the maximum average home range of feral pigs in that location. In western New South Wales, control areas need to be at least 50 square kilometres, but in the southern highlands 35 square kilometres will suffice.[48] Similarly, fox control by an individual farmer to protect his lambs or protection of wildlife by a reserve manager can be quickly negated by rapid invasion of animals from surrounding properties. Thus, to protect endangered native animals in a national park it is recommended that fox density is kept low, not only in the park, but in a buffer zone of up to 20 kilometres around the boundary.[198]

A coordinated group approach to pest management is also likely to be advantageous[48] because it:

- makes effective use of resources such as traps, bait-laying devices, helicopters and bulldozers, and local skills and experience;
- enables the pest animal problem to be tackled over a larger area and facilitates more strategic and usually longer term management of the damage;
- encourages strong ownership of the problem by the group through the cohesiveness that develops;

In many cases a collaborative group approach to pest management is more effective than individual action. Government can assist with the formation and maintenance of land management groups.
Source: Noel Preece & Penny van Oosterzee

- often allows underlying conflicts about pest animals or other issues to be raised, openly discussed and often resolved;
- can encourage others who may be reluctant to undertake pest control to be involved through peer pressure; and
- promotes a greater interest and awareness within the group and local community of the problem and the potential solutions.

Formation and maintenance of management groups

The formation and maintenance of groups is often difficult. At least some group members need to have good negotiation, leadership, chairperson and conflict resolution skills. It is often difficult to find these skills among a group of land managers, and even if they can be found, the whole process can be time consuming. This is where government can assist at State, Territory and Commonwealth level (see 'Feral goat management in south-western Queensland: encouraging participation and ownership', pages 111–112).

Most State and Territory agencies have extension officers trained in communication skills; their role is to act as facilitators and coordinators for management groups and associated stakeholders as well as to provide information and advice. Under the National Landcare Program, groups often have access to experienced group facilitators and they can employ coordinators. Facilitators help groups make best use of people both within the group and between the group and outside sources of information and assistance. Most facilitators are skilled listeners, asking the right question of the right people at the right time. They challenge farmers and other land managers to open their minds to new possibilities and new ways of looking at problems. The whole process is time consuming and often intimidating to the inexperienced, but the facilitator's role may be critical to achieving a successful outcome.

Like facilitators, coordinators have a major role in group formation and maintenance, but they tend to work at the local scale, often with one or two groups. Typically, they are employed when the activities of the group become too much for volunteers alone. Coordinators sustain the momentum of the group, help to keep members interested and involved and ensure that pest management or other plans are implemented. They also organise meetings, lead the planning and management of group projects and locate sources of advice and assistance.

The role and importance of facilitators and coordinators in pest animal control and other aspects of sustainable land management has recently received considerable attention. Government officers are being trained in the use of better communication strategies and group processes (see 'The role of extension in pest animal management', pages 112–114). However, there is still a long way to go, especially as many government agencies are reducing their field resources which places greater pressure on those officers who remain.

Feral goat management in south-western Queensland: encouraging participation and ownership

(Adapted from Kelly[105])

Uncontrolled feral goats are regarded as a major impediment to sustainable use of the mulga lands of south-western Queensland. However, they are only one of several factors affecting the viability of farms, including falling prices for wool and meat, weeds, insufficient property size and reduced soil fertility. Given the complexity of issues, the former Queensland Department of Lands commenced a participatory process aimed at developing a partnership between government and local producers to address the feral goat problem. The Participatory Problem Solving model[105] was used: it is a cyclical process to assist land managers and other stakeholders to identify problems, plan actions and trial solutions before evaluating whether they have enhanced their problem solving skills and knowledge of the issue.

The aim of participation in the cyclical process is to enhance the effectiveness of learning for both the producers and government representatives, and to encourage action and provide for evaluation and feedback. The Participatory Problem Solving model promotes continual feedback to participants which allows them to adapt to changing circumstances such as fluctuating markets, unexpected weather or new information. It can deal with relevant environmental, social and economic issues and a key principle in the process is learning by doing.

In the mulga land feral goat project, a Mulga Land Advisory Group formed by producers first identified the feral goat problems. The Department of Lands organised public meetings with producers, scientists and representatives of the commercial feral goat industry to flesh out other aspects of the issue and this formed the base information for the project.

The Department of Lands in consultation with producer organisations then identified suitable properties to test various strategies for controlling

Uncontrolled feral goats are regarded as a major impediment to sustainable use of Australia's rangelands. Source: Robert Henzell, APCC feral goats. Management units of six to eight neighbouring properties were chosen as the optimum size to maximise discussion and learning opportunities.

Government took the lead in bringing people together to talk about goats. As one grazier explained, no-one wanted to initiate the group for fear of being seen as the leader and trying to control their peers. Using a trained government facilitator also helped to mediate between different social groups within the area. The study team found people who had lived in the area for 20 years who had never crossed the main river to visit people on the other side even though they had met each other in other situations. The social boundaries of the participants did not correspond to the best boundaries for managing feral goats. Although individual producers had been involved up to this point, they still did not feel any ownership of the project.

The next stage was to determine local best practice for managing feral goats and to develop ownership of the solution. In the first part of this stage of the process, meetings were held with producers and other key players to discuss and record perceptions of feral goats and how they could best be managed. These meetings were informal and on-site, often in the house of a local producer. Opinions were respected and no judgement placed on whether the suggestions were wrong or right.

In the second part of this stage, information on feral goat management was gathered from experts who had worked on feral goats in Queensland, New South Wales, South Australia and Western Australia. This was presented to producers and other players, again in informal meetings. In addition, reports from discussions in the first stage were checked for accuracy with participants. Based on discussion of the expert information and their own ideas, the participants for each area developed and committed themselves to a management plan to manage feral goats in their area for the life of the project. The Department of Lands maintained overall coordination of the project and monitored the benefits and costs of the different management strategies.

The process developed strong participation and commitment to the project and its outcomes. An important issue that emerged was for facilitators to be aware of their tendency to take over the meeting and push participants in certain directions. Extension officers and researchers should realise that often complex social changes are needed at the local and regional level and that these may take time. It is essential that managers make the decisions and are not pushed into them. Only then will they own them; and only with ownership is there likely to be adoption of new practices.

The role of extension in pest animal management

> *The role of the extension officer in vertebrate pest management is often broader than the provision of information.*[48]

For many years State and Territory pest animal agencies have used extension officers to broadcast information about how best to manage pest animals to farmers and other land managers. Traditionally this has been a top down approach where the officers take government policy and results from research and pass them on to the end user through field days, pamphlets and meetings.

However, extension is now seen as more than simple dissemination of knowledge; it also promotes cooperation, coordination and change. Accordingly, it is broken down into several sub-elements:

- raising awareness of the issue;
- developing understanding of the issue;
- changing attitudes toward the issue; and
- encouraging adoption of new practices.

Extension officers now focus less on telling managers what to do and more on providing the information and decision-making framework from which managers can draw their own conclusions. Hopefully, in this way, both government and land managers will have greater understanding of the complexity of pest management problems and the possible solutions. This participatory learning approach also provides land managers with ownership of the problems and solutions. Extension workers and researchers need to understand the goals, motivation and constraints that land managers work within as well as the biology of pest animals and techniques for their control.

Often, dealing with the diversity of human issues connected with pest animal problems can be more important than coping with the pest itself. One challenge to the extension worker is that not all groups require the same level of understanding of the issue. City dwellers need merely be aware of rabbit damage and what action should be taken. Farmers may need to have a much greater understanding of rabbit biology, the damage rabbits cause and the options for control, as well as feeling confident that any change in practice will be to their benefit. Social factors may prevent a new desirable management practice being adopted. Some groups might be reluctant to follow a practice because it is not widely used or understood by the wider community. Each audience and aspect requires a different approach from the extension officer.

One of the reasons that extension has had variable success is that scientists often work independently of the other groups. The risk from this is that their research may have little relevance to the end user. An example is the tarbaby technique developed by CSIRO for rabbit control. The technique involves placing 1080-poisoned grease at the entrance of rabbit warrens. Rabbits entering or leaving the warren pick up some of the grease on their bodies and ingest the poison when they groom themselves. CSIRO showed that the technique was highly specific to rabbits and effectively reduced their numbers. However, when farmers and national park workers tried to use tarbaby they had little success, and in some cases rabbit numbers even increased despite its use.[196] The problem was that for the technique to be successful all warren entrances had to be treated. While researchers were particular about this, most farm and reserve workers missed several entrances that the rabbits then used to avoid the grease. Despite several years of development, tarbaby was quickly abandoned as impractical for wide-scale control of rabbits.

According to Hart and Kelly,[87] extension should:

- offer a range of options rather than dictating what should be done;
- take a whole property management approach by recognising that managers allocate budgets to deal with many risks and opportunities and are rarely able to fund pest control at the optimal level;
- offer concise information that is relevant to regional needs;
- provide a framework for making management decisions built on broader based information combined with local observation;
- take into account the regional availability of pest management tools such as bulldozers and Global Positioning Systems so that recommended control techniques are appropriate;
- ideally, implement local field trials, and from these coordinate regional pest management strategies to achieve optimal adoption and effectiveness; and
- facilitate communication between policy makers and researchers and land managers and others with an interest in pest management.

Computer technology may be a partial solution to the decreasing government resources available for extension. It will enable pest animal information to be provided electronically and readily updated. The information could be linked to decision support systems to provide land managers with a 'step-by-step' process to self-assess their problem and determine the best strategy for their particular situation. Of course, the usefulness of such an electronic extension service would be dependent on the extent to which land managers adopt computer technology.

Successful group approaches

The success of the National Landcare Program shows the benefit of using a group approach to address broadscale community problems. Landcare is a government supported but relatively unstructured movement of community groups based mainly in rural areas. It started in the early 1980s when voluntary groups formed to tackle problems such as salinity, rabbit control and weeds on a broad scale. The groups were encouraged by State government agencies such as soil conservation departments. The movement became particularly strong in Victoria where, in 1986, groups were encouraged to register under the Landcare program through which they could receive government assistance.[39] In 1990, an historic agreement to foster a national land management program was made between the National Farmers' Federation and the Australian Conservation Foundation. This resulted in the establishment of the National Decade of Landcare Program and a commitment to provide over $320 million for landcare and related tree planting, and conservation of remnant vegetation.

The Landcare movement has grown rapidly and in 1994 there were 2700 registered groups, representing about a third of all farming families.[3] Landcare groups usually involve less than 100 members, most commonly 20 to 30, and cover an area from a few thousand hectares up to several million hectares in the arid centre. Most groups form to address a particular issue such as woody weed control, rabbit control or salinity. However, as the group develops more confidence they often broaden their attention to a range of land degradation issues. Common activities of Landcare groups include field days, demonstration projects, development of catchment or district plans, and coordination of the purchase and use of resources such as soil conservation equipment.

On the whole, Landcare is not directed by government, although the guidelines for funding projects under the National Landcare Program strongly influence the activities of the groups. Nevertheless, Landcare groups determine their membership, the boundaries of their group, the priority areas that they want to address and how they want to go about it.

The National Landcare Program is now encouraging groups to work together to develop strategic regional plans that take an integrated approach to the management of land, water and natural biodiversity. Ideally plans should be in line with National and State strategies for managing the natural environment, such as the National Strategy for the Conservation of Australia's Biodiversity, National Strategy for Ecologically Sustainable Development and the National Feral Animal Control Strategy. Landcare has great potential to assist communities to address land degradation and other problems including pest animal damage.

Some of the advantages of adopting a coordinated group approach are demonstrated by a rabbit management project undertaken by the Sutton Grange Landcare Group near Bendigo, Victoria (see 'An unsuccessful group approach to rabbit management', pages 136–139). The group decided to treat the area sequentially, using a combination of harbour removal, warren ripping, poisoning and fumigation. Part way through the program, an archaeologist who was surveying the district for Aboriginal sites discovered that some Aboriginal middens had been ripped inadvertently. Apparently, rabbits favour the softer soils and north and east facing sites of kitchen middens for their burrows. The issue had potential to cause major problems between the farmers and the local Aboriginal community and threatened the rabbit control program. However, because of the good communications and cooperation developed by the Landcare group, the group coordinator and community leaders were able to quickly organise a meeting between farmers, the archaeologist and the local Djadja Wurrung Aboriginal Community to discuss the issue. An agreement was developed whereby rabbit infested middens were covered with rabbit-proof netting. This met the farmers' needs and also protected the middens from rabbit damage. An additional benefit was the assistance farmers gave the archaeologist and the local Aboriginal people in locating additional Aboriginal sites.

Such cooperative approaches to managing the diverse impacts of pest animals are becoming more common. Another example is the joint government and community program to control rabbit and fox damage to cereal crops and Malleefowl in the South Australian mallee[226] (see below 'Implementing a group management plan to protect Malleefowl').

Implementing a group management plan to protect Malleefowl

It is now widely recognised that the reservation of large tracts of suitable habitat is not sufficient to conserve native biodiversity.[70,71,134,196] Off-reserve management, much of it on private land, is also essential to maintain Australia's biological heritage, but governments do not have sufficient funds to purchase all the necessary habitat and manage it appropriately.

In South Australia, the government and a local community are cooperating to conserve natural resources on private land.[234] An example concerns Malleefowl which, in the South Australian mallee, are threatened by habitat fragmentation, introduced predators and rabbit damage to vegetation. Remaining Malleefowl populations are on both private land and nature reserve. The traditional approach to conserving them has been to purchase the private land, develop extensive networks of native habitat to connect remaining fragments, and to control rabbits, foxes and feral cats. This is an expensive undertaking both in initial land acquisition and ongoing management.

Following the introduction of native vegetation clearance controls in South Australia in the 1980s, the management of remnant habitats has become a focus for community land management and conservation effort. In the Mantung/Maggea district of the Murray mallee, landholders have established a land management group to implement a district conservation plan. A major goal of the plan is to protect Malleefowl and manage their habitat, although control of rabbit and fox damage to local farming is also a concern. Shared objectives were developed between officers of the South Australian National Parks and Wildlife Service managing reserved land and farmers and their families from 11 adjoining properties. A major task for the group was to coordinate fox and rabbit control across the Malleefowl habitat.

The group approach has helped the Mantung/Maggea farmers to:

- obtain government grants;
- develop and coordinate pest management to protect Malleefowl;
- provide a structure to test fox-baiting techniques and strategies; and
- gain easier access to advice and assistance from relevant government departments.

Group approaches to the management of the damage that pests cause, such as protection of Malleefowl from fox predation, can be successful if all the key players are actively involved.
Source: Noel Preece

Since it was formed in 1989, the group has made significant progress. Neighbouring landholders are seeking to join the group, which has already expanded to cover an area of 580 square kilometres. The conservation plan shows promise as a useful model. Its effectiveness will be assessed by landholders and the South Australian National Parks and Wildlife Service monitoring of both the Malleefowl population and the regeneration of native vegetation. The success of the program has been due primarily to the conscious effort to involve all players as equal partners from the start. Spin-offs include better acceptance of government officers by the local community, wider involvement of community members in local matters, and the recognition by scientists that farmers have much to offer in the research and management of wildlife.

Monitoring and evaluation

A management plan is not complete without a monitoring and evaluation program. Operational monitoring, and performance monitoring and evaluation are often forgotten but essential aspects of a pest management program. Both forms of monitoring provide information that can be used to improve the effectiveness of the control strategy, or if necessary, to modify the objectives.

Operational monitoring aims to assess the efficiency of the control operation. It is concerned with the actual pest control operation and addresses such questions as what was done, where and at what cost. The New South Wales government has developed a pest animal control system (PACS) that has been adopted by some Rural Land Protection Boards and can assist monitoring of pest control operations.

Performance monitoring aims to assess the effectiveness of the control strategy (see below 'Assessing progress: the use of indicators') and asks whether the management strategy reduced the damage to an acceptable level. For example, was the lambing percentage increased by 20 per cent following fox control? If the objective was not met, the management strategy may need to be modified or the initial pest problem reassessed to determine whether factors other than fox predation were the cause of poor lambing success. A study of 3000 lamb carcasses in New South Wales found that about half were mutilated by predators. However, foxes, pigs, dogs and native predators were the primary cause of death for only 10 per cent of the lambs. The remainder of the lambs were already dead or dying from other causes such as mismothering. Further analysis suggested that all predators together took only 2 per cent of total lamb production in the area.

Monitoring is not simple and can require considerable effort; as a consequence it is often poorly done or not attempted at all. For fox control, depending on the objectives, monitoring may measure changes to lambing rates, the distribution and abundance of native prey species, or fox density or activity. Ideally, monitoring programs should compare treated sites (for example, sites where poison is used for pest control) with untreated sites (for example, non-poisoned site) and accurately measure the damage, but this is not always feasible. For a farmer, techniques may need to be modified so that they are compatible with the resources and skills available. Of course they also need to fit within the normal farming operation. The national guidelines for rabbits and foxes give examples.[198,225]

Assessing progress: the use of indicators

Indicators are a means to monitor progress towards achieving the set objectives of the management plan, or to warn of imminent failure. Ideally they should be measurable and directly related to the outcome expected from the management program—for example, expressed as trends in the size of the population of endangered plants or animals (see 'Understanding population dynamics', pages 42–45), as increase in production or profit, or decrease in land degradation. If the objective is to reduce bird damage to a crop by 90 per cent between one season and the next, then the performance indicator could be the actual percentage by which damage is reduced in the given time. If recovery of a population of a rare animal under threat from fox predation is the objective, then the indicator might be the number of breeding pairs of the rare species present at the beginning of each breeding season, expressed as a percentage of the desired number at the end of the nominated period.

Often it is difficult to accurately measure progress toward achieving the outcome, especially for land managers with little formal training in scientific methodology and without access to scientific equipment. In these cases pastoralists may decide to use indicators of trends such as less pest animals seen, or taking regular photographs of the same area of vegetation. These checks can often be incorporated into the daily rounds of the property. Success of goat control at Arkaroola-Gammons in the Flinders Ranges of South Australia was determined by visually gauging the reduction in the impact of goats on vegetation, especially the obvious regeneration of native perennial vegetation, and by an apparent reduction in goat numbers and a decrease in complaints about the presence of goats.[173]

If indicators reveal a lack of progress, such as the achievement of only a 10 per cent reduction in parrot damage or minimal increase in the rare animal population, it may be time to reassess or even abandon the management plan.

Grazing of seedlings by rabbits is preventing regeneration in the Great Victoria Desert, Western Australia. The success of rabbit management could be measured by counts of seedlings in marked plots, before control and at regular time intervals thereafter, and by comparison with similar areas where rabbits are uncontrolled. Source: Noel Preece & Penny van Oosterzee

9 Case studies

Previous chapters explained the process for developing and implementing a plan to manage pest animal damage. In this chapter, case studies illustrate the key elements of the process. They are based on a whole land system plan, and emphasise control of the damage that pests cause rather than simple reduction in pest numbers. Each example runs through the five key steps for effective management:

- define the problem in terms of pest damage;
- determine objectives;
- identify and evaluate management options;
- implement a management plan; and
- monitor and evaluate the outcome.

The first case study deals with the management of feral pig damage to production and conservation values in the tropics (adapted from Choquenot et al.),[48] another examines management of fox damage to rock-wallabies (adapted from Saunders et al.)[198], and a third compares four strategies for managing feral pig damage to sheep production in the rangelands (adapted from Choquenot et al.).[48] The fourth study centres on control of feral goats in a national park and pastoral land in the Flinders Ranges of South Australia (adapted fom Parkes et al.).[173] These four studies are hypothetical, but contain elements of actual pest control programs. The fifth study is an example of learning by doing on an almond farm, where lateral thinking and some non-lethal control techniques were effective in controlling raven damage (compiled from information supplied by R. Sinclair).[242] The final study describes a group project aimed at managing rabbit damage, and illustrates some of the pitfalls of pest management, particularly maintaining motivation of land managers, even when resources are adequate (adapted from Hunter & Coman;[98] also see 'Successful group approaches', pages 114–117).

Case study 1
Management of feral pig damage in the wet tropics of North Queensland

(Adapted from Choquenot et al.)[48]

The wet tropical zone of North Queensland covers about 125 000 square kilometres between Townsville and Cooktown. It is made up of three major geomorphic areas—a belt of coastal lowlands, an intermediate Great Escarpment, and the tablelands of the Great Divide. Mean annual rainfall varies throughout the region from 120 centimetres on the western edge to over 400 centimetres near the coast, and occurs mainly during the wet season (December to April). The native vegetation is predominantly rainforest, which occurs largely as a continuous belt along the Great Escarpment, with pockets on the tablelands and coastal lowlands. Most of the forest areas, which represent about 80 per cent of the remaining rainforest in Queensland and contain many plants and animals unique to the region, are included within a World Heritage Area (WHA). Most of the adjacent lowlands are used for production of sugar cane, bananas and other tropical fruits. There are a number of tourist resorts along the coast and the area is only a few hours by road from an international airport.

Feral pigs occur throughout the region, and during the wet season are mainly confined to the forests, but during the dry season roam more widely into sugar cane and tropical fruit crops in search of food.

Defining the problem

Feral pigs are estimated to cause at least $0.5 million damage to sugar cane crops in the region each year, as well as an unmeasured amount of damage to bananas and other crops. They are a threat to WHA values, particularly the conservation and rehabilitation of native rainforest associations, although the extent of the damage there is not quantified. Pigs may also pose a direct threat to wildlife, particularly ground-nesting birds. In addition, they carry several diseases and parasites of stock and humans, as well as being a potential host for exotic diseases such as foot-and-mouth disease, should it ever enter Australia. Indeed tropical northern Australia is considered to be one of the prime entry sites for foot-and-mouth disease.

The local cane and tropical fruit growers called a meeting to discuss the problem. They invited the local tourist industry, the Cassowary Conservation group, recreational and commercial pig hunters, the Wet Tropics Management Authority and the Queensland Department of Natural Resources. Farmers adjoining the WHA saw it as the main source of feral pigs, although in discussion it was agreed that feral pigs also occurred on the farmland and would not be as common if they could not feed on the crops during the dry season. It was also decided that any control would need to be focussed on the cropping land as the elongated shape and dense vegetation of the WHA made it almost impossible to conduct pig control. Because of concerns about non-target kills from poisoning and the high value of feral pigs it was decided that live trapping was the best control option. The key players agreed that they would cooperate to control feral pig damage in the WHA and the production areas and maintain it at or below a maximum acceptable level.

Management objectives

Neither the farmers nor the Wet Tropics Management Authority were sure about the level of damage feral pigs caused but they both agreed to set measurable objectives to be achieved from feral pig control. The sugar cane farmers and tropical fruit growers aimed to reduce their losses to feral pigs by 70 per cent. Because the level of pig damage in the WHA was not well known, the aim for this area was to reduce obvious sign of pig rooting by 60 per cent.

It was agreed that studies and careful monitoring of the benefits from the control were needed to obtain a more accurate measure of feral pig damage so that the optimum level of control could be determined. Modeling of the likely outcomes from outbreaks of exotic diseases in feral pigs in the region, and greater education of the public on the risks of infection by diseases and parasites from eating or handling feral pigs was also deemed necessary.

Management units

Because of the large size of the area, it was broken into seven sub-units based on natural boundaries such as rivers, high mountain ridges and major roads. Within each area, sites of particular concern were identified. These included an area of rainforest which cassowaries seemed to prefer for nesting, a creek flood-out in which feral pigs had recently started to wallow that contained two endangered species of native frog, and some high-value melon crops. Each area had its own sub-plan for pig control, for example, the melon crops were protected by temporary electric fencing during the period that they were most vulnerable to feral pigs.

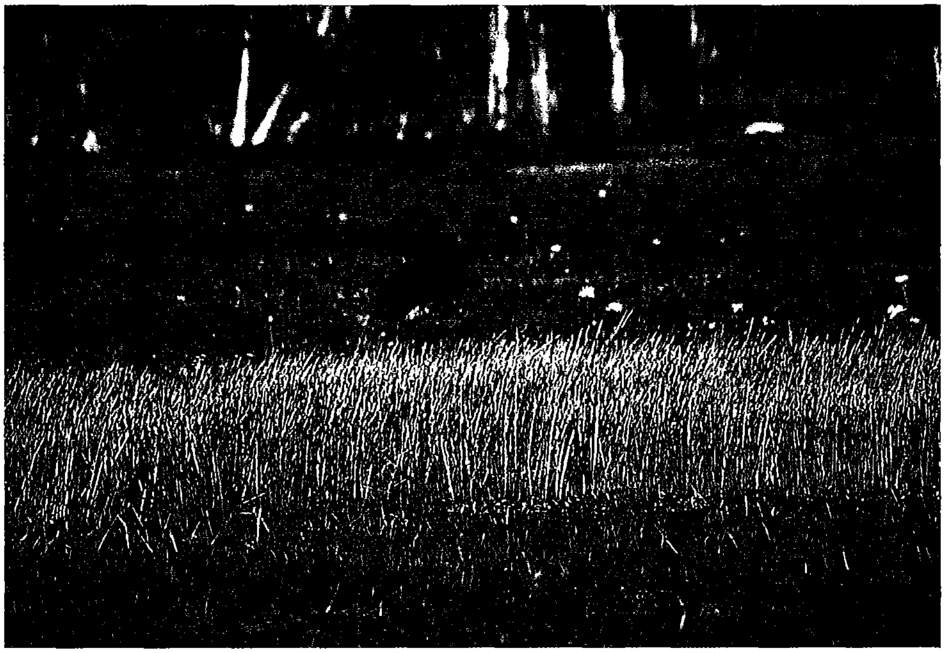
Management options

The group agreed that it was not possible to eradicate feral pigs in the area. Much of the country was inaccessible and even if complete removal could be achieved, it was considered likely that more pigs would be released due to strong hunter interest in the region.

It was agreed that the aim would be strategic control targeted at the time and sites where pigs were causing significant damage. These were the high value conservation and melon crop areas identified in the planning stage and also at the margins of the tropical fruit and sugar cane crops. Control would be concentrated during the dry period when feral pigs were most actively searching for food.

A variety of techniques was available to control the pigs. Ground hunting of pigs, with or without dogs, is generally considered to be ineffective and the dogs often take non-target animals, such as cassowaries. Fencing, including electric fencing, is probably only cost effective around small ecologically significant areas or, in some instances, for endangered species protection. It was thought to be useful to direct feral pigs to areas where they could be trapped, and for temporary protection of the melons. Although potentially the single most effective technique for the region, poisoning was not acceptable in the WHA because of concerns about poisoning of non-target animals. It was also unsuitable for use on adjoining properties, where captured or shot pigs were sometimes subsequently used for food. It was decided to trial poisoning in certain areas such as the margins of the WHA if suitable poisons, baits and delivery systems could be identified. However, over most of the units, live trapping was the preferred technique.

Extensive free-feeding prior to trapping is necessary to attract pigs to traps, and traps are very labour intensive and often impractical for larger, more remote areas. Nevertheless, they were considered to be effective for many small areas or local situations, particularly as part of coordinated programs between government authorities and landholders. Because of concerns by the Cassowary Conservation Group and the Wet Tropics Management Authority, traps set in areas containing



Pig densities are often greatest on floodplains and wetlands adjoining forest.
Source: CCNT

cassowaries were modified so that these endangered birds could not trip the door and become entrapped. This reduced their effectiveness but was considered essential as experience had shown that trapped cassowaries can severely damage themselves.

Implementation

The management group agreed that to be effective, feral pig control had to be coordinated across the region. An aerial map of the district was used to determine the sites at which traps would be located, fences erected and the poisoning trial undertaken. A local tropical fruit farmer, along with an extension officer from the Queensland Department of Natural Resources, coordinated the purchase and construction of traps and distribution of non-commercial bananas as bait.

Monitoring and evaluation

Measurements of damage and indices of pig density before and after the control programs helped to determine threshold pig densities and evaluate whether the programs were achieving their goals. If the goals were not being achieved, then improved strategies and community involvement would have been necessary. Monitoring and evaluation also indicated which techniques were most effective, provided motivation and direction to control efforts, and helped promulgate research results, such as new trap designs and baits. It also indicated whether there was a need for further research on, say, the rate of increase of pigs after different levels of population control, including any effects of environmental factors such as delays in the onset of the wet season or poor fruiting in the rainforests. Such information, along with that on the relationship between effort expended on control and the resulting reduction in damage, was used to evaluate the different strategies for sustained control or local exclusion in each of the different management units.

Case study 2
Control of fox predation on rock-wallabies

(Adapted from Saunders et al.)[198]

This case study is set in a 3000 hectare national park in the Grampian Ranges of Victoria. The park consists mostly of dry sclerophyll forest and contains a number of granite outcrops that are known to harbour the threatened Brush-tailed Rock-wallaby. Other important native animals present include the Southern Brown Bandicoot and Spotted-tailed Quoll. Foxes and feral cats are often seen and rabbits are common in the more open areas. The park is surrounded by open woodland interspersed with farms that produce lambs and wheat.

Information collected when preparing the management plan for the park suggested that rock-wallaby populations were much smaller than might be expected from historical records. There was evidence that they previously occupied a much wider range of habitats than the isolated rocky outcrops to which they were now confined. Similar declines and local extinctions in this and other species of rock-wallabies had been recorded in other parts of Australia and there was good evidence that fox predation was a major cause.

Defining the problem

In response to these observations, the Parks and Wildlife Service conducted preliminary surveys of all rock-wallaby populations within the park. This showed that:

- the populations were small and declining and three out of the five sites supported less than ten individuals;
- the populations were confined to areas where the rocks were fragmented, forming break-aways which provided protective cover from environmental and predation stresses, and larger areas of suitable habitat were not being used;
- brush-tailed rock-wallaby hair was found in two fox scats collected in the park;
- periodic assessments revealed that many populations were declining even though most females were carrying pouched young. Recruitment was low and there were few independent young animals;
- the animals were in good condition even during a drought-declared year; and
- there was no evidence of disease.

The preliminary surveys revealed a population of fit and healthy animals, unaffected by food shortages or disease and apparently not occupying all suitable habitat within the park. They were carrying young and therefore possessing potential for growth, yet there was no population increase. From the available evidence it was concluded that foxes, through their heavy predation of young wallabies, were the greatest threat to rock wallaby conservation within the park. Other factors such as the lack of an essential habitat requirement may have been contributing to the lack of growth, but these could not be detected unless the threat of predation was first removed. It was therefore decided that a fox management program should be implemented.

Because foxes were also common outside the park, to prevent reinvasion the manager decided that fox control would be needed in a buffer zone around the park. The manager called a meeting of key stakeholders, including local lamb and wheat farmers, the Department of Agriculture, the local shire council and local Landcare coordinators. It was agreed that a coordinated fox control program was necessary within the park and in a 20 kilometre buffer zone. The point was raised that fox control could lead to an increase in rabbit densities and rabbit damage both within the park and on surrounding farms. Hence it was agreed that rabbit control was also required in the area where foxes were to be controlled.

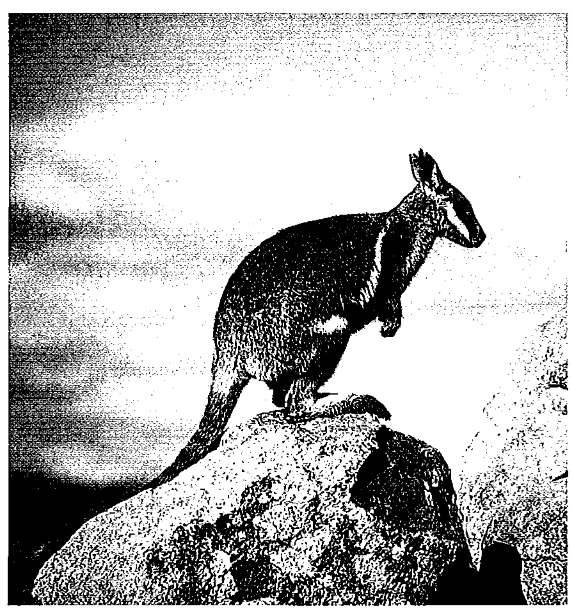
Management objective

The extent to which fox predation was suppressing rock-wallaby densities was not accurately known but was considered to be significant. Providing the wallabies were able to use additional habitats in the absence of fox predation, it was decided that a realistic objective was for their population within the park to increase by 200 per cent over the ensuing four years. The main measure of performance toward meeting this objective was set as the percentage increase in the rock-wallaby population, based on a continued census. The participation of all adjacent land managers in a parallel rabbit and fox management program was identified as a supplementary objective.

Management options

To re-establish the rock wallaby populations, strategic sustained fox and rabbit management (see 'Strategic management', pages 98–100) was considered to be the most feasible option within the park. Local eradication, the preferred option, was not realistic unless a very expensive rabbit- and fox-proof fence could be constructed and maintained around the park. Similarly, given the limited resources of the surrounding farmers, strategic fox and rabbit management in the buffer zone was the appropriate choice.

Advice was sought on control techniques and it was decided that programs of sustained baiting with 1080 were the most effective means of alleviating fox predation in conservation areas.[108] The techniques used to prepare and deliver 1080 baits for fox control varied between States and with local circumstances. In



LEFT *Potential non-target effects, particularly secondary poisoning of native species such as the Tiger Quoll, may make pest management by poisoning unsuitable for parks and reserves.*
Source: Chris Belcher
RIGHT *Feral goats are thought to compete with Yellow-footed Rock-wallaby for food and shelter*
(source unknown).

Victoria, for example, baits must be buried to a depth of at least 8 centimetres. This requirement is mainly to protect non-target species such as the Tiger Quoll and farm dogs. In Western Australia, where native wildlife have a relatively high tolerance to 1080 which occurs naturally in local plants, aerial baiting is possible in national parks.

Manufactured baits were chosen for the program because of their ease of use and safety. Sustained management of foxes requires regular, ongoing poisoning of foxes for the foreseeable future. The extent to which this can be maintained will depend on long-term resources. This in turn will influence the size of the area to be treated and the intensity of baiting.

It was decided that baits would be put out in the park and buffer zone at least every three months. The poisoning was to be supplemented by den fumigation during the breeding season and by spotlight shooting if time permitted. Fox control on surrounding agricultural land was usually targeted to protect production (for example, lambs) at the appropriate time of the year. However, to protect the park from reinvasion by foxes, control was also needed during the peak dispersal period of foxes (autumn).

The wheat producers agreed to lay poisoned fox baits if the Parks Service provided the baits. Only the lamb producers agreed to pay the full cost of fox control in the buffer zone, but all farmers agreed to conduct simultaneous rabbit control at their own expense.

For rabbit control, similar strategies were planned for both agricultural and conservation areas. In areas of low conservation value the technique was to remove surface harbour, destroy warrens by ripping and follow up with further ripping or fumigation. The use of 1080 poison to control rabbits was considered to be useful on agricultural land because it would also kill foxes through secondary poisoning. However, it was not an option for the park because of potential non-target effects, particularly secondary poisoning of Tiger Quolls.

Implementation

The fox and rabbit management program was conducted simultaneously by the park managers and farmers on surrounding agricultural land. The entire park was a management unit for fox management. Mapping of tracks and trails provided a useful guide to bait placement and also assisted in the relocation of baits on a regular basis so that those that were removed could be replaced. The same applied to neighbouring agricultural land. Previously selected rabbit management units were treated in order of priority, and adjacent units were treated in sequence because this has been found to minimise the level of recolonisation.[225]

Monitoring and evaluation

The effectiveness of the program was determined by a regular survey of the rock-wallaby population. An increase in numbers or in habitat utilisation by the wallabies was to be used as an indicator of the effectiveness of the program. It was also considered essential to monitor fox density within the park because of concerns about the effectiveness of the fox control techniques. Concerns included poor poison success due to incorrect baiting technique or bait shyness by foxes, and immigration of foxes from the buffer zone. If fox density did not decrease, these issues would need to be addressed.

If the rock-wallaby population did not increase despite an effective fox control program, the next step would be look at other factors that might be limiting the population. It may be that competition with feral goats for nutritious feed and shelter sites is important. Supplementary feeding or the reduction of goat numbers may be useful means of determining whether any such competition is important.

Case study 3
A comparison of four strategies to control feral pig damage to lamb production in the rangelands

(Adapted from Choquenot et al.)[48]

A computer simulation was used to compare the costs and benefits of four different strategies for managing lamb predation by feral pigs on identical wool-growing properties in western New South Wales rangelands. Each property was 45 000 hectares, 22 000 of which was riverine floodplain on which feral pigs frequently reached very high densities. The floodplains were also the only part of the properties that had sufficient forage during drought to allow ewes to successfully wean their lambs. When the biomass of forage was greater than 300 kilograms per hectare, ewes could be lambed away from the floodplain, thus greatly reducing predation by feral pigs.

The following assumptions were made for each property. All lambing occurred during spring and the stocking rate was 2.5 ewes per hectare giving a total ewe population of 18 000. Of these 17 000 (95 per cent) lambed each year with 21 per cent giving birth to twins, for a potential annual lamb drop of 20 691.

Defining the problem

The potential farm losses due to feral pigs were a reduction in lamb production and the cost of feral pig control. The costs of feral pig control on the pig-prone floodplain were estimated based on the feral pig control technique selected for each property.

Control costs were calculated by multiplying the cost of removing each pig which varied with the density of pigs, and was cheaper at higher densities. When poison was used, the manager also needed alternative pasture to spell the ewes from the paddocks where poisoned baits were laid.

The benefits of control were expressed as the dollar value of any reduction in total lambs lost to predation. Loss of lambs due to other factors such as mismothering, difficult birth and lack of cover was assumed to be constant at a level of 20 per cent for each property. Loss of lambs could affect property income in two ways:

- if pig predation was extreme, the woolgrower may not have had enough hoggets to replace unproductive ewes and hence may have needed to purchase more sheep; and
- woolgrowers may have lost any income they would have received from the sale of lambs that were killed by feral pigs.

Replacement cost or income lost per lamb, at $20 per head, was assumed to be the same for each property. The rate of feral pig predation in any given year was drawn randomly from the probability distribution associated with the current density of feral pigs. To make allowance for the reduced level of pig control when graziers were able to lamb away from the pig-prone floodplain, the estimated rate of predation was reduced by 50 per cent when pasture biomass was greater than 300 kilograms per hectare.

The computer-generated models for each property considered the costs and benefits over 100 years of simulated variation in rainfall and associated pasture conditions. For each property, the costs and benefits were averaged for five runs of the model.

Management objective

The objective of each property manager was to maximise their economic returns.

Management options

None of the managers measured the level of damage, instead they used their perception of the problem to help them decide which type of pig control to use. Ideally, they would have kept good records of the costs and benefits of past pig control strategies as a guide. Nevertheless, they were aware that losses of lambs to feral pigs could be as high as 40 per cent of all lambs born.

The manager of Dontcare Downs conducted no pig control, believing that there would be no gain from any form of control. The manager of Pragmatic Park chose to control pigs when they exceeded moderate densities. The woolgrower on Killemall preferred to try to reduce and maintain pigs at very low densities, and the owner of Doubleup decided to attempt local eradication.

The only suitable control techniques were shooting from helicopters and 1080 poisoning. The manager of Pragmatic Park decided to shoot once per year. The neighbours agreed to participate in the annual shoots, which reduced the cost of ferrying the helicopter to $500 per year. Because of the high cost, the manager decided to shoot in parts of the farm where pigs were concentrated (mainly on the floodplain) and to stop shooting when the kill rate per hour of helicopter time began to drop dramatically; this occurred when a threshold of about four to five pigs per square kilometre was reached. Because it was difficult to decide exactly when to stop, to be sure that the kill rate had declined they continued to shoot for three hours after the pig density dropped below the threshold. Although they did not need to shoot in years when pig density was below the threshold, they did not know what the density was until they commenced the operation. Hence even in these years there was a minimum expenditure based on the cost of ferrying the helicopter and three hours of shooting.

The manager of Killemall decided to poison feral pigs whenever pasture biomass dropped below about 750 kilograms per hectare. At this density there was sufficient feed to put sheep on alternative paddocks until the 1080 poison degraded. The process required an initial free-feed of unpoisoned bait to see whether there were sufficient feral pigs—judged to be when a minimum of 30 per cent of baits were taken—to warrant laying poisoned bait for the next three days. The cost of the free-feed program on the pig-prone country was $1199. The cost of poisoning was the same, $1199 per day plus the additional cost of poisoned bait to replace the bait taken by pigs. Poisoned bait cost $3.93 per 20 kilograms including the purchase of warning signs.

At Doubleup the manager decided to conduct a helicopter shoot each winter to reduce feral pig density to about four pigs per hectare. In years when the pasture biomass was less than 750 kilograms per hectare, shooting was followed up with a free-feeding program to determine whether it was sensible to follow up by poisoning. The costs for shooting and poisoning were the same as for the other properties.

Implementation

The managers decided to work independently but two agreed to share cost of ferrying the helicopter.

Monitoring and evaluation

Because there was no control on Dontcare Downs, pig numbers varied according to seasonal conditions, which in turn influenced the rate of pig predation. The results of simulation predicted that the loss of lambs and hence income was considerable, with an average loss in value of $15 658 annually (see Table 9.1). Clearly, adopting a no-control strategy greatly reduced potential property income.

The simulated cost of sustained control to reduce pigs to moderate densities across the whole of Pragmatic Park was $1547 per year with the result that the value of lambs lost was reduced to an average of $10 178. Shooting from helicopters was a relatively cheap form of control, although the cost of reducing pigs to low levels in the first year of control, approximately $8400, was fairly high.

Poisoning, as used on Killemall, was more expensive than shooting but it achieved a much greater reduction in feral pig density. The average value of lambs lost was reduced to about $3556 per year. However, at about $17 360, the cost of the initial knockdown, in the first year, was high.

The intensive feral pig control on Doubleup was the most expensive management strategy but only marginally so, and the value of lambs saved was not much better than poisoning alone could achieve, as on Killemall.

To determine which of the three active strategies produced the best return per cost of control, the benefit was divided by the cost. All strategies produced a positive benefit to cost ratio. Overall, poisoning at Killemall to reduce feral pigs to a low density gave the best benefit to cost ratio (4.71), followed by Doubleup

Predation by feral pigs can cause significant lamb losses.
Source: Peter Pavlov

Table 9.1 Comparison of annual costs and benefits from four different pig control strategies

	Dontcare Downs	*Pragmatic Park*	*Killemall*	*Doubleup*
Management strategy	No control	Sustained control	Sustained control	Local eradication
Managed for pig density that is	Uncontrolled	Moderate	Low	Low
Control technique	None	Shooting	Poisoning	Shooting/poisoning
Resulting pigs per square kilometre	2.44	0.80	0.18	0.15
Cost of control ($)	Nil	1 547	2 572	3 074
Lambs lost to pigs	783	509	178	174
Value of lambs lost ($)	15 658	10 178	3 556	3 470
Benefit as lambs saved ($)	0	5 490	12 102	12 188
Benefit:Cost	-	3.54	4.71	3.96

Source: adapted from Choquenot et al.[48]
Note: The value of lambs saved (the benefit of control) was calculated as the difference between the value of lambs lost at Dontcare Downs, where there was no pig control, and that at each of the other three properties. Most of the values varied considerably from year to year, however, only the averages are shown.

where helicopter shooting, followed by poisoning when necessary, was used to keep pigs at a marginally lower average density (3.96). The benefit to cost ratio for Pragmatic Park was the poorest (3.54).

It may seem counter-intuitive that, compared with a strategy that keeps pigs at or below moderate density, the overall benefits increase when pigs are held at low density but do not continue to increase when eradication is attempted. This is because the benefit to cost ratio begins to decline when pig densities fall to very low levels, below about 0.18 pigs per square kilometre. It takes a huge effort and cost to find and remove the last few pigs and this cost far outweighs the benefits in extra lambs saved. Thus, in this example, it was not economically sensible to try for eradication, nor was it wise to leave pigs uncontrolled.

Case study 4
Management of feral goats in a national park and surrounding pastoral land

(Adapted from Parkes et al.)[173]

This case study is set in a 1500 square kilometre national park and surrounding pastoral leases used for sheep grazing in the northern Flinders Ranges. In the park, jagged mountains and densely shrubbed plateaus are flanked by precipitous gorges and scree-slopes with intervening valleys and watercourses. Most of the vegetation is adapted to hot and dry conditions, whereas the cooler elevated areas and the moist shady gorges provide refuges for relict populations of ferns, other plants, and native animals such as the Yellow-footed Rock-wallaby. The park has outstanding aesthetic, biogeographical and conservation values and conservation is the primary management aim. However, the rugged terrain with its permanent springs and waterholes and still-abundant perennial vegetation supports vigorous populations of exotic animals including feral goats, rabbits and foxes. Feral animals are also common in the surrounding pastoral land, which is primarily chenopod shrubland dominated by saltbush. There the land is flat and the only reliable water is from capped bores and associated water troughs.

Defining the problem

Feral goats were not considered to be a problem in the area until after Dingoes were excluded in the late 1930s. The goats were controlled on most properties in the northern Flinders Ranges and the surrounding pastoral leases, including the national park, by mustering, netting-off water holes, shooting and, occasionally, by poisoning. However, in the early 1970s, goat numbers rose to unprecedented levels throughout the Dingo-free pastoral areas south of the Dingo fence, due mainly to excellent seasonal conditions and a general decline in the number of people (and hence potential musterers) on pastoral leases. At this time, goat populations in the adjoining national park were estimated at a peak of 120 000, assisted by a flush in vegetation due to the removal of domestic livestock in part of the park that was once a pastoral lease.

By 1990, the goat problem was such that it prompted a meeting of the local land managers, convened under the umbrella of the North Flinders Soil Conservation Board. Local pastoralists, the manager and staff of the national park, as well as a scientist from the South Australian Animal and Plant Control Commission who had undertaken an extensive study of feral goats in the area, attended. Because muster of goats was seen as a primary management technique, the manager of the company that bought feral goats from the area was also invited.

The pastoralists complained that any effort they undertook to control goats was thwarted by rapid reinvasion from the national park. The park staff acknowledged the concerns but pointed out that there were times when feral goats had also reinvaded the park from the surrounding pastoral leases. The scientist then explained the damage caused by feral goats, based partly on an assessment of changes in vegetation recorded in areas from which goats had been excluded. In goat infested areas, regenerating perennial plants grew past the seedling stage but were kept less than 2 metres high by goat browsing and highly palatable plant species were severely affected or killed. Of particular concern was the long-term survival of the wattle *Acacia araneosa* which is on the list of endangered plants for South Australia.

It was concluded that without adequate control of goat grazing, several species of palatable plants were at risk in the national park and that the floristic composition on the pastoral leases would shift toward species inedible to stock. Based on other studies, it was concluded that the shift was being hastened by the relatively high density of rabbits on the pastoral leases and in the national park.

Another concern was the impact of feral goat dung on the local waterholes where, in places, a carpet of dung several centimetres deep had been recorded. The dung, and the decomposing bodies of goats that had fallen into the water and perished, polluted the water especially during dry times, when goats congregated around remaining water. As well as fouling water used by large native animals such as wallabies and birds, freshwater plants, fish, frogs and invertebrate animals were also severely affected.

In addition to the concerns about feral goats and rabbits, the meeting agreed that fox predation of native wildlife, especially the rare Yellow-footed Rock-wallaby, needed attention.

Although a range of techniques had been used to control feral goats in the past, the meeting agreed that they had achieved only limited success because:

- control was extremely difficult in some areas—goats could not be mustered in most of gorge country;
- resources devoted to the task, especially people to help muster goats, had been insufficient;
- commercial mustering had reduced feral goat density in the park and on pastoral land in the late 1970s and early 1980s, but virtually ceased in the late 1980s when goat prices fell;
- goat control operations on neighbouring properties and the national park were often out of phase—goats reinvaded properties on which they had been controlled, discouraging and frustrating land managers who had attained high levels of control; and
- some landholders failed to control their goats, or clandestinely 'farmed' them by allowing their numbers to build up in order to increase the number that could be sold each year and to reduce the unit mustering cost.

The meeting agreed to develop and implement a joint plan to manage feral goats on the national park and surrounding pastoral leases covered by the North Flinders Soil Conservation Board. It was agreed first to concentrate on feral goats and then to develop a separate management strategy for rabbits and foxes.

Management objectives

The main objective of goat control in the national park was to reduce the impact of feral goats to the point that:

- there was significant regeneration of palatable native plants including the vulnerable *A. araneosa*;
- feral goat fouling of the major permanent waters was eliminated within two years; and
- complaints by visitors to the national park about feral goat damage and numbers were reduced to less than five per year within two years.

The objective for the pastoral land was to reverse the shift in pasture composition so that there were more edible perennial plants and fewer inedible annuals. Because it might take many years and a good growth season before this pasture improvement could be demonstrated, it was decided to reduce feral goats density to the point where less than one goat was seen at each bore during the weekly bore run on each lease.

Management options

The managers of both the pastoral leases and the conservation lands decided to adopt strategic sustained management (refer to the section 'Strategic management', pages 98–100). All managers agreed to first conduct a series of coordinated musters until commercially viable loads of goats could no longer be mustered.

The area to be treated was mapped and broken into units of about 500 square kilometres for the musters. For the national park, boundaries were determined by topographical features such as gorges and mountain ranges. Where possible, these were also used for the pastoral leases although well-maintained fences helped to divide the area into manageable units.

In the national park, access by feral goats to several key waterpoints was temporarily blocked with an electric fence a week before the muster to concentrate the goats around remaining waters and hence improve the effectiveness of the muster. Once mustering was no longer efficient, a helicopter was used to further reduce goat density to the point where less than 15 goats could be located and shot per hour. The efficiency of the operation was improved by using a fixed winged aircraft with a Global Positioning System to locate mobs of goats and to transfer the locations to the helicopter shooting team.

At this point two other techniques were used to further reduce feral goat density in key areas of the park. In the prime sites for *A. araneosa*, three goats were caught and fitted with radio transmitters and released to join other goats missed in the earlier shoots (see 'Shooting', pages 59–60). After a week these Judas animals were located and the goats that they had joined were shot and the Judas goats left to join another mob. To reduce feral goats further in the gorge country, carefully screened volunteers from the Hunting and Conservation Branch of the Sporting Shooters' Association of Australia undertook a well-organised ground-shoot around the permanent waters.

On the pastoral leases, self-mustering traps were established around the bores. Feral goats were held and fed in the traps until there were sufficient animals for a commercial load. The return from the sale of goats—$12 per head after muster costs—was used to pay for the traps. After commercial loads could no longer be captured, the population was maintained at a low density by the managers shooting animals at bores during the weekly bore run.

Implementation

A sequential, coordinated group approach to mustering was used to minimise reinvasion and to ensure that the commercial buyer was not swamped with goats at the start of the program. To organise and coordinate the program, the North Flinders Soil Conservation Board employed a coordinator, partly funded under the National Landcare Program. Technical advice and the radio transmitters and receivers for the Judas goats were supplied by the Animal and Plant Control Commission.

Monitoring and evaluation

To monitor changes in vegetation following goat control, a series of sites were established on which detailed measures of quantity and composition of pasture were conducted every six months. Special sites were established to monitor changes in the regeneration of the wattle *A. araneosa*.

Estimates of feral goat density were conducted during the annual aerial monitoring of kangaroo density. In the park and on each of the leases, records were kept of the number of feral goats removed, costs involved and returns from sale of goats.

Evaluation of the early results indicated that the decline in palatable plant species seemed to have been halted, although it may take several seasons to assess long-term changes. Aerial counts showed that feral goat density in the conservation areas was less than 0.5 per square kilometre and less than 0.3 per square kilometre on most of the surrounding pastoral leases. However, there were several pockets in both the leased land and the conservation areas where feral

Income from commercial mustering in the initial stages of a goat management program can help to offset costs.
Source: Robert Henzell, APCC

goat density was greater than five per square kilometre and a meeting was planned to discuss control options for these areas. The coordinator reviewed costs and returns, which showed considerable variation in efficiency between the various groups. Some of the differences could be explained by differences in accessibility to the units, but some also seemed to be due to the skills of the individual operators. A field day is planned to observe a muster in a neighbouring district and to swap ideas about techniques and strategies.

Case study 5
Management of raven damage to an almond crop

(Compiled from information supplied by Ron Sinclair)[242]

This case study examines the benefits of flexible management run as an ongoing experiment. The study is set on a 200 hectare orchard similar to those at Lindsay Point, Victoria, devoted solely to the production of almonds. It adjoins a national park with mallee and riverflats, a cereal farm with patches of mallee and another similar 200 hectare orchard. In the general area there are several horticultural farms which produce stone fruits, citrus fruits, nuts and cereal crops.

Three varieties of almond are grown on the property; the early ripening variety is grown in blocks and the two later varieties are planted in rows of two of one variety then a row of the other variety. There is no other significant timber on the property. The almond varieties ripen sequentially, beginning in February.

Defining the problem

The farmer estimated that the average annual loss to bird damage was about 3 per cent or $60 000. This was despite pest control costs of about $22 000, spent on shooters and gas guns.

Observations indicated that Little Ravens caused most of the damage. Other birds that fed in the orchard included Galahs, Crimson (Yellow) Rosellas, Major Mitchell's Cockatoos and, less often, Little Corellas, Sulphur-crested Cockatoos and, rarely, Australian Ringnecks, but the damage they caused was considered insignificant. The ravens damaged the crop by knocking the almonds from the tree with their beaks or by flapping their wings. They hopped to the ground to feed and hammered open many of the almonds—preferring the softer variety—but ate only the small pieces of the shattered nut, leaving the largest pieces to be cleaned up by flocks of starlings.

The orchard was vulnerable for about 100 days a year. The birds caused most damage early in the season when the almonds were fragile and easily removed. Although uneaten nuts knocked from the trees were harvested, they were low-grade due to their small size. The trees did not appear to compensate for losses by putting more resources into the remaining nuts so that they grew larger (also see 'Rat damage to Hawaiian macadamia nuts: a perceived rather than a real problem', page 82).

After harvest, the orchardist encouraged ravens to visit the orchard by laying out carrion. The ravens cleaned remaining almonds from the trees, which prevented disease and minimised carob moth damage. This saved the farmer an estimated $100 000 in losses to disease and moth damage and almost eliminated spray costs for moth control.

The orchardist sought advice from the Animal and Plant Control Commission, South Australia. To gain a better understanding of the situation they arranged for a student to study the biology of the ravens. It was discovered that the birds fed on native vegetation in the nearby riverflats first thing each morning before moving into the crop later in the day. The ravens entered the crop stealthily, at particular points where their movements were hidden, such as through a strip of mallee in the national park and by flying low along a small valley.

Management objective

To reduce annual losses in almond yields due to bird damage to insignificant levels without increasing the costs of control.

Management options

The orchardist had used a light aircraft, at a cost of about $100 000 a year, to herd and scare away the ravens, but it was decided that this was not cost effective. Moreover, it might have caused more damage because the ravens may have needed to eat more to make up for increased energy spent avoiding the aircraft. Bird netting was considered expensive and impractical.

Complete removal of the ravens, even if it was possible, was undesirable because they were useful after harvest, replacements would have arrived quickly, and it was considered better to train the residents to keep out of the crop at the critical times. Gas guns to scare the birds and shooting of the occasional bird as a deterrent were useful in the short term, but the ravens quickly became used to these devices. It was decided to stay with these temporary deterrents, but to keep them novel by monitoring the birds' reactions and changing the techniques and their placement when they began to be less effective.

It was also decided to lay out decoy food during the time when the almonds were vulnerable. At first old sheep and kangaroo carcasses were left on the riverflats identified by the student, about 700 metres from the orchard, in the hope that this would lessen the need for the ravens to feed in the crop and to train them to come to a particular site to feed. Later, the abundant waste from the almond processing plant, which would otherwise have been taken to the dump, was put out as a decoy food. To prevent Emus from eating the food, a temporary, inexpensive electric fence was erected. The almond waste was laid in a line so that all the ravens were able to feed and was replenished at the same time daily, by the same person in the same clothes, to avoid scaring the birds. No deterrence was carried out near the decoy feeding site.

Shooting was carried out at the few points where the student had noted the birds entering the orchard. The ravens began to recognise and avoid the shooter, so it was decided to dress the shooter in a distinctive red T-shirt. The ravens quickly came to associate the red shirt with shooting, so other farm workers also wore red to deter the birds. After a short while, the shooter changed the colour of his shirt until the birds became wary of him again. This arrangement was altered continually so that the birds did not have a chance to habituate. Several scarecrows, complete with guns, were dressed in red and were moved frequently. At times even the gas bottles on the gas guns were clothed in red T-shirts. Because the ravens also recognised the motorbike and fled at the sound of it approaching, the shooter occasionally drove the utility normally used by other farm workers so that the ravens became wary of the utility. Occasionally, and unpredictably, the gas guns were used as supplementary scarers. The guns were mounted on wheels so they could be quickly and easily moved, and when in operation, fired at low frequency (five to six shots per hour) to minimise the rate of habituation.

Raven management was necessary only for the three months when the almonds were vulnerable. During this period, the main plan was to keep the pattern of use of deterrents unpredictable, so that the ravens did not become accustomed to any of the techniques, and to encourage the ravens to feed in the 'safe' area on the riverflats rather than in the crop.

Well installed bird netting is often effective and can be cost-effective when crops are valuable.
Source: Dave Clarke, Parks & Wildlife Commission, NT

Implementation

The orchardist paid the student and the shooter for about three months' work. All farm workers reported their experiences with ravens and the feedback was used by the student to direct management and keep it fluid and effective.

Monitoring and evaluation

The student monitored almond losses by counting damaged nuts in quadrants under a random sample of trees of each variety and the orchardist was able to compare past with present losses. As the result of the new management plan, losses in almond production to birds were insignificant. Expenditure on labour and other costs, such as fencing and petrol, was about the same as it was prior to implementation of the plan, but there were considerable savings in not using the fixed-wing aircraft and pilot. Any additional expenses, such as the cost of red shirts and of fitting wheels to the gas guns, were largely offset by savings on waste disposal and reduced use of gas guns.

Case study 6
An unsuccessful group approach to rabbit management

(adapted from Hunter & Coman[98] by Quentin Hart)

This case study outlines the Sutton Grange Landcare Group's endeavours to manage a rabbit problem near Bendigo in Victoria. The area consists of rolling to steep granitic hills and creek flats. Although there is some remnant native vegetation, improved and unimproved pasture predominates and provides grazing for sheep and cattle. Rainfall is 650 millimetres and there is a distinct summer dry season.

Once the ground cover is disturbed, the undulating topography of the area makes it subject to soil erosion and this is often exacerbated by rabbit activity. Rabbit control is difficult due to the range of refuge habitats available, including remnant vegetation, roadside verges and rocky outcrops. As a result, rabbits were recognised as a major management problem and this prompted the formation of the Sutton Grange Landcare Group, which is concerned with a range of local land management issues.

Defining the problem

The Group formed in 1990 and, after several meetings, identified a range of likely rabbit damage, including grazing pressure, contribution to soil erosion with resultant reservoir siltation, and reduced regeneration of native vegetation. They were unable to quantify the rabbit problem in terms of damage because it was difficult to measure competition between rabbits and grazing stock and to assess the relative contribution of rabbits to soil and pasture degradation. In general, significant competition between rabbits and stock occurs only when pasture availability falls below a certain level, such as in winter and during drought. Although there is usually little direct competition between rabbits and livestock in spring when pasture growth is abundant, any increased grazing pressure by rabbits during this time may reduce the amount of fodder reserves for stock to carry them through summer and autumn.

The Group believed that a benefit of strategic, group rabbit management would be a reduction in control costs and poison use in the long term. They agreed to develop and implement a coordinated plan to manage rabbits in the area. In 1994, they prepared a successful proposal to the Bureau of Resource Sciences for the funding of a group rabbit management program.

Management objective

In keeping with the notion that strategic pest management is best based on reduction in pest damage, the long-term objective of rabbit management in the area was improved pasture availability and quality, reduced soil erosion and consequent increase in long-term stock production. However, there was no good information on either the level of rabbit damage or the relationship between rabbit numbers and damage. Therefore, it was decided that the immediate objective would be to reduce rabbits to very low densities—the assumption being that this would result in an increase in production which was worth more than the cost of initial and ongoing rabbit control.

Initial spotlight transect counts indicated rabbit numbers of more than 10 per spotlight kilometre. Based on existing knowledge of rabbits in this and other areas, it was considered that the ability of the rabbit population to recover to former numbers would be low if they were reduced to a density of 0.5 rabbits per kilometre. Whereas, at a density index of two to three rabbits per kilometre, or higher, rabbits could increase to problem numbers in one good season. Thus, the Group decided that the initial aim would be to reduce the number of rabbits to 0.5 per kilometre over the next three years. The longer term aim was to maintain this low density.

Management options

The Group then selected the management options they believed would achieve and maintain the desired population reduction in a cost-effective manner. They agreed to carry out the following program:

- initial use of high-cost techniques (poison baits, warren fumigation and ripping) to reduce rabbit numbers to less than four per kilometre;
- then medium-cost, follow-up control—treating re-opened warrens and warrens in areas which could not be accessed with large ripping machinery—to reduce rabbit numbers to less than one per kilometre;
- followed by low-cost ongoing maintenance control—regular maintenance using a contracted maintenance control team to reduce rabbits, rabbit warrens and harbour—to reduce rabbit numbers to less than 0.5 per kilometre and hold them there.

They developed a management structure and plan which included the following tasks and objectives:

- establish a core group of landholders to plan and coordinate the project;
- obtain commitment from landholders and local land management bodies to the program;

- allocate management units using a computerised Land Information System (see 'Defining management units', page 102); and
- develop and implement an appropriate monitoring strategy, including the use of spotlight transect counts and stock production records (see 'Monitoring and evaluation', pages 117–118).

Implementation

The Group established a representative committee, appointed a coordinator, and the wider landholder community was sent an open letter of invitation. Because the Group was already well established, this letter was sufficient to obtain a high level of involvement. Meetings, training days and consultations helped to inform participants of the details of implementation of the plan.

The management area was broken up into three management units so that adequate equipment and human resources could be concentrated on key areas at critical stages of the program.

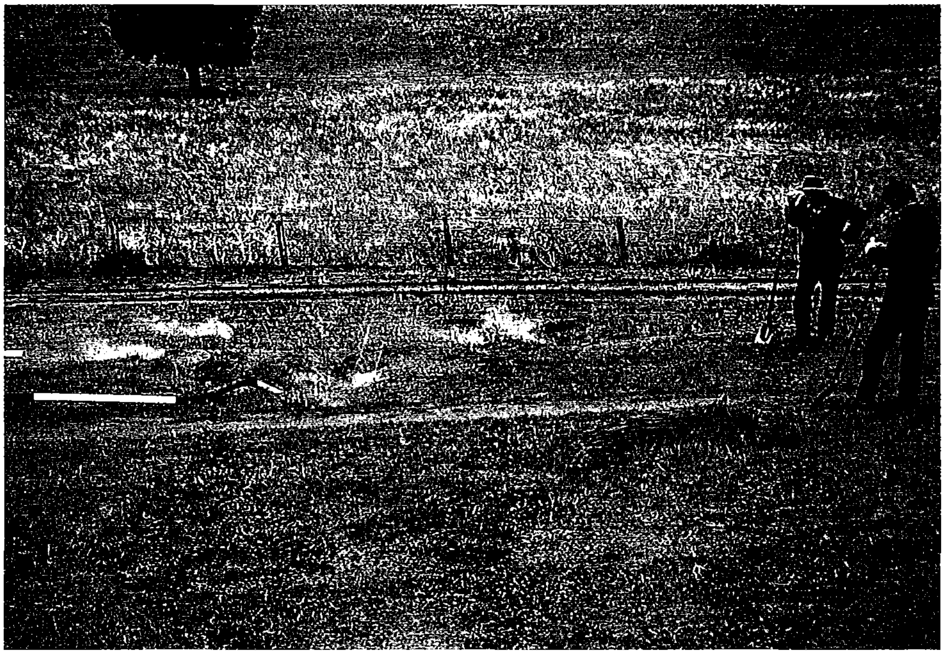
Monitoring and evaluation

The participation level of 80 per cent of land managers (or about 70 landholders over 25 000 hectares), was an indication of the success of the project in achieving wide initial cooperation and commitment. However, despite the high participation rate, low rabbit numbers were not achieved and/or maintained across the management area. This was partly because initial population reduction in some areas was inadequate, making follow-up maintenance less effective. Nevertheless, a number of landholders were able to achieve rabbit numbers of less than one per kilometre despite managing country where rabbit control was difficult due to poor machinery access. It was concluded that the effectiveness of rabbit management in the area was more dependent on landholder motivation to resolve the rabbit problem than the technical ability to do so. This loss of commitment to the project became more evident after the release of rabbit calicivirus (RCD).

The balance between the costs and benefits (costs:benefits) of any rabbit control depends on a number of factors including the value of any increased production, susceptibility of the property to erosion, and difficulty, and thus cost, of reducing rabbit numbers and maintaining them at sufficiently low levels to reduce damage. The Group estimated that with adequate population reduction measures, such as warren ripping and harbour destruction, ongoing maintenance control could be as low as $1–3 per annum per hectare. Given the high value of many of the grazing enterprises in the area, for example, fine wool production and raising high-value cattle such as Belgium Blues, it is quite likely that such management would be economic, although initial population reduction costs also need to be considered.

A number of landholders involved in the project believe that rabbit control in the area is cost-effective and are continuing to pay for the services of the contracted team to maintain low rabbit numbers beyond the life of the original project. Ongoing monitoring of rabbit numbers, stock production records and any increased regeneration of native plants should indicate whether significant benefits are realised in the longer term.

The Sutton Grange rabbit management project was unusual in several respects. It was based on an existing well established group, already committed to doing something about the pest problem. External funding supported the high costs of initial reduction in rabbit numbers and also allowed appointment of a coordinator, which is critical to the success of group pest management schemes. Even with these apparent advantages, the main objective was not met across the management area. Future group initiatives would be wise to address the issue of the 'rugged individualism' of landholders, cited as a major impediment to wider success in reduction of rabbit numbers. Nevertheless, the project was a success in terms of initial participation and interest, and several landholders have opted to continue at their own expense.



Fumigation is usually used as a follow-up to warren ripping, to treat reopened burrows. Pressure fumigation is preferred when warrens are extensive.
Source: NSWAF

10 Pest management for the future

What is the future of pest management?

The final question is where to now? Much has been learnt from Australia's past pest animal problems. The new approach recommended in this book is based on sustainable land management which involves all the key stakeholders and places emphasis on reduction in the damage that pests cause rather than reduction in pest numbers. Its is built around five interrelated steps:

- define the problem in terms of pest damage;
- determine objectives;
- identify and evaluate management options;
- implement a management plan; and
- monitor and evaluate the outcome (including, if necessary, redefining the problem).

A similar approach can be used to deal with other land management problems, such as weeds, soil acidification and dryland salinity. In this final chapter, some of the issues that can assist adoption of this approach, and improve its effectiveness, are discussed.

Although it is unlikely that all the information necessary for precise planning of management will ever be available. Adaptive management or 'learning by doing' will help to continually improve management practices, and the increasing potential for rapid dissemination of knowledge will facilitate this flexible approach. It is essential that all key players work together to understand the full dimension of a pest problem and plan a cooperative approach to its management. Thus, many of the barriers between groups that traditionally have not worked together need to be broken down. The success of the Landcare Program and associated increase in use of a strategic regional approach to sustainable land management demonstrates what can be achieved. New techniques, new research and improved communication systems can only enhance this dynamic approach to pest management.

Research: new approaches, new directions

Have researchers been asking the right questions about pest animals?

It is not clear that our approach to rabbit management has evolved significantly in the past 30 years. At Australia's National Vertebrate Pest Conferences there have been more papers presented on rabbits and rabbit control than on any other topic. The national guidelines for managing rabbits contains 550 references, mostly about rabbits. Yet, despite extensive research, there is still little good information about the level of rabbit damage or the relationship between rabbit density and the level of damage.[162] Consequently, it is difficult for managers to determine the return they can expect from a given effort of rabbit control. It could be asked whether researchers have been addressing the right questions. At the time it was thought so, but with the benefit of hindsight it seems apparent that more effort should have gone into quantifying pest animal damage and developing an integrated and strategic approach to managing rabbits and other pest animals.

A lot of past research has concentrated on understanding the biology of the pest animal and the interaction between the pest and its environment. As a result, knowledge of the links between rabbit reproduction, nutrition and the type of plants they prefer, for example, is excellent. Researchers now need to tackle the economics of pest animal management, attitudes to pest control, and how best to integrate the environmental, social and economic aspects of pest control for sustainable land management. Not only do researchers need to reassess their research topics, they should also consider how they conduct research. One example is that of enclosure studies which showed that 16 rabbits eat as much as one sheep.[204] This led to estimates that pastoralists could stock X/16 more sheep where X is the number of rabbits removed in control programs. However, studies in the field often failed to show anywhere near this level of benefit from rabbit control. It is now known that on a larger scale the situation is much more complex. Much of the time, pasture systems produce more feed than grazing animals can eat. As an example, in western New South Wales, it is not until the pasture biomass falls below about 250 kilograms per hectare that there is significant competition for pasture between sheep and other grazers such as rabbits, feral goats and kangaroos.[204]

To better understand the relationship between pest control and damage mitigation, more studies are required at the farm management level rather than, as in the past, concentrating on intensive studies of parts of the system. For example, a researcher who wants to determine the benefit to lamb production from different levels of fox control would not study in detail the behaviour of a group of foxes and lambing ewes. Rather they would compare the lamb marking percentage between similar properties that were subject to different levels of fox control. This is not to say that these detailed studies are no longer necessary, but they need to be balanced by a more adaptive approach to pest management. Adaptive management is based on a whole system approach on the property or other land management unit that is most appropriate.

Not only are larger scale studies necessary, but wherever practicable, all key players should be fully consulted in the planning, conduct and analysis of the research. Failure to do so can often lead to research that is at best poorly understood by those who are meant to benefit or, at worst, leads to research that has little relevance to the end user (see 'tarbaby' example in 'The role of extension in pest animal management', pages 112–114). Furthermore, there is little use in conducting applied research if the results are presented only at conferences or left to adorn the shelves of libraries, rather than disseminated to the appropriate end users.

The inclusion of land managers as coresearchers has several benefits. Co-opted managers are more likely to make their land available for research and to maintain a treatment regime throughout the course of the study. They can also contribute their knowledge and experience to the experimental design and ensure that control strategies will fit in with essential management operations. For instance, if a pest control strategy needs to be applied at a particular time, but the timing coincides with shearing and drenching, it may be useless to the woolgrower. Managers are more likely to understand and feel ownership of the results of the study, and hence adopt it, if they have been consulted.

However, there are also problems associated with large-scale studies, not least the requirement to establish and maintain a sound experimental design. To assess different pest management strategies, an appropriate experimental procedure is important (see the section 'The logic and function of experiments: an example', pages 91–93). Nevertheless, it can be difficult to achieve and maintain if it conflicts with the land manager's need to run the farm or nature reserve. Also, economic constraints or chance events such as drought may lead land managers to press for change to the experimental treatments before the end of the study. There is no simple solution, but some scientists try to compensate land managers for any losses due to the experiments and are able to build an allowance for compensation into the costs for the study.

There are other problems for scientists, not least that many do not have the time and/or the necessary communication skills required to fully involve land managers in the study. One way around this is to use trained facilitators and coordinators (see 'Feral goat management in south-western Queensland', pages 111–112).

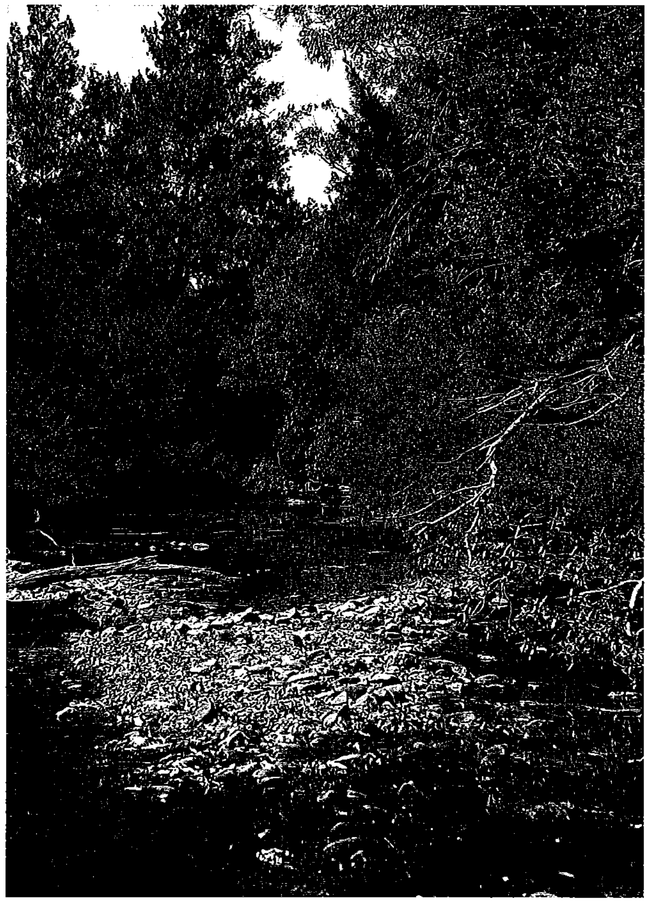
Despite these difficulties, there is a pressing need for research that compares different pest management strategies using large-scale studies based on a functioning system and with close involvement of the land manager. Such an approach is more likely to yield practical, meaningful results that are more widely adopted than has often been the case in the past.

Improved planning

When the aim of pest control was to try and get rid of as many animals as possible, the temptation was often to get out there and do as much on-ground control as possible. Planning was often seen as counter-productive. Why spend the time planning, when it could be better spent getting rid of the pests! Even if pest control was as simple as this, planning could have greatly assisted the effectiveness of a pest control program. However, pest animals are but one factor in a complex environmental, economic and social system that needs to be strategically managed to achieve desired land management outcomes, whether for production or nature conservation.

Increasingly, land managers are being encouraged through National and State programs to take a catchment or regional approach to land management issues including pest animal control. An example is the regional approach to sustainable land management under the Natural Heritage Trust (see below 'Natural Heritage Trust: an integrated approach to sustainable land management'). At the local level, Property Management Planning can help land managers address the complex of issues. However, managers will need considerable assistance with both levels of planning. For Property Management Planning, modules that are relevant to the local region need to be developed and must cover the various key elements including soil structure, acidity and salinity, weeds, pest animals, farm business plans, livestock acquisition, and conservation of biodiversity. A process for assessing and integrating the components then needs to be followed. A mixture of semi-formal courses such as might be run by a College of Technical and Further Education and less formal workshops can assist planning. Skilled and trained facilitators and presenters are also required; their role is to work with the diverse range of players which may be involved, such as banks, financial and legal advisors as well as others more directly concerned with pest management.

The need for better planning is becoming widely accepted, but considerable effort is needed to equip people with the necessary knowledge and skills.



Natural waterways with their catchments intact, such as the Clyde River on the South Coast of New South Wales, are unlikely to experience problems from introduced fish.
Source: Noel Preece & Penny van Oosterzee

Natural Heritage Trust: an integrated approach to sustainable land management

Australia has a comprehensive array of national strategies that set goals and priority action to improve the environment and promote sustainable land management. These include Ecologically Sustainable Development (see 'Ecologically Sustainable Development', page 76), National Strategy for the Conservation of Australia's Biodiversity, National Water Quality Management Strategy and the National Weeds Strategy.

The Natural Heritage Trust (NHT) is a five year program that commenced in 1996–97.[158] It aims to stimulate activities in the national interest that achieve conservation, sustainable use and repair of Australia's natural environment.

The specific objectives of the NHT are:

- to provide a framework for strategic capital investment and stimulate additional investment in the natural environment;
- to achieve complementary environment protection, natural resource management and sustainable agriculture outcomes consistent with agreed national strategies; and
- to provide a framework for cooperative partnerships between communities, industry and all levels of government.

The longer term outcomes sought from the NHT are:

- to develop and implement integrated approaches to the ecologically sustainable management of land, water and marine resources and environments;
- to arrest biodiversity losses and improve long-term protection and management of native vegetation and representative ecosystems;
- to maintain and improve the sustainable productive capacity of Australia's environmental and natural resource base; and
- to empower people to take responsibility for ecologically sustainable management.

There are four main elements to the NHT, the National Vegetation Initiative, the National Landcare Program, the National Rivercare Initiative and the Murray–Darling 2001 Initiative. In addition there are several other smaller programs such as the National Feral Animal Control Program and the National Weeds Strategy.

A primary goal of the NHT is to develop regional strategies. Regions tend to be areas of common interest that may be based around a catchment, a land vegetation type or a socio-economic group, within which sustainable management requires an integrated approach across a range of issues. Much of pest animal management fits this regional scale, especially for managing pest animal damage to nature conservation values.

Improved communication

A lot of past communication between researchers and end users was through extension officers and various forms of pamphlets and brochures such as *AgFacts*. Often neither the extension officer nor the end user was consulted or fully understood the research and its relevance to their problem.

In recent years, there has been much greater attention given to how best to deliver the message to the end user (see 'Formation and maintenance of management groups', pages 110–114). The emphasis of State and Territory pest animal extension officers is changing from the top-down approach of telling managers what to do, often supported by strict legislation, to working with them. The aim now is to provide land managers with the best available information on pest animal management and to help them plan and manage their pest problems. Ultimately, farmers and other land managers are responsible for managing their land and, as an advisor, the role of the extension officer is to guide and assist, not to dictate what should be done. The longer term goal is for land managers to have the commitment, knowledge and methodology to adapt their pest

At Dryandra State Forest, management to promote vegetation cover increases protection for endangered animals from foxes. Improved research and communication can encourage similar initiatives elsewhere.
Source: Noel Preece & Penny van Oosterzec

management to the changing economic, technological, environmental and social conditions in which they are operating.

Effective information transfer relies on several key factors:

- a clear understanding of the target audience and their needs;
- information that is important and likely to deliver tangible benefits; and
- delivery in a form appropriate to the end user.

This requires that extension officers and others involved in information transfer have a range of skills including sound scientific and technical knowledge, understanding of the broader aspects of the farm or other land management system, and good communication, facilitation and negotiation skills. The Vertebrate Pests Committee of the Standing Committee on Agriculture and Resource Management is developing a list of core competencies (skills and knowledge) for pest animal management advisors. Once developed, it is important that the recommendations be incorporated into a curriculum for use by agricultural and other relevant tertiary training institutions.

New technology

There are several technological developments that are beginning to help disseminate information and assist managers to plan their management of pest animal damage. An area that shows great promise is the development of computer assisted learning and decision support technology.[58] The aim is to communicate knowledge, skills and principles of pest management to a wide audience which includes producers, extension officers, students, research workers and policy makers. A key component is the development of experience-based decision support packages. These are user-friendly programs that lead farmers and other managers through the process of identifying their problem and finding solutions to it. The packages include images and video clips that aid with identification and help to explain concepts. The packages can be used by advisors or by managers with the appropriate computer technology and basic computer skills. They are simple to use and interactive, requesting users to enter their own information. They are also relatively cheap to produce and can be readily updated with a new computer disc or through the Internet. The CSIRO Division of Wildlife and Ecology is currently developing such a package to help grain producers predict and deal with mouse plagues.

Although still relatively new, Decision Support Systems, CD-Rom technology and other digital information systems such as the Internet are becoming increasingly more accessible and are likely play an important role in assisting managers to better plan and manage their pest problems. The Internet can also be used as a bulletin board for land managers to share experiences about pest animal management.

Another relatively new technological development, Global Positioning Systems (GPS) are small, often hand-held units that use satellites to accurately determine the coordinates of a location. They can be purchased for less than $1000 and have been used in various aspects of pest animal management including helping to prepare maps. In programs involving shooting from helicopters, one innovation has been to use a spotter plane and a GPS to locate and transmit to the helicopter the exact location of animals. This greatly increases efficiency and lowers the cost of the program. Similarly, GPS have been used to increase the efficiency of ripping rabbit warrens. The GPS is used to locate warrens and the information is transferred to a computer on board the bulldozer undertaking the ripping. A computer program plots the most efficient course for the bulldozer to follow from one warren to the next.

Geographic Information Systems (GIS) use data from satellites to develop base maps of an area which can be upgraded with additional information to produce comprehensive regional resource maps. The value of the system is that it is relatively cheap, accurate and can also be used to track changes in the vegetation and other parameters in response to management action.

New control techniques and new pests

The search for the perfect pest control technique continues (see 'Biological control', pages 65–70). It is acknowledged that some current methods are inhumane; chloropricrin for fumigating rabbits is a classic example.[225] At present there are few alternatives to some of these questionable techniques. However, there is potential to develop more humane and effective methods, such as carbon monoxide for fumigating rabbit warrens and fox dens. Another technique being investigated is the development of baiting strategies that incorporate a quick-acting narcotic to reduce any suffering.

There are likely to be new pests in the future. They may be animals that are already present but which become pests due to changing land use. For example, high quality fruits for export are now being grown in new areas such as the western goldfields of Western Australia and Central Australia. As the industry develops, it is possible that local native and non-native animals may cause problems to these developing industries. The decision-making framework outlined in this book will help managers to deal with these emerging problems.

Other pests may come from new arrivals or releases or escapes from captivity. Australia has a system to screen animals proposed for import according to their

Greater community awareness of the attractiveness, plight and needs of native animals such as the Bilby, can only enhance commitment to wise pest management.
Source: unknown

agricultural and environmental pest potential and to regulate the keeping of animals that are of concern (see 'Potential pests: exotic animals and translocated natives', pages 32–34). These systems need to be continually evaluated and refined to ensure that they are effective. Contingency plans to deal quickly with escapees are being developed.

Newly detected diseases can turn their animal vectors into pests. Lyssa virus, one of the same group of viruses as rabies, has recently been detected in Australian bats and has killed a wildlife rehabilitator bitten by one of her patients. Its presence may turn possums and bats into pests because they are suspected to be the main carriers.

Conclusion

Pest animal management is a complex and dynamic scene. In the future, it is likely that changes in land use and new crops will provide native and exotic animals with new opportunities to become pests. Pest management must become smarter and more sensitive, and adapt to the ever-changing needs of land managers and the desires of the community. It is hoped that this book will play a role in encouraging the adoption of a flexible, strategic approach to the management of pest animals. This can be achieved by the use of scientifically based procedures that are humane, cost-effective and integrated with ecologically sustainable land management.

References

1. AIDAB (Australian International Development Assistance Bureau) (1990). Ecologically Sustainable Development in international development cooperation. An iterim policy statement. Australian Government Publishing Service, Canberra.
2. Alexander, P (1990). Progress report on investigations in long-billed corellas and other ground feeding cockatoos in the south-east of South Australia, 1988–89. In: P Fleming, I Temby & J Thompson (eds). Proceedings National Bird Pest Workshop, Armidale, 1990, pp. 25–33. Victorian Department of Conservation Forests and Lands & NSW Agriculture & Fisheries.
3. Alexander, H (1995). A framework for change; the state of the Community Landcare Movement in Australia. National Landcare Facilitator Annual Report, National Landcare Program, Canberra.
4. Allen, L (1996). Managing feral goats and their impact on Townshend Island in Shoalwater Bay Training Area. In: P Crabb, J Kesby & L Olive (eds). Environmentally Responsible Defence. Australian Defence Study Centre, Canberra.
5. Allen, L (1997). The management of feral goat impact on Townshend Island. Progress report, Resource Sciences Branch, Queensland Department of Natural Resources.
6. Allen, GR & Steene, RC (1988). Fishes of Christmas Island Indian Ocean. Christmas Island Natural History Association, Christmas Island.
7. ANCA (Australian Nature Conservation Agency) (1994). Christmas Island National Park Plan of Management. Australian Nature Conservation Agency, Canberra.
8. Anderson, I & Nowak, R (1997). Australia's giant lab. New Scientist 2070: 34–37.
9. Anon. (1825). Journal of an excursion across the Blue Mountains of N.S.W. In: J Field (ed.). Geographical Memoirs of N.S.W. Murray, London.
10. Archer, M, Flannery, TF & Grigg, GC (1985). The Kangaroo. Weldon, Sydney.
11. Arthington, AH (1986). Introduced cichlid fish in Australian inland waters. In: P De Deckker & WD Williams (eds). Limnology in Australia, pp. 239–248. CSIRO, Melbourne & Dr W Junk, Dordrecht.
12. Arthington, AH, Gamlet, S & Bluhdorn, DR (1990). The role of habitat disturbance in the establishment of introduced warm-water fishes in Australia. In: DA Pollard (ed.). Introduced and Translocated Fishes and their Ecological Effects, pp. 61–66. Proceedings Australian Society for Fish Biology Workshop, No 8, 1989, Magnetic Island, Townsville, Queensland. Bureau of Resource Sciences, Canberra.
13. Auld, TD (1995). The impact of herbivores on regeneration in four trees from arid Australia. The Rangeland Journal 17 (2): 213–227.
14. Baker, JK & Reeser, DW (1972). Goat management problems in Hawaii Volcanoes National Park: a history, analysis, and management plan. National Park Natural Resources Report, Hawaii.
15. Barry, G, Shaw, I, Beare, S & Short, C (1993). The costs and consequences of an FMD outbreak: implications of zoning policies for Australian broadacre agriculture. Australian Bureau of Agriculture and Resource Economics Conference Paper 93: 19.
16. Begon, M, Harper, JL & Townsend, CR (1996). Ecology: Individuals, Populations and Communities. Third edition. Blackwell, Oxford.
17. Blakers, M, Davies, SJJF & Riley PN (1984). The Atlas of Australian Birds. Melbourne University Press, Melbourne.
18. Bomford, M (1988). Effect of wild ducks on rice production. In: GA Norton & RP Pech (eds). Vertebrate Pest Management in Australia: A Decision Analysis/Systems Analysis Approach, 1988, pp. 53–57. Project Report No. 5. CSIRO, Division of Wildlife & Ecology, Canberra.
19. Bomford, M (1990a). Assessing the risks of importing and keeping exotic birds in Australia. In: P Fleming, I Temby & J Thompson (eds). Proceedings National Bird Pest Workshop, Armidale, 1990, pp. 67–77. Victorian Department of Conservation Forests & Lands and NSW Agriculture & Fisheries.
20. Bomford, M (1990b). A role for fertility control in wildlife management? Bureau of Rural Resources Bulletin No. 7. Australian Government Publishing Service, Canberra.
21. Bomford, M (1991). Importing and keeping exotic vertebrates in Australia—criteria for assessment and risk. Bureau of Rural Resources Bulletin No. 12. Australian Government Publishing Service, Canberra.
22. Bomford, M (1992a). Report: Vertebrate Pest Control and Animal Welfare. The Animal Welfare Unit. Department of Primary Industries & Energy, Canberra.
23. Bomford, M (1992b). Bird pest impact and research in Australia: A survey and bibliography. Working Paper No. WP/3/92, Bureau of Rural Resources, Department of Primary Industries & Energy, Canberra.
24. Bomford, M & Caughley, J (1996a). Lessons from the past and opportunities for the future. In: M Bomford & J Caughley (eds). Sustainable Use of Wildlife by Aboriginal Peoples and Torres Strait Islanders, pp. 189–199. Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.
25. Bomford, M & Caughley, J (1996b). Ecologically sustainable harvesting of wildlife by Aboriginal Peoples. In: M Bomford & J Caughley (eds). Sustainable Use of Wildlife by Aboriginal Peoples and Torres Strait Islanders, pp. 60–74. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
26. Bomford, M & O'Brien, P (1995). Eradication or Control for Vertebrate Pests? Wildlife Society Bulletin 23: 249–255.
27. Bomford, M & O'Brien, P (1997, in press). Potential use of contraception for managing wildlife pests in Australia. Bureau Resource Sciences. Australian Government Publishing Service, Canberra.
28. Bomford, M, Newsome, A & O'Brien, P (1995). Solutions to Feral Animal Problems: Ecological and Economic Principles. Dept. Primary Industries & Energy, Bureau Resource Sciences.
29. Bowman, DMJS & Panton, WJ (1991). Sign and habitat impact of Banteng (*Bos javanicus*), and pig (*Sus scrofa*), Cobourg Peninsula, northern Australia. Australian Journal of Ecology 16 (1): 15–17.

30. Braysher, M (1993). Managing Vertebrate Pests: Principles and Strategies. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
31. Braysher, M. (1994). Principles and Strategies for Managing Vertebrate Pests. Australian Veterinary Association. Urban Animal Wildlife Conference, Canberra, 1994.
32. Breckwoldt, R (1988). A Very Elegant Animal: The Dingo. Angus and Robertson, North Ryde.
33. Bridgewater, P & Potter, C (1993). Endangered species: the rabbit's role. In: BD Cooke (ed.). Proceedings Australian Rabbit Control Conference, April 1993, pp. 26–34. Adelaide.
34. BRS (Bureau of Resource Sciences) (1996). Rabbit Calicivirus Disease: a report under the Biological Control Act 1984. Bureau of Resource Sciences, Canberra.
35. Burbidge AA & McKenzie NL (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. Biological Conservation 50: 143–198.
36. Burchmore, J, Faragher, R & Thorncraft, G (1990). Occurrence of the introduced Oriental Weather Loach (*Misgurnus anguillicaudatus*) in the Wingecarribee River, New South Wales. In: DA Pollard (ed.). Introduced and Translocated Fishes and their Ecological Effects, 1990, pp. 38–46. Proceedings Australian Society for Fish Biology Workshop, No 8, 1989, Magnetic Island, Townsville, Queensland. Bureau of Resource Sciences, Canberra.
37. Bureau of Sugar Experimental Station (1995). BSES Advancing Sugar Bulletin No. 52. Indooroopily, Queensland.
38. Cadwallader, PL (1996). Overview of the impacts of introduced salmonids on Australian native fauna. Australian Nature Conservation Agency, Canberra.
39. Campbell, A (1996). Land literacy in Australia: Landcare and other new approaches to inquiry and learning for sustainability. Working Paper 1996/4, Centre for Resources and Environmental Studies, Australian National University, Canberra.
40. Carter, D (compiler) (1994). Feral cats—a national approach towards a threat abatement plan. Proceedings Workshop, Australian National Botanic Gardens, 1994. Commonwealth Feral Pests Program. Australian Nature Conservation Agency, Canberra.
41. Caughley, G (1977). Analysis of Vertebrate Populations. John Wiley, London.
42. Caughley, G (1987). Introduction to the sheep rangelands. In: G Caughley, N Shepherd & J Short (eds). Kangaroos: Their Ecology and Management in the Sheep Rangelands of Australia. Cambridge University Press, Cambridge.
43. Caughley, G (1994). Directions in conservation biology. Journal of Animal Ecology 63: 215–244.
44. Caughley, G & Sinclair, ARE (1994). Wildlife Ecology and Management. Blackwell Scientific Publications, Oxford.
45. Caughley, J, Bomford, M, Parker, B, Sinclair, R, Griffiths, J & Kelly, D (in preparation). Managing Vertebrate Pests: Rodents. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
46. Choquenot, D (1991). Density-dependent growth, body condition, and demography in feral donkeys: testing the food hypothesis. Ecology 72: 805–813.
47. Choquenot, D (1994). The Dynamics of Feral Pig Populations in the Semi-arid Rangelands of Eastern Australia. PhD Thesis, University of Sydney.
48. Choquenot, D, McIlroy, J & Korn, T (1996). Managing Vertebrate Pests: Feral Pigs. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
49. Christidis, L & Boles, WE (1995). The Taxonomy of Species of Birds of Australia and its Territories. RAOU Monograph 2. Royal Australasian Ornithologists Union, Hawthorn.
50. Cochran, WG & Cox, GM (1957). Experimental Design. Second Edition. Wiley & Sons, New York.
51. Cogger, HD (1994). Reptiles and Amphibians of Australia. Reed, Chatswood.
52. Collins, J, Klomp, N and Birckhead, J (1996). Aboriginal use of wildlife: past present and future. In: M Bomford & J Caughley (eds). Sustainable Use of Wildlife by Aboriginal Peoples and Torres Strait Islanders, pp. 14–36. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
53. Coman, B (1992). Introduced predators—pest status and control techniques. In: NCCAW. Vertebrate pest control and animal welfare. A report of the National Consultative Committee on Animal Welfare, February, 1992.
54. Cooke, B (1996). Modelling the spread of RCD: a review of work in progress. Report to the Meat Research Corporation.
55. Corbett, L (1995). The Dingo in Australia and Asia. University of New South Wales Press, North Ryde.
56. Cowan, DP (1987). Aspects of the social; organisation of the European wild rabbit (*Oryctolagus cuniculus*). Ethology 75: 197–210.
57. Coyne, P (1982). Day of the rabbits. Georgetown Law Journal 4: 30–39.
58. CRC (Cooperative Research Centre for Tropical Pest Management) (1994–1995). Research and Development Report, 1994 and 1995, University of Queensland.
59. CSIRO (Commonwealth Scientific and Industrial Research Organisation) (1989). Policy proposals for the future of Australia's rangelands. Prepared by B Foran, M Friedel, N Macleod, DM Stafford Smith & A Wilson, CSIRO National Rangelands Program, CSIRO Division of Wildlife and Ecology.
60. CSIRO (Commonwealth Scientific and Industrial Research Organisation) (1990). Australia's environment and its natural resources—an outlook. Prepared by M Young, D Cocks & S Humphries, CSIRO Institute of Natural Resources and Environment.
61. CSIRO (Commonwealth Scientific and Industrial Research Organisation) (1996). Report of cane toad research. Division of Wildlife and Ecology, Canberra.
62. Darwin, C (1859). The Voyage of the Beagle. Dent, London.
63. Davidson, S (1990). Foot and mouth disease: the feral pig factor. Rural Research 148: 20–26.
64. De Decker, P & Williams, WD (eds)(1986). Limnology in Australia. CSIRO, Melbourne & Dr W Junk Publishers, Dordrecht.
65. Denny, M (1982). Kangaroos: an historical perspective. In: C Haigh (ed.). Kangaroos and other Macropods of New South Wales, pp. 36–44. NSW National Parks and Wildlife Service, Sydney.
66. Dickman, CR (1996). Overview of the impacts of feral cats on Australian native fauna. Australian Nature Conservation Agency, Canberra.
67. Dobbie, WR, Berman, D McK & Braysher, ML (1993). Managing Vertebrate Pests: Feral Horses. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
68. Eason, CT (1992). Old pesticide—new data. New Zealand Science Monthly March 1992: 15–16.
69. ENRC (Environment and Natural Resources Committee)(1995). Report on Problems in Victoria caused by Long-billed Corellas, Sulphur-crested Cockatoos and Galahs. Environment and Natural Resources Committee, Parliament of Victoria, No. 67 Session 1994/95. Victorian Government Printer, Melbourne.
70. ESD (1991). Ecologically Sustainable Development Working Groups. Final report—Agriculture. Australian Government Publishing Service, Canberra.
71. ESD (1992). Ecologically Sustainable Development Working Groups. Australian Government Publishing Service, Canberra.
72. Fenner F (1983). Biological control, as exemplified by smallpox and myxomatosis. Proceedings of the Royal Society of London B 218: 259–285.
73. Fenner, F & Myers, K (1978). Myxoma virus and myxomatosis in retrospect: the first quarter century of a new disease. In: E Kurstak & K Maramorosch (eds). Viruses and the Environment.

Academic Press, New York.
74. Fennessy, BV (1962). Competitors with sheep: mammal and bird pests of the sheep industry. In: A Barnard (ed.). The Simple Fleece, pp. 221–240. Melbourne University Press, Melbourne.
75. Fleming, P (1990). The impact and management of birds on the Ord River development in WA. In: P Fleming, I Temby & J Thompson (eds). Proceedings National Bird Pest Workshop, Armidale, 1990, pp. 13–14. Victorian Department of Conservation Forests & Lands & NSW Agriculture & Fisheries.
76. Fletcher, AR (1986). Effects of introduced fish in Australia. In: P De Decker & WD Williams (eds). Limnology in Australia, pp. 231–238. CSIRO, Melbourne & Dr W Junk, Dordrecht.
77. Fraser, W (1995). Public attitudes to introduced wildlife and wildlife management in New Zealand. In: Proceedings 10th Australian Vertebrate Pest Control Conference, pp. 101–106. DPIF, Tasmania.
78. Freeland, WJ & Kerin, SH (1988). Within-habitat relationships between invading *Bufo marinus* and Australian species of frog during the tropical dry season. Australian Wildlife Research 15: 293–305
79. Friend, JA (1990). The Numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and potential for recovery. Proceedings Ecological Society of Australia 16: 369–377.
80. Garner, MG & O'Brien, PH (1988). Wildlife disease status in Australia. Review sci. tech. Off. int. Epiz. 7: 823–841.
81. Garnett S (ed.)(1992). Threatened and extinct birds of Australia. Second, corrected edition. RAOU Report 82. Royal Australasian Ornithologists Union, Melbourne & ANPWS, Canberra.
82. Geering, WA, Forman, A & Nunn, MJ (1995). Exotic diseases of animals: a field guide for Australian veterinarians. Australian Government Publishing Service, Canberra.
83. Gibson, DF, Lundie-Jenkins, G, Langford, DG, Cole, JR, Clarke, DE & Johnson, KA (1994). Predation by feral cats, *Felis catus*, on the Rufous Hare-wallaby, *Lagorchestes hirsutus*, in the Tanami Desert. Australian Mammalogy 17: 103–107.
84. Gilbert, N, Myers, K, Cooke, BD, Dunsmore, JD, Fullagar, PJ, Gibb, JA, King, DR, Parer, I, Wheeler, SH & Wood, DH (1987). Comparative dynamics of Australian rabbit populations. Australian Wildlife Research 14: 491–503.
85. Halse, S (1990). Review of bird pest research in Western Australia. In: P Fleming, I Temby & J Thompson (eds). Proceedings National Bird Pest Workshop, Armidale, 1990, pp. 34–40. Victorian Department of Conservation Forests & Lands and NSW Agriculture & Fisheries.
86. Harris, S (1989). When is a pest a pest? New Scientist 4 March, 1989, pp. 49–51.
87. Hart, Q & Kelly, D (1996). Best practice extension in pest management. In: D Choquenot, J Mcllroy & T Korn. Managing Vertebrate Pests: Feral Pigs, pp. 142–143. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
88. Hassall & Associates (1996). Economic evaluation of the role of bounties in pest management. Report submitted to the Bureau of Resource Sciences, Canberra.
89. Henzell, RP (1981). Technical notes on the shooting of feral goats on Arkaroola from 1–5 June, 1981. Animal and Plant Control Commission, Adelaide.
90. Henzell, RP (1984). Methods of controlling feral goats. Department of Agriculture, South Australia. Fact Sheet No 20/84.
91. Henzell, RP (1991). Rabbits, feral goats, mulga and rangeland stability. In: Working papers of the 9th Australian Vertebrate Pest Control Conference, April 1991, pp. 18–21. Adelaide.
92. Henzell, R (1995). Feral herbivores and the Wildlife and Exotic Disease Preparedness Program. Proceedings of the 10th Australian Vertebrate Pest Control Conference, pp. 267–270. Department of Primary Industry and Forestry, Tasmania.
93. Hodgkinson, K (1991a). Elements of an agenda for renewal of rangeland resources. Unpublished paper presented to ANZAAS, 1991.
94. Hodgkinson, K (1991b). Elements of grazing strategies for perennial grass management in rangelands. In: GP Chapman (ed.). Desertified Grasslands: Their Biology and Management, pp. 77–94. Academic Press & Linnean Society, London.
95. Hone, J (1994). Analysis of Vertebrate Pest Control. Cambridge University Press, Cambridge.
96. Hone, J & Pech, RP (1990). Disease surveillance in wildlife with emphasis on detecting foot and mouth disease in feral pigs. Journal of Environmental Management. 31: 173–84.
97. Hume, ID, Jarman, PJ, Renfree, MB, & Temple-Smith, PD (1989). 29. Macropodidae. In: DW Walton & BJ Richardson (eds). Fauna of Australia. Vol. IB Mammalia, pp. 679–715. Australian Government Publishing Service, Canberra.
98. Hunter, M & Coman, B (1996). Best practice rabbit management for higher rainfall areas. Final project report of the Sutton Grange LandCare Group Inc. to the Bureau of Resource Sciences, Canberra.
99. Hurlbert, SH (1984). Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54: 187–211.
100. IGAE (InterGovernmental Agreement on the Environment) (February 1992). Commonwealth of Australia, Canberra.
101. IUCN (1978). Red Data Book IUCN. Morges, Switzerland.
102. Jarman, P (1986). Vertebrate Wildlife. In: HF Recher, D Lunney & I Dunn (eds). A Natural Legacy. Ecology in Australia. Pergamon Press, Sydney.
103. Johnson, KA (1989). 25. Thylacomyidae. In: DW Walton & BJ Richardson (eds). Fauna of Australia. Vol. IB, Mammalia. Australian Government Publishing Service, Canberra.
104. Jurd, G (1989). Norfolk Island Environment Book. Australian National Parks and Wildlife Service, Canberra.
105. Kelly, D (1995). Government pests or community pests—integrating different perspectives for improved pest management. Proceedings of the 10th Vertebrate Pest Conference, Hobart. Department of Primary Industry and Fisheries, Tasmania.
106. King, CM (1990). The Handbook of New Zealand Mammals. Oxford University Press, Auckland.
107. King, DR, Oliver, AJ & Mead, RJ (1981). *Bettongia* and fluoroacetate: a role for 1080 in fauna management. Australian Wildlife Research 8: 529–536
108. Kinnear, JE, Onus, ML & Bromilow, RN (1988). Fox control and rock wallaby dynamics. Australian Wildlife Research 15: 435–450.
109. Krebs, CJ (1972). Ecology. Harper & Row, New York.
110. Krefft, G (1866). On the vertebrated animals of the lower Murray and Darling, their habits, economy and geographical distribution. Transactions of the Philosophical Society of New South Wales 1862–1865, Sydney.
111. Landcare (1991). Decade of landcare plan, Commonwealth component. Australian Government Publishing Service, Canberra.
112. Landcare (1994). Monitoring Rangeland in the Northern Territory. Landcare, Northern Territory.
113. Langdon, JS (1990). Disease risks of fish introductions and translocations. In: DA Pollard (ed.). Introduced and Translocated Fishes and their Ecological Effects, pp. 98–107. Proceedings Australian Society for Fish Biology Workshop, No 8, 1989, Magnetic Island, Townsville, Queensland. Bureau of Resource Sciences, Canberra.
114. Lange, RT & Graham, CR (1983). Rabbits and the failure of regeneration in Australian arid zone Acacia. Australian Journal of Ecology 8: 377–81.
115. Laurance, WF (1991). Ecological correlates of extinction proneness in Australian tropical rainforest mammals. Conservation Biology 5: 79–89.
116. Lenghaus, C, Collins, BJ, Ratnamohan, N & Morrissy, CJ (1996). Laboratory investigation of a rabbit calicivirus for biological

control of wild rabbits *Oryctolagus cuniculus* in Australasia (unpublished draft).

117. Letts, GA, Bassingthwaighte, A & de Vos, WEL (1979). Feral Animals in the Northern Territory. Report of the Board of Enquiry. Department of Primary Production, Northern Territory Government.
118. Lever, C (1985). Naturalised Animals of the World. Longman, London.
119. Lim, TK, Bowman, L & Tidemann, S (1993). A report on the survey of winged vertebrate pest damage on crops in the Northern Territory. Technical Bulletin No. 209. Department of Primary Industry & Fisheries, Darwin.
120. Lintermans, M, Rutzou, T & Kukolic, K (1990). Introduced Fish of the Canberra Region—Recent Range Expansions. In: DA Pollard (ed.). Introduced and Translocated Fishes and their Ecological Effects, pp. 50–60. Proceedings Australian Society for Fish Biology Workshop, No 8, 1989, Magnetic Island, Townsville, Queensland. Bureau of Resource Sciences, Canberra.
121. Lloyd LN & Tomasov, JF (1985). Taxonomic status of the mosquitofish, *Gambusia affinis* (Poeciliidae) in Australia. Australian Journal of Marine and Freshwater Research 36: 447–451.
122. Lloyd, L (1990). Native fishes as alternatives to the exotic fish *Gambusia* for insect control. In: DA Pollard (ed.). Introduced and Translocated Fishes and their Ecological Effects, pp. 115–122. Proceedings Australian Society for Fish Biology Workshop, No 8, 1989, Magnetic Island, Townsville, Queensland. Bureau of Resource Sciences, Canberra.
123. Long, JL (1981). Introduced Birds of the World. Reed, Chatswood.
124. Long, JL (1988). Introduced Birds and Mammals in Western Australia. Agriculture Protection Board of Western Australia, Technical series No. 1, 2nd edition.
125. Loope LL & Mueller-Dombois D (1989). Characteristics of invaded islands, with special reference to Hawaii. In: JA Drake, HA Mooney, F di Castri, RH Groves, FJ Kruger, M Rejmanek and MW Williamson (eds). Biological Invasions: A Global Perspective, pp. 257–280. Wiley & Sons, Chichester.
126. Lundie-Jenkins G (1993). Ecology of the Rufous Hare-wallaby *Lagorchestes hirsutus* Gould (Marsupialia: Macropodidae), in the Tanami Desert, Northern Territory. I. Patterns of habitat use. Wildlife Research 20: 457–476.
127. Lundie-Jenkins G, Corbett, LK & Phillips CM (1993a). Ecology of the Rufous Hare-wallaby *Lagorchestes hirsutus* Gould (Marsupialia: Macropodidae), in the Tanami Desert, Northern Territory. III. Interactions with introduced mammal species. Wildlife Research 20: 495–511.
128. Lundie-Jenkins G, Phillips CM & Jarman PJ (1993b). Ecology of the Rufous Hare-wallaby *Lagorchestes hirsutus* Gould (Marsupialia: Macropodidae), in the Tanami Desert, Northern Territory. II. Diet and feeding strategy. Wildlife Research 20: 477–494.
129. Lunney, D (1994). Review of official attitudes to western New South Wales 1901–93 with particular reference to the fauna. In: D Lunney, S Hand, P Reed and D Butcher (eds). Future of the Fauna of Western New South Wales, pp. 1–26. Royal Zoological Society of New South Wales, Mosman.
130. Lunney, D & Leary, T (1988). The impact on native mammals of land-use changes and exotic species in the Bega district, New South Wales, since settlement. Australian Journal of Ecology 13 (1): 67–92.
131. Mackay, N & Eastburn, D (1990). The Murray. Murray Darling Basin Commission. Inprint, Brisbane.
132. Mahood, IT (1985). Some Aspects of Ecology and the Control of Feral Goats (*Capra hircus* L.) in western New South Wales. M.Sc. Thesis, Macquarie University.
133. Manly, BFJ (1992). The Design and Analysis of Research Studies. Cambridge University Press, Cambridge.
134. Margules CR, Nicholls AO & Pressey RL (1988). Selecting networks of reserves to maximise biological diversity. Biological Conservation 43: 63–76.
135. Mattison, C (1992). Frogs and Toads of the World. Blandford, London.
136. Maxwell, S, Burbidge, AA & Morris, K (1996). The 1996 Action Plan for Australian Marsupials and Monotremes. Wildlife Australia, Canberra.
137. Maynes, G (1993). Kangaroo Management—A National Perspective in Workshop on Kangaroo Management: Removal of Impediments to a Sustainable Commercial Kangaroo Industry, Adelaide 21–22 July 1993. Department of Primary Industries and Energy, Canberra.
138. McDowall, RM (1980). Freshwater Fishes of South-eastern Australia. Reed, Chatswood.
139. McLennan, WC (1996) Australians and the Environment. Australian Bureau of Statistics Catalogue No 4601.0, Canberra.
140. Meek, PD & Nazer C (1995). Invasion by vertebrate pests and weeds. In: G Cho et al. (eds). Jervis Bay: A Cultural, Scientific and Educational Resource. Kowari 5. Australian Government Publishing Service, Canberra.
141. Mollah, WS (1982). Humpty Doo. Rice in the Northern Territory. Australian National University North Australian Research Unit, Monograph, Darwin, Northern Territory.
142. Morison, A & Hume D (1990). Carp (*Cyprinus carpio*). in Australia. (Poster). In: DA Pollard (ed.). Introduced and Translocated Fishes and their Ecological Effects, pp. 110–113. Proceedings Australian Society for Fish Biology Workshop, No 8, 1989, Magnetic Island, Townsville, Queensland. Bureau of Resource Sciences, Canberra.
143. Morton, SR (1990). The impact of European settlement on the vertebrate animals of arid Australia: A conceptual model. In: Australian Ecosystems: 200 Years of Degradation and Reconstruction. Proceedings of the Ecological Society of Australia 16: 201–213.
144. Morton, SR & Pickup, G (1992). Sustainable Land Management in Arid Australia. Search, Vol 23, No 4, March 1992.
145. Morton, SR, Stafford Smith, DM, Friedel, MH, Griffin, GF & Pickup, G (1994). The stewardship of Arid Australia: Ecology and Landscape Management. Journal of Environmental Management 42: 181–204.
146. Munro, RK & Williams, RT (eds)(1994). Rabbit Haemorrhagic Disease: issues in assessment for biological control. Bureau of Resource Sciences, Canberra.
147. Murray, G (1993). Proceedings of the National Symposium on Foot-and-Mouth Disease. Canberra, 8 September 1992. Australian Government Publishing Service, Canberra.
148. Myers, K (1962). A survey of myxomatosis and rabbit infestation trends in the eastern Riverina New South Wales 1951–60. CSIRO Wildlife Research 7: 1–12.
149. Myers, K (1986). Introduced vertebrates in Australia with emphasis on the mammals. In: RH Groves & JJ Burdon (eds). Ecology of Biological Invasions: An Australian Perspective, pp. 120–36. Australian Academy of Science, Canberra.
150. Myers, K, Parer, I & Richardson, BJ (1989). Leporidae. In: DW Walton & BJ Richardson (eds). Fauna of Australia. Vol IB, Mammalia, pp. 917–931. Australian Government Publishing Service, Canberra.
151. Myers, K & Poole, WE (1962). A study of the biology of the wild rabbit *Oryctolagus cuniculus* (L.) in confined populations. III. Reproduction. Australian Journal of Zoology 10: 225–267.
152. Naismith, T (1992). Feral goat control in national parks in the Flinders and Gammon Ranges. In: LW Best (ed.). Feral Goat Seminar: Proceedings, pp. 32–33. Department of Environment and Planning, Adelaide.
153. NCCAW (National Consultative Committee on Animal Welfare) (1992). Vertebrate pest control and animal welfare. A report of the National Consultative Committee on Animal Welfare. February, 1992.
154. Neilsen, WA & Wilkinson GR (1995). Browsing damage, site

quality and species selection—case study of their effects on the economic viability of eucalypt plantations in north eastern Tasmania. Proceedings of the 10th Australian Vertebrate Pest Control Conference, pp. 161–170. DPIF, Tasmania.

155. New Zealand Department of Conservation (1994). National possum control plan 1993–2002. Department of Conservation, Wellington.

156. New Zealand Department of Conservation (1996). National feral goat control plan 1993–2002. Department of Conservation, Wellington.

157. Newland, NP (1971). Vermin control in South Australia—an historical account of legislative efforts to control animals defined as vermin. Department of Lands, Adelaide.

158. NHT (Natural Heritage Trust) (1997). Guide to regional arrangements 1997–98. Commonwealth Government, Canberra.

159. Norton, G (1988). Philosophy, concepts and techniques. In: GA Norton & RP Pech (eds). Vertebrate Pest Management in Australia: A Decision Analysis/Systems Analysis Approach. CSIRO, Division of Wildlife and Ecology.

160. Nugent, R (1988). Aboriginal Attitudes to feral animals and land degradation. Central Land Council, Land Management Section, Alice Springs.

161. O'Brien, P & Bomford, M (1994). Pest Animal Management: A Bureau of Resource Sciences Perspective. NSW Conservation Council Paper.

162. O'Brien, P & Braysher, M. (1995). Vertebrate Pest Management: a BRS perspective. Proc. 10th Australian Vertebrate Pest Control Conference, pp. 2–9. Dept of Primary Industry & Forestry, Hobart.

163. O'Brien, P & Korn, T (1989). Feral pigs: identifying the problem. Agfact A9.0.13, New South Wales Agriculture and Fisheries.

164. O'Brien, P & Saunders, G (1986). Socio-economic and biological impact of the feral pig in New South Wales: an overview and alternative management plan. Fourth Biennial Conference, Australian Rangeland Society, Armidale.

165. Oogjes, G (1995). Considering the animal's interests in the 'pest control' debate. In: Proceedings 10th Australian Vertebrate Pest Control Conference, pp. 298–302. Department of Primary Industry and Forestry, Hobart.

166. Parer, I (1977). The population ecology of the wild rabbit *Oryctolagus cuniculus* (L.) in a Mediterranean-type climate in New South Wales. Australian Wildlife Research 4: 171–205.

167. Parer, I & Milkovits, G (1994). Recolonisation by wild rabbits (*Oryctolagus cuniculus* L.) after warren ripping and warren fumigation. Rangelands Journal 15: 51–63.

168. Parer, I & Parker, B (1986). Recolonisation by rabbits (*Oryctolagus cuniculus*) after warren destruction in western New South Wales. Australian Rangelands Journal 8, 150–152.

169. Parer I & Pech RP (1988). 3. Rabbit Management. In: GA Norton & RP Pech (eds). Vertebrate Pest Management in Australia: A Decision Analysis/Systems Analysis Approach, pp. 38–52. CSIRO, Division of Wildlife and Ecology, Canberra.

170. Parkes JP (1990). Feral Goat Control in New Zealand. Biological Conservation 54: 335–348.

171. Parkes JP (1993). The ecological dynamics of pest–resource–people systems. New Zealand Journal of Zoology 20: 223–230.

172. Parkes JP (1996). Integrating the management of introduced mammal pests of conservation values in New Zealand. Wildlife Biology 2: 179–184.

173. Parkes, J, Henzell, R & Pickles, G (1996a). Managing Vertebrate Pests: Feral Goats. Bureau Resource Sciences and Australian Nature Conservation Agency. Australian Government Publishing Service, Canberra.

174. Parkes, JP, Nugent, G & Warburton, B (1996b). Commercial exploitation as a pest control tool for introduced mammals in New Zealand. Wildlife Biology 2: 171–177.

175. Pavlov, PM, Hone, J, Kilgour, HT & Pedersen, H (1981). Predation by feral pigs on Merino lambs at Nyngan, New South Wales. Australian Journal of Experimental Agriculture and Animal Husbandry 21: 570–4.

176. Pech, RP & Hone, J (1988). A model of the dynamics and control of an outbreak of foot-and-mouth disease in feral pigs in Australia. Journal of Applied Ecology 25: 63–77.

177. Pech, R, Hood, GM, McIlroy, J & Saunders, G (1997). Can foxes be controlled by reducing their fertility? Reproduction, Fertility and Development 9: 41–50.

178. Pech, RP, Norton, GA, Hone, J & McIlroy, JC (1988). 5. Exotic disease in feral pigs. In: GA Norton & RP Pech (eds). Vertebrate Pest Management in Australia: A Decision Analysis/Systems Analysis Approach, pp. 58–66. Project Report No. 5. CSIRO Division of Wildlife & Ecology, Canberra.

179. Pech, R, Sinclair, ARE & Newsome, AE (1995). Predation models for primary and secondary prey species. Wildlife Research 22: 55–64.

180. Pech, RP, Sinclair, ARE, Newsome, AE & Catling, PC (1992). Limits to predator regulation of rabbits in Australia: evidence from predator-removal experiments. Oecologia 89: 102–112.

181. Priddel, D (1990). Conservation of the Malleefowl in New South Wales: an experimental management strategy. In: JC Noble, PJ Joss & GK Jones (eds). The Mallee Lands: a Conservation Perspective. CSIRO, Canberra.

182. Priddel, D (1991). Assessment of the potential food resources available to malleefowl (*Leipoa ocellata*). Report No. 1, NSW National Parks and Wildlife Service.

183. Raloff, J (1994). The gender benders. Science News 145: 24–27.

184. Ramsay, BJ (1994). Commercial Use of Wild Animals in Australia. Department of Primary Industry & Energy. Australian Government Publishing Service, Canberra.

185. Ramsay, B & O'Brien, P (1991). Pest control and commercial use of introduced animals: what are the issues? In: Ninth Australian Vertebrate Pest Control Conference, Adelaide, 1991, pp. 310–314.

186. Redhead, T, Singleton, G, Myers, K & Coman, B (1991). Mammals introduced to southern Australia. In: RH Groves & F DiCastro (eds). Biogeography of Mediterranean Invasions, pp. 293–308. Cambridge University Press, Cambridge.

187. Reynolds, LF (1983). Migration patterns of five fish species in the Murray Darling River System. Australian Journal of Marine and Freshwater Research 34: 857–871.

188. Ridpath, MG (1991). Feral animals and their environment. In: CD Haynes, MG Ridpath & MAJ Williams (eds). Monsoonal Australia: Landscape, Ecology and Man in the Northern Lowlands, pp. 169–191. Balkema, Rotterdam.

189. Ritson, P (1995a). Parrot damage to Bluegum tree crops: A review of the problem and possible solutions. Resource Management Technical Report 150, Agriculture Western Australia, 50 pp.

190. Ritson, P (1995b). Silviculture for managing parrot damage to Bluegum tree crops. Information paper, September 1995. Commonwealth Bureau of Resource Sciences, Vertebrate Pest Program, Department of Conservation & Land Management, Bunnings Treefarms Pty Ltd. & Australian Eucalypts Ltd.

191. Ritson, P (1995c). Control of parrot damage to Bluegums: A progress report on silviculture trials. Report to Commonwealth Bureau of Resource Sciences, Vertebrate Pest Program, November, 1995.

192. Robertson, LN, Story, PG & Wilson, J (1995). Integrated pest management for rodents in sugarcane. Unpublished Proceedings of the Conference of Australian Society of Sugarcane Technologists.

193. Rolls, EC (1969). They All Ran Wild. Angus & Robertson, Sydney.

194. Rose, B (1995). Land management issues: attitudes and perceptions amongst Aboriginal people of central Australia. Central Land Council, Alice Springs.

195. Royal Commission on Western Lands (1901). Western Division of New South Wales, Royal Commission to enquire into the condition of Crown Tenants. Report and Summary of Evidence, Part I. Votes and Proceedings of the Legislative Assembly 1901, Vol. 4.

196. Ryan, GE & Murray, RL (1973). An assessment of the Tarbaby method of rabbit control in New South Wales. New South Wales Department of Agriculture, Noxious Animal Research Report No. 1.
197. Saether, BE & Jonsson, B (1991). Conservation biology faces reality. Trends in Ecology and Evolution 6: 37–8.
198. Saunders, G, Coman, B, Kinnear, J & Braysher, M (1995). Managing Vertebrate Pests: Foxes. Department of Primary Industries & Energy. Australian Government Publishing Service, Canberra.
199. Scheiner, SM & Gurevitch, J (1993). Design and Analysis of Ecological Experiments. Chapman and Hall, New York.
200. Schodde, R & Tidemann, SC (1986). Reader's Digest Complete Book of Australian Birds. Readers's Digest Services, Surry Hills.
201. Seabrook, W (1993). Viewpoint: Cane toads—a criticism of research directions. In: D Lunney & Ayers (eds). Herpetology in Australia, a Diverse Discipline. Transactions of the Royal Zoological Society of New South Wales, Surrey Beatty Chipping Norton.
202. Seebeck, JH, Greenwood, L & Ward, D (1991). Cats in Victoria. In: The Impact of Cats on Native Wildlife. Workshop Proceedings, pp. 18–29. Australian National Parks and Wildlife Service, Canberra.
203. Shepherd, N & Caughley, G (1987). Options for management of kangaroos. In: G Caughley, N Shepherd, & J Short (eds). Kangaroos: Their Ecology and Management in the Sheep Rangelands of Australia. Cambridge University Press, Cambridge.
204. Short, J (1985). The functional response of kangaroos, sheep and rabbits in an arid grazing system. Journal of Applied Ecology 22: 435–447.
205. Singleton, GR & Brown, PR (in press). Management of mouse plagues in Australia: integration of population ecology, bio-control and best farm practice. Proceedings of the First European Vertebrate Pest Management Conference, September 1997, York.
206. Smith, MJ (1990). The role of bounties in pest management with specific reference to state Dingo control programs, study submitted to Charles Sturt University, Riverina.
207. Smith, P & Smith, J (1994). Historical change in the bird fauna of western New South Wales: ecological patterns and conservation implications. In: D Lunney, S Hand, P Reed and D Butcher (eds). Future of the Fauna of Western New South Wales, pp. 123–147. Royal Zoological Society of New South Wales, Mosman.
208. Strahan, R (ed.)(1995). The Mammals of Australia. Reed, Chatswood.
209. Streeting, MC (1990). A survey of the Hedonic Price Technique. RAC Research Paper No.1, Resource Assessment Commission. Australian Government Publishing Service, Canberra.
210. Thompson, P (1990). Dingo. In: J Lond (ed.). Declared Animal Handbook. Agriculture Protection Board, Western Australia.
211. Thomson, JM, Long, JL & Horton, DR (1987). 10. Human exploitation of and introductions to the Australian fauna. In: GR Dyne & DW Walton (eds). Fauna of Australia, Vol 1A—General Articles. Australian Government Publishing Service, Canberra.
212. Tilmouth, T (1995). Aboriginal perceptions of pest animals. A paper from Tracker Tilmouth, Central Land Council for the Vertebrate Pest Management Conference, Hobart, May 1995.
213. Tisdell, CA (1982). Feral pigs: environmental pest or economic resource? Pergamon, Sydney.
214. Tisdell, CA (1987). Feral pigs as a resource. In: Management of the feral pig in Australia. Report of a workshop, pp. 11–14. Agriculture Research Centre, Trangie, NSW.
215. Tisdell, CA. & Takahashi, S (1988). Feral animals in Australia—economic and ecological impact. Geographical Sciences 43: 37–50.
216. Tobin, ME, Koehler, AE, Sugihara, RT, Ueunten, GR & Yamaguchi, AM (1993). Effects of trapping on rat populations and subsequent damage and yields of macadamia nuts. Crop Protection 12: 243–248.
217. Twigg, LE, Martin, GR, Lowe, TJ, Griffin, SL & Gray, GS (1995). An experimental evaluation of controlling the fertility of wild rabbits (*Oryctolagus cuniculus*). Proceedings of the 10th Australian Vertebrate Pest Conference, Hobart, 384–391.
218. Tyndale-Biscoe, H (1990). Viral vectored immunosterilisation: a new concept in biological control of wild animals. Proceedings Fertility Control in Wildlife Conference, Melbourne.
219. Tyndale-Biscoe, H (1994). The CRC for Biological Control of Vertebrate Pest Populations: fertility control of wildlife for conservation. Pacific Conservation Biology 1(3): 163–68.
220. Tyndale-Biscoe, H (1995). Vermin and Viruses. Risks and Benefits of Viral-Vectored Immunosterilisation. Search 26(8): 239–244.
221. Underwood, AJ (1990). Experiments in ecology and management: their logics, functions and interpretations. Australian Journal of Ecology 15: 365–389.
222. van der Lee, G (1994). Tallaganda Times, 15 June 1994.
223. Watson, JS (1961). Feral rabbit populations on Pacific islands. Pacific Science 15: 591–593.
224. Wilks, L (1990). A survey of the contingent valuation method. RAC Research Paper No.2, Resource Assessment Commission. Australian Government Publishing Service, Canberra.
225. Williams, K, Parer, I, Coman, B, Burley, J & Braysher, M (1995). Managing Vertebrate Pests: Rabbits. Bureau of Resource Sciences & CSIRO Division of Wildlife and Ecology. Bureau of Resource Sciences. Australian Government Publishing Service, Canberra.
226. Williams, SL (1995). Malleefowl as a flagship for conservation on farms in the Murray Mallee of South Australia. In: DA Saunders, JL Craig & E Mattiske (eds). Nature Conservation 4: The Role of Networks, pp. 316–320. Surrey Beatty, Chipping Norton.
227. Wilson, AD & Hodgkinson, KR (1991). The response of grasses to grazing and its implications for their management of native grasslands. In: D Garden & AC Grice (eds). Proceedings of a Workshop on Australian Native Grasses, pp. 47–54. Australian Wool Corporation, Melbourne.
228. Wilson, G & Choquenot, D (1996). Review of feral pigs and exotic disease preparedness. Report in preparation for the Bureau of Resource Sciences, Canberra.
229. Wilson, G, Dexter, N, O'Brien, P & Bomford, M (1992). Pest Animals in Australia: A survey of introduced wild animals. Kangaroo Press & Bureau of Rural Resources, Canberra.
230. Winer, BJ, Brown, DR & Michels, KM (1991). Statistical Principles in Experimental Design, Third Edition. McGraw-Hill, New York.
231. Wirth, HJ (1995). Vertebrate pest control and animal welfare—the National Consultative Committee on Animal Welfare view. Unpublished paper presented at the 10th Vertebrate Pest Control Conference, Hobart.

Personal communications

232. Blick, R, Sydney, 1996.
233. Braysher, M, Canberra, 1997.
234. Copley, P, Department of the Environment and Natural Resources, 1992.
235. Garnett, S, Birds Australia, Melbourne, 1996.
236. Marks, C, Department of Environment and Conservation, Victoria, 1996.
237. Maynes, G, Environment Australia, 1997.
238. Ramsay, B, Pork Council of Australia, 1993.
239. Ritson, P, Agriculture Western Australia, 1996.
240. Saunders, G, NSW Agriculture, 1997.
241. Scheurmann, E, International Wool Secretariat, 1994.
242. Sinclair, R, Animal and Plant Control Commission, South Australia, 1995.
243. Temby, I, Natural Resources and Environment, Victoria, 1996.
244. Tilzey, R, Bureau of Resource Sciences, 1997.

Appendix 1

Selecting a management option

When evaluating management options, each situation needs to be assessed and the appropriate management option or combination of options identified. Too often, costly but inappropriate strategies are adopted in managing for both production and wildlife conservation values.

To help decide how best to allocate scarce resources, the Department of Conservation in New Zealand use a process for ranking areas according to their priority for pest control.[48, 155, 156]

First, conservation areas are divided into management units based on features such as catchments, vegetation types, or limits to the distribution of threatened plants or animals. Large areas are broken into smaller sub-sections whereas very small reserves may be grouped for ranking.

To determine the primary conservation score, the management units are ranked according to their conservation value. There are three steps in this process. First, the unit is scored on the value of its threatened native plants and animals. Plant and animal values are ranked on the following criteria: a high score of six for threatened plants or animals of national significance; five for those of exceptional value; four for those of very high value; three for high value; two for moderate value; and one for plants of animals of potential value. Factors considered include rarity, whether the species occurs elsewhere and the importance of the population as a representative of species throughout New Zealand.

Second, the unit is scored according to its vulnerability to pest animal damage. Scores vary from one for a unit in which the current level of pest damage is considered to be of no immediate threat, to 3.5 for a unit where a plant or animal species is considered to be at risk of national extinction due to pest animal damage.

Last, the primary score for each management unit is calculated by multiplying the highest score for native wildlife, whether it be a plant or an animal, by vulnerability to pest animal damage. For a management unit with a plant score of five, an animal score of four and a vulnerability weighting of three the score is 15. This is calculated by multiplying the highest score (five, for plants) by the vulnerability rating (three).

If necessary, management units with equal ranking can be sorted using a hierarchy of land attributes. Factors considered include the security of land tenure, presence of other valued native plants and animals, cultural heritage values, ease of access for control, absence of other pests and previous management action on the pests.

Those reserves where eradication is possible are assessed separately, according to criteria for eradication (see 'Criteria for local eradication', page 104–106).

Appendix 2

List of scientific names of species mentioned in the text

Arranged in alphabetical order, according to common name.

Plants

Australian hoop pines *Araucaria* spp.
Blackberry *Rubus fruticosus*
Bluegum *Eucalyptus globulus*
Norfolk Island Abutilon *Abutilon julianae*
Phillip Island Hibiscus *Hibiscus insularis*
saltbush *Atriplex* spp.
wattles *Acacia* spp.

Insects

blowflies *Calliphora* spp.

Fish

Atlantic Salmon *Salmo salar*
Black Mangrove Cichlid *Tilapia mariae*
Brook Trout *Salvelinus fontinalis*
Brown Trout *Salmo trutta*
European Carp *Cyprinus carpio*
European Perch (Redfin) *Perca fluviatilis*
Golden Perch *Macquaria ambigua*
Goldfish *Carassius auratus*
Mozambique Tilapia *Oreochromis mossambicus*
Murray Cod *Macculochella macquariensis*
Oriental Weather Loach *Misgurnus anguillicaudatus*
Rainbow Trout *Oncorhynchus mykiss*
Red-finned Blue-eye *Scaturiginichthys vermeilipinni*
Roach *Rutilus rutilus*
Silver Perch *Bidyanus bidyanus*
Tench *Tinea tinea*
Topminnow (Mosquito Fish) *Gambusia affinis*

Amphibians

Brown Tree Frog *Litoria ewingii*
Cane Toad *Bufo marinus*
Green and Golden Bell Frog *Litoria aurea*

Reptiles

goannas *Varanus* spp.
Grass Skink *Lygosoma bowringii*
House (Barking) Gecko *Hemidactylus frenatus*
Poisonous snakes *Elapids*
Saltwater Crocodile *Crocodylus porosus*

Birds

Australian Brush-turkey *Alectura lathami*
Australian Magpie *Gymnorhina tibicen*
Australian Ringneck *Barnardius zonarius*
Black Swan *Cygnus atratus*
Blue-faced Honeyeater *Entomyzon cyanotis*
Cape Barren Goose *Cereopsis novaehollandiae*
Common Blackbird *Turdus merula*
Common Myna *Acridotheres tristis*
Common Pheasant *Phasianus colchicus*
Common Starling *Sturnus vulgaris*
Crimson Rosella *Platycercus elegans*
crows and ravens *Corvus* spp.
currawongs *Strepera* spp.
Diamond Firetail *Emblema guttata*
ducks, several species
Eastern Rosella *Platycercus eximius*
Emu *Dromaius novaehollandiae*
Eurasian Tree Sparrow *Passer montanus*
European Goldfinch *Carduelis carduelis*
European Greenfinch *Carduelis chloris*
Figbird *Sphecotheres viridis*
Galah *Cacatua roseicapilla*
Great Bowerbird *Chlamydera nuchalis*
Great Cormorant *Phalacrocorax carbo*
House Sparrow *Passer domesticus*
Java Sparrow *Lonchura oryzivora*
Kakariki *Cyanoramphus novaezelandiae erythrotis*
Kangaroo Island Glossy Black-Cockatoo *Calyptorhynchus lathami halmaturinus*
Laughing Kookaburra *Dacelo novaeguineae*
Little Corella *Cacatua sanguinea*
Little Penguins *Eudyptula minor*
Little Pied Cormorant *Phalacrocorax melanoleucos*
Little Raven *Corvus mellori*
Long-billed Corella *Cacatua tenuirostris*
Lord Howe Woodhen *Gallirallus sylvestris*
Magpie Goose *Anseranas semipalmata*
Major Mitchell's Cockatoo *Cacatua leadbeateri*
Mallard *Anas platyrhyncos*

Malleefowl *Leipoa ocellata*
Nankeen Night Heron *Nycticorax caledonicus*
Norfolk Island Kaka *Nestor productus*
Nutmeg Manakin (Spice Finch) *Lonchura punctulata*
Rainbow Bee-eater *Merops ornatus*
Rainbow Lorikeet *Trichoglossus haematodus*
Red-billed Quelea *Quelea quelea*
Red-tailed Black-Cockatoo *Calyptorhynchus banksii*
Red-Whiskered Bulbul *Pycnonotus jocosus*
Rock Dove (Domestic Pigeon) *Columba livia*
Rose-ringed Parakeet *Psittacula krameri*
Senegal Turtledove *Streptopelia senegalensis*
shearwaters *Puffinns* spp.
Silvereye *Zosterops lateralis*
Skylark *Alauda arvensis*
Song Thrush *Turdus philomelos*
Spotted Turtledove *Streptopelia chinensis*
Sulphur-crested Cockatoo *Cacatua galerita*
Wedge-tailed Eagle *Aquila audax*
Weka *Gallirallus australis*
White-faced Heron *Egretta novaehollandiae*
Yellow Oriole *Oriolus flavocinctus*
Yellow-tailed Black-Cockatoo *Calyptorhynchus funereus*

Mammals

Agile Wallaby *Macropus agilis*
Alpaca *Lama pacos*
Bali Banteng *Bos javanicus*
Bilby *Macrotis lagotis*
Black (Ship) Rat *Rattus rattus*
Black Flying-fox *Pteropus alecto*
Black-footed Rock-wallaby *Petrogale lateralis*
Black-striped Wallaby *Macropus dorsalis*
Bridled Nailtail Wallaby *Onychogalea fraenata*
Brown Hare *Lepus capensis*
Brown Rat *Rattus norvegicus*
Brush-tailed Bettong *Bettongia penicillata*
Brush-tailed Rock-wallaby *Petrogale penicillata*
Burrowing Bettong *Betongia lesueur*
Canefield Rat *Rattus sordidus*
Cat *Felis catus*
Chital (Axis) *Axis axis*
Common Brush-tailed Possum *Trichosurus vulpecula*
Common Wallaroo *Macropus robustus*
Common Wombat *Vombatus ursinus*
Dingo *Canis familiaris dingo*
Dog *Canis familiaris*
Donkey *Equus asinus*
Eastern Barred Bandicoot *Perameles gunnii*
Eastern Grey Kangaroo *Macropus giganteus*
Eastern Hare-wallaby *Lagorchestes leporides*
Fallow Deer *Dama dama*
Ferret *Mustela furo*
Field Vole *Microtus agrestis*
Fox *Vulpes vulpes*
Goat *Capra hircus*
Grassland Melomys *Melomys burtoni*
Himalayan Thar *Hemitragus jemlahicus*
Hog Deer *Cervus porcinus*
Horse (Brumby) *Equus caballus*
House Mouse *Mus musculus*
Koala *Phascolarctos cinereus*
Little Red Flying-fox *Pteropus scapulatus*
native quolls *Dasyurus* spp.
Numbat *Myrmecobius fasciatus*
One-humped Camel *Camelus dromadarius*
Pale Field-rat *Rattus tunneyi*
Parma Wallaby *Macropus parma*
Pig *Sus scrofa*
Pig-footed Bandicoot *Chaeropus ecaudatus*
Platypus *Ornithorhyncus platyrhynchus*
Rabbit *Oryctolagus cuniculus*
Red Deer *Cervus elaphus*
Red Kangaroo *Macropus rufus*
Red-necked (Bennett's) Wallaby *Macropus rufogriseus*
rock-wallabies *Petrogale* spp.
Rufous Hare-wallaby (Mala) *Lagorchestes hisutus*
Rusa Deer *Cervus timorensis*
Sambar Deer *Cervus unicolor*
Sheep *Ovis aries*
Southern Brown Bandicoot *Isoodon obesulus*
Southern Hairy-nosed Wombat *Lasiorhinus latifrons*
Spotted-tailed Quoll *Dasyurus maculatus*
Swamp Buffalo *Bubalus bubalis*
Swamp Wallaby *Wallabia bicolor*
Tammar Wallaby *Macropus eugenii*
Western Grey Kangaroo *Macropus fuliginosus*
Western Ringtail Possum *Pseudocheiris occidentalis*
Whiptail Wallaby *Macropus parryi*
Yellow-footed Rock-wallaby *Petrogale xanthopus*

Animal names according to:

Christidis, L & Boles, W.E (1995). The Taxonomy of Species of Birds of Australia and its Territories. RAOU Monograph 2. Royal Australasian Ornithologists Union, Hawthorn.
De Decker, P & Williams, W.D (eds)(1986). Limnology in Australia. CSIRO, Melbourne and Dr W. Junk Publishers, Dordrecht.
Mackay, N & Eastburn, D (1990). The Murray. Murray Darling Basin Commission. Inprint, Brisbane.
Cogger, HD (1994). Reptiles and Amphibians of Australia. Reed, Chatswood.
Strahan, R (ed.)(1995). The Mammals of Australia. Reed, Chatswood.

Index

PEST ANIMALS cause losses worth many millions of dollars to Australia's agricultural production each year. They also contribute to land degradation and pose a major threat to some endangered native plants and animals. Rabbits, foxes, feral cats, horses, goats, pigs, carp and even mice all damage our agricultural and ecological communities. Yet many of these pest animals were introduced with the best intentions last century, in the belief that they would be an asset.

Why were such mistakes made? Can we stop it happening again? Can we control the damage caused by pests? This book looks at these questions, and the advances science has made in the field of pest control, and presents some new approaches and solutions.

Australia's Pest Animals is written for a general audience and no scientific training is needed to understand it. Dr Penny Olsen's writing is mostly non-technical and always easy to read. Yet, it describes sophisticated, scientifically-based techniques and strategies for pest animal control. These techniques are humane, cost-effective and fully consistent with the principles of ecologically sustainable land management.

This book will help farmers and natural resource managers to successfully reduce damage caused by pest animals. As a comprehensive overview of pest animal problems and their management, the book is also an important reference for policy-makers, teachers and students. Land managers, conservationists and other interested readers will gain fresh insights into one of the most significant environmental and agricultural protection issues in Australia today.

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