AUSTRALIAN VETERINARY EMERGENCY PLAN

AUSVETPLAN

2000

Wild Animal Management Manual

Strategic and Operational Guidelines

AUSVETPLAN is a series of technical response plans that describe the proposed Australian approach to an exotic animal disease incursion. The documents provide guidance based on sound analysis, linking policy, strategies, implementation, coordination and emergency-management plans.

Agriculture and Resource Management Council of Australia and New Zealand

This manual forms part of:

AUSVETPLAN Edition 2 1996

[AUSVETPLAN Edition 1 was published in 1991]

This document will be reviewed regularly. Suggestions and recommendations for amendments should be forwarded to the AUSVETPLAN Coordinator (see Preface)

Record of amendments to this manual:

Manual 6 of 6

PREFACE

This **Wild Animal Management Manual** is an integral part of the **Australian Veterinary Emergency Plan**, or AUSVETPLAN (Edition 2.0). AUSVETPLAN structures and functions are described in the **Summary Document**.

This manual sets out the management strategies and overall control procedures for wild animals for use in an animal health emergency in Australia. It has been approved by the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) out-of-session in December 1999.

This document replaces the series of manuals that comprised **Volume 4 Wild Animal Control**.

Technical information and policies for individual diseases are provided in the AUSVETPLAN **Disease Strategies.** The **Management Manuals** and other **Operational Procedures Manuals** provide information on the field implementation of strategies. Cross-references to strategies, manuals and other AUSVETPLAN documents are expressed in the form:

Document Name, Section no.
For example, **Decontamination Manual, Section 3**.

In addition, *Exotic Diseases of Animals: A Field Guide for Australian Veterinarians* by W.A. Geering, A.J. Forman and M.J. Nunn, Australian Government Publishing Service, Canberra, 1995 (**Exotic Diseases Field Guide**) is a source for some of the information about the aetiology, diagnosis and epidemiology of the disease and should be used in conjunction with this strategy.

Important documents that have been the source of some of the information in this manual and are useful resource material are provided in the References section.

The manual will be reviewed regularly. Suggestions and recommendations for amendments should be forwarded to:

The AUSVETPLAN Coordinator
National Office of Animal and Plant Health
Agriculture, Fisheries and Forestry — Australia
GPO Box 858
Canberra ACT 2601
Tel: (02) 6272 5540; Fax: (02) 6272 3372

Funding for production of this manual came largely from the Wildlife Emergency Disease Preparedness Program.

Membership of writing group

Glen Saunders (convenor)	NSW Agriculture
Chris Bunn	Agriculture, Fisheries and Forestry – Australia
Graeme Eggleston	NSW Agriculture
Graeme Garner	Agriculture, Fisheries and Forestry – Australia
Robert Henzell	Animal and Plant Control Commission of South Australia

Previous members

Graham Wilson	Department of Primary Industry and Fisheries, Northern Territory

Consultants

Hedy Bryant	NSW Agriculture
Sylvana Maas	NSW Agriculture

The writing group was responsible for drafting this manual. However, the text may have been amended at various stages of the consultation/approval process and the policies expressed in this version do not necessarily represent the views of all members of the writing group. Contributions may also have been made by other people not listed above and the assistance of all involved is gratefully acknowledged.

CONTENTS

TABLES and FIGURES

Part 1 STRATEGIC GUIDELINES

Part 1 of this manual provides the information needed for strategic planning of wild animal management programs, including:

1 INTRODUCTION

This manual has been written to assist with the management of wild animals in an emergency animal disease outbreak.

1.1 What are wild animals?

Wild animals include:

- *feral animals* (domestic animals that are free-ranging or have 'gone wild')
- *exotic fauna* (eg foxes)
- *native wildlife* (animals that are indigenous to Australia)

Feral animals and some introduced wild animals are often collectively referred to as *vertebrate pests*. These animals may be important in maintaining and/or transmitting livestock diseases and specific control activities may be necessary. Their involvement may also complicate the demonstration of disease freedom at the end of an eradication program. In other cases their involvement may be incidental, eg when they are 'dead-end' hosts, and no further action may be required.

Australia is fortunate that native wildlife do not appear to be at risk from many of the emergency diseases of concern (see the AUSVETPLAN **Summary Document** and the AUSVETPLAN **Zoos Enterprise Manual, Section 1.2**). However there are significant populations of feral animals that are undoubtedly susceptible to the same diseases as their domestic counterparts.

The key species covered by this manual are:

- large, feral herbivores—buffalo, camels, cattle, deer, donkeys, goats and horses
- feral pigs, also referred to as wild pigs
- wild carnivores—introduced foxes, feral and stray cats, and wild and urban/stray dogs and native dingoes

Other species include wild birds and bats. Rodents are not included in this manual as, with the exception of Aujeszky´s disease, their likely association with emergency disease is commensal. In an outbreak, control measures would probably be handled by commercial operators under direction from government agencies. While it is unlikely that any major control activities would be undertaken with these species, managers may well want to collect samples from them for disease surveillance.

1.2 Legislation and codes of practice

Legislation for the purpose of controlling emergency animal diseases has been enacted at Commonwealth and State levels. The Commonwealth legislation is primarily concerned with preventing the introduction and establishment of disease or of things that may carry disease. Statutory provisions exist in all States/Territories for the control and eradication of disease in animals. These provide for controls over animal movement, treatment, decontamination, slaughter and compensation. Wide powers are conferred on government inspectors, including the power to enter premises, order stock musters, test animals and order the destruction of animals and products that are suspected of being infected or contaminated.

The following State/Territory legislation may impinge on the activities that may be undertaken in controlling wild animals during an emergency disease outbreak:

- agricultural and veterinary chemicals and dangerous goods legislation covering the use of vertebrate pest poisons;
- workplace health and safety legislation;
- animal welfare legislation;
- legislation designed to protect endangered flora and fauna and sites of importance to indigenous communities (the types of control activities that may be undertaken may vary between States);
- other conservation legislation; and
- legislation requiring landholders to suppress and/or destroy various species of wild animals that pose a threat to agricultural production and the environment.

A more detailed list of the various Acts impinging on wild animal control in emergency diseases is given in Appendix 4. Also refer to Braysher (1993) *Managing Vertebrate Pests: Principles and Strategies* and subsequent species-specific volumes in this series (feral horses, rabbits, foxes, feral goats, feral pigs, wild dogs and rodents), for information on current vertebrate pest legislation.

2 EMERGENCY DISEASES OF CONCERN

2.1 Major emergency diseases which may affect wild animals

A brief introductory summary of each emergency disease that may affect wild animals is provided below. The list is limited to those diseases for which AUSVETPLAN strategies have been produced. Refer to the relevant parts of AUSVETPLAN **Disease Strategies, Sections 1.2 and 1.4.1** for information on susceptible species and clinical signs. Further information is also available in Geering et al (1995). A summary of the disease susceptibility of wild animal species is shown in Table 1.

Table 1 Emergency disease susceptibility of wild animal species

DISEASE	Horse	Pig	Goat	Deer	Cattle	Buffalo	Camel	Donkey	Fox	Dog	Cat	Bird	Bat	Rodent
AHS	■							■		▒				
ASF		■												
Aujeszky's		■	■	■	■	■	■		■	■	■			■
Bluetongue			■	■	■	■								
Capripox			■											
CSF		■												
EI	■							■						
FMD		■	■	■	■	■	■							
JE	■	■										■		
LSD					■	■								
ND												■		
PPR			■											
Rabies	■	■	■	■	■	■	■	■	■	■	■		■	■
RVF	▒		■		■	■	■	▒	▒	▒				▒
Rinderpest		▒	■		■	■	■							
SWF	■	■	■	■	■	■	■	■	■	■	■			
SVD		■												
TGE		■							■	■	■			
TSEs			■	■	■	■					■			
VE		■												
VAI												■		
VS	■	■	▒		■	■		■						

Key: ■ = susceptible ▒ = unknown □ = not susceptible

African horse sickness (AHS)

An infectious, insect-borne, viral disease of horses and mules. Horses are more susceptible than mules. In general donkeys have a lower susceptibility. It is frequently fatal in susceptible horses. The virus is transmitted by midges (*Culicoides* spp) Consequently there is a seasonal incidence in temperate climates. Recovered horses develop good immunity to the serotype that infected them but remain susceptible to other serotypes. Horses do not become long-term carriers. Dogs can become infected through the ingestion of virus-contaminated horsemeat. Usually they contract a fatal form of the disease, and it is doubtful whether dogs play any role in the spread or maintenance of disease virus.

Susceptible wild animals: ***horses, donkeys and dogs***

African swine fever (ASF)

A highly contagious, generalised viral disease affecting only pigs. It is transmitted by direct contact, inanimate objects and ticks. The virus is very resistant to inactivation. The acute form of the disease is characterised by a mortality of up to 100% in infected herds. Milder forms of the disease also occur. Pigs that survive acute disease or are infected by mild strains can become chronically infected for several months although virus is only thought to be excreted for 5–6 weeks. In Europe, wild pigs can become infected and may be a reservoir of infection for domestic pigs.

Susceptible wild animals: ***pigs***

Aujeszky’s disease (pseudorabies)

This disease is caused by a herpes virus that infects the nervous system and other organs such as the respiratory tract. Pigs are the major hosts, with sporadic cases occurring in cattle, sheep, goats, foxes, rats and other species. Ruminants are generally considered to be ‘dead-end’ hosts. Rodents and wild animals may have a role in maintaining and spreading the disease. In dogs and cats there can be intense pruritus, paralysis of the throat, convulsions with deaths occurring in 48 hours in dogs, and often more rapidly in cats. Pigs may remain latently infected following clinical recovery.

Susceptible wild animals: ***pigs, cattle, goats, dogs, cats, foxes and rats***

Bluetongue

A viral disease of ruminants transmitted only by specific species of biting midges (*Culicoides* spp). Sheep are the most severely infected; infection in cattle is generally subclinical. Naturally occurring disease has not been seen in Australia, although serotypes of the virus, some pathogenic, have been detected in northern and eastern Australia.

Susceptible wild animals: ***cattle, goats, buffalo and deer***

Capripox (sheep pox and goat pox)

Sheep and goat pox are closely related diseases, often with a high mortality rate. Sheep and goat pox are generally host specific, but strains from some areas have been reported to affect both species. The viruses are very resistant to inactivation in the environment. Insects may be involved in spreading the virus. Feral goats could be involved in maintaining the disease in some areas of Australia.

Susceptible wild animals: ***goats***

Classical swine fever (hog cholera; CSF)

A highly contagious and usually fatal viral disease capable of spreading rapidly in susceptible pig populations. Strains of lower virulence cause subacute and chronic forms of the disease. Some pigs can become subclinical carriers of the disease. In Europe, infection of wild pigs is important in the maintenance of the disease.

Susceptible wild animals: ***pigs***

Equine influenza (EI)

An acute respiratory viral disease that may cause rapidly spreading outbreaks in congregated horses. It is caused by two members of the genus *Influenzavirus.* Other equines are susceptible. Particularly severe disease has been seen in donkeys. Feral horses and donkeys are unlikely to serve as a source of infection to domestic horses since close direct contact is required to spread the disease, and the virus only retains infectivity in the environment for a couple of days.

Susceptible wild animals: ***horses and donkeys***

Foot-and-mouth disease (FMD)

An acute, highly contagious viral infection of domestic and wild cloven-hoofed animals. Serious production losses can occur, but deaths are unlikely except among young animals. Pigs are considered important amplifying hosts because of their susceptibility to oral infection and their capacity to excrete large amounts of virus. Cattle are considered good indicators of the presence of the disease because of their high sensitivity to infection. Sheep and goats are often considered maintenance hosts because disease can be present with few clinical signs. Ruminants, but not pigs, can become carriers of the virus. The role of carrier animals in the transmission of FMD has been uncertain, and transmission from carrier to susceptible cattle has never been unequivocally demonstrated. However, there is now clear evidence from Africa of transmission from carrier buffalo and cattle under field conditions.

Susceptible wild animals: ***cattle, buffalo, deer, pigs, goats and camels***

Japanese encephalitis (JE)

A mosquito-borne viral disease of humans and animals that occurs throughout much of Asia. In pigs, it is mainly associated with abortion, in humans and horses with encephalitis, which is often severe and fatal. Waterbirds (herons and egrets) are the main reservoir for spreading the JE virus, and together with pigs are important amplifying hosts. Inapparent infections occur in cattle, sheep, goats, dogs, cats, rodents, snakes and frogs. While several species of bats are susceptible to the virus, generally the susceptibility of native fauna is not known, but they may prove to be significant hosts.

Key susceptible wild animal: **pigs, horses, waterbirds (inapparent disease)**

Lumpy skin disease (LSD)

An acute, highly infectious, generalised viral skin disease of cattle. It is caused by a member of the *Capripoxvirus* genus, similar to that which causes sheep and goat pox. Biting flies and mosquitoes are thought to transmit the virus mechanically. Cattle are thought to be the maintenance host and feral cattle and buffalo could be a source of infection for domestic animals.

Susceptible wild animals: ***cattle and buffalo***

Newcastle disease (ND)

A highly contagious, lethal, viral disease of chickens, turkeys and other birds. Many species of wild birds are susceptible. Psittacines and pigeons have been implicated in outbreaks overseas. Viral strains vary widely in their virulence. Severe strains cause rapid death. Destruction of wild birds is impractical and control should centre on ensuring wild birds do not come into contact with domestic birds. Some sampling of wild birds may be required.

Susceptible wild animals: ***many species of wild birds***

Peste des petits ruminants (PPR)

PPR in sheep and goats resembles rinderpest of cattle (see below) and is caused by a closely related virus. It produces high morbidity and mortality. It tends to be more severe in goats than sheep. Recovered animals do not become chronic carriers.

Susceptible wild animals: ***goats***

Rabies

An almost invariably fatal viral encephalitis affecting all warm-blooded animals. Birds are of very limited importance in the epidemiology of rabies. It has a long and variable incubation and is transmitted by the bite of a rabid animal. While the virus can infect a wide range of species, in any given region it tends to be ‘maintained’ by a particular species to which the virus is adapted. In different parts of the world different species can be maintenance hosts. There are both urban and sylvatic (wildlife) rabies cycles. In urban cycles, dogs are the species responsible for maintaining and spreading rabies. With sylvatic rabies, the main maintenance hosts include members of the family Canidae (wild dogs, foxes, jackals, wolves), with other species including the raccoon, skunk, mongoose, meerkat and bats. If rabies is controlled in the maintenance species then the disease tends to die out. It is extremely important to determine the strain involved, as this will establish the key animals that need to be targeted in control programs. Depending on the strain of rabies introduced, sylvatic cycles could become established involving wild dogs, foxes, bats or cats[1] as maintenance hosts in Australia. Recently, a lyssavirus closely related to rabies has been found in bats in Australia.

Susceptible wild animals: ***dogs, cats, foxes and bats are potential hosts***

Rift Valley fever (RVF)

This is a mosquito-borne disease affecting a wide range of vertebrate hosts. Mosquitoes are believed to maintain the virus, which can remain in dormant mosquito eggs for several years. Cattle, sheep, goats and humans are the major species affected; amplification of the virus occurs in cattle. The disease is characterised by high rates of abortion and high rates of mortality in young animals. Severe disease can occur in humans so special safety precautions are required.

Susceptible wild animals: ***goats, cattle, buffalo, camels, donkeys, horses, foxes, dogs and rodents***

Rinderpest

An acute, highly contagious disease, for which cattle and buffalo are the major hosts. Subclinical infections may occur in sheep and goats. The virus is related to measles, canine distemper, and PPR. The virus is not stable in the environment. When the disease occurred in Southeast Asia, native breeds of pigs were quite susceptible, but European breeds were resistant. Many cloven-hoofed wild animal species in Africa are susceptible, including African buffalo and species of wild pig. There is no chronic carrier state. Because of their isolated populations, feral cattle and buffalo are unlikely to play a major role in spreading the disease in Australia. The potential role, if any, of feral pigs in spreading the disease in Australia is unclear.

Susceptible wild animals: ***cattle, pigs, goats, buffalo and camels***

Screw-worm fly (SWF)

Myiasis caused by larvae of the screw-worm fly is characterised by larvae feeding on living tissues in open wounds of any warm-blooded animal host, resulting in debility and some deaths. The flies prefer warm moist conditions and temperatures from 16° to 30°C.

Susceptible wild animals: ***potentially all wildlife species***

Swine vesicular disease (SVD)

Swine vesicular disease is caused by an enterovirus closely related to the human Coxsackievirus B5. It is characterised by fever and lameness due to vesicles and erosions on the feet. It is clinically indistinguishable from FMD. The virus is resistant to inactivation. Feral pigs could become infected through eating contaminated garbage.

Susceptible wild animals: ***pigs***

---

[1] On their own cats are unlikely to be a maintenance host. In the WHO World Survey of Rabies (1996) only seven cats compared with 969 dogs were considered to be the source for cases of human rabies.

Transmissible gastroenteritis (TGE)

An enteric virus disease of pigs, caused by a coronavirus, which results in rapid death of piglets under three weeks of age. Disease only occurs in pigs, although dogs, cats and foxes are susceptible to infection. The virus is spread by the faecal–oral route. Recovered pigs occasionally become carriers. Dogs, cats and foxes may be a source of infection for pigs.

Susceptible wild animals: ***pigs, dogs, cats and foxes are susceptible***

Transmissible spongiform encephalopathies (TSEs)

This disease group includes bovine spongiform encephalopathy (BSE) found in cattle, scrapie in sheep and goats, and chronic wasting disease in deer (CWD). They are all progressive degenerative diseases of the central nervous system and are always fatal. All are believed to be caused by an unconventional agent usually called a prion.

BSE

Cattle are the main natural hosts. There are no known breed differences in susceptibility per se, but epidemiological factors have dictated a much higher incidence in dairy breeds overseas. Some cases of spongiform encephalopathy, related to the BSE epidemic, have also occurred in antelopes and cats (both domestic and exotic).

Scrapie

Sheep and goats are affected. Scrapie can be experimentally transmitted to mice, rats, hamsters, monkeys and a wide range of other wild or laboratory species as well as to its natural hosts.

Chronic wasting disease

CWD is a spongiform encephalopathy of cervids that was recognised in 1967 and has been identified in mule deer, white-tailed deer and elk in the United States. Most cases have been in captive deer but some cases have occurred in free-ranging animals. CWD is transmissible and fatal. The main clinical signs are progressive weight loss, behavioural changes, excessive salivation, excessive water consumption and frequent urination. The pathology in the brain is typical of the other spongiform encephalopathies.

Susceptible wild animals: ***cattle, buffalo, goats and deer, cats***

Vesicular exanthema (VE)

The clinical disease is indistinguishable from FMD. The VE virus is very closely related to viruses isolated from marine animals. Disease in pigs has been associated with the feeding of contaminated food scraps containing marine animal product. The pig is the only terrestrial mammal in which VE has been observed under natural conditions.

Susceptible wild animals: ***pigs***

Virulent avian influenza (fowl plague; VAI)

A lethal generalised disease of poultry caused by specific types of avian influenza virus. Disease outbreaks occur most frequently in chickens and turkeys. Many wild bird species, particularly waterbirds and seabirds, are also susceptible, but infections are generally subclinical. Waterbirds are suspected of being the source of infection for domestic poultry in many outbreaks, including those that have occurred in Australia. Destruction of wild birds is impractical and control should centre on ensuring wild birds do not come into contact with domestic birds. Some disease sampling of wild birds may be required.

Susceptible wild animals: ***many species of wild birds, especially waterbirds***

Vesicular stomatitis (VS)

Vesicular stomatitis is principally a disease of cattle, horses, and pigs. It can cause signs indistinguishable from FMD. The disease has only been seen in North, Central and South America. The epidemiology of the disease is still unclear, but transmission cycles between insects and small wild ruminants are known to occur. A wide range of other species may be involved, including New World species of wildlife (deer, antelope, big-horn sheep, monkeys, rodents and bats).

Susceptible wild animals: ***horses, goats, donkeys, cattle, buffalo and pigs***

3 SPECIES ECOLOGY AND BIOLOGY

3.1 Introduction

This section provides information on the ecological factors that affect the likelihood that a wild animal species will *contract, maintain and/or spread disease*.

There are a number of ecological factors that affect disease transmission, maintenance, dispersal and the rate of spread.

- *Population distribution and density*—affects contact rates between susceptibles and infectives. Disease maintenance and transmission is enhanced at higher densities, while distribution of wildlife can determine the area over which a disease is likely to occur (eg isolated versus continuous).

- *Habitat requirements* (including food requirements, refuges, denning sites etc)—directly linked to the likely density and distribution of wildlife hosts and the limitations of control operations.

- *Social organisation*—group sizes and dominance hierarchies may affect disease transmission and maintenance. Herding versus solitary behaviour can affect ability to detect disease within a population, while changes to social organisation at particular times of the year (eg breeding) can cause increases in contact rates and transmission. Territorial versus non-territorial behaviour can also influence disease dynamics.

- *Reproductive status and seasonality*—normal breeding and seasonal behaviours will lead to variability of contact rates, range size and population density.

- *Age structure of population*—disease dynamics differ between populations with a uniform age distribution or a high turnover (eg diseases with a long latent period might only be detected in older animals).

- *Home range*—directly determines the area over which the disease can be spread and the likely requirements of population control. As a general rule, the larger the animal the larger the home range.

- *Movements and distances travelled*—there may be sex and seasonal as well as group effects. Some species (eg foxes) undergo yearly periods of dispersal during which large distances can be travelled in short time periods. There can also be large variation in rate of movement and distances travelled by individuals within populations at any time of the year.

- *Barriers to dispersal*—some natural or artificial barriers will restrict movements of animals and hence rate of disease spread. These can also be used as boundaries to control operations.

- *Response to disturbance*—in some cases the imposition of control operations could cause animals to disperse from localised areas, although existing evidence suggests otherwise.

- *Interactions between wildlife species and domestic stock*, for example at water points.

Local wildlife/vertebrate pest control officers or species experts/wildlife biologists should be consulted to obtain current and local information on the ecology of susceptible wild animal species.

The role that wild animals would play in an emergency disease outbreak is unclear. There is enormous variation in their distribution, density and habits between and within regions in Australia. Wild animals in Australia are generally difficult to manage. The success of control operations is also frustrated by the ability of some species to avoid detection; relocate to other, sometimes inaccessible, areas under the pressure of control or hunting; rapidly repopulate areas that have been subject to control operations; and breed all year round where water, food and other necessary resources are abundant. As a guide, the key factors likely to influence the maintenance and/or transmission of an emergency disease and its control in each wild animal species are presented in boxed summaries that follow. Some of the main ecological and biological attributes are shown in Tables 2, 3, and 4.

3.2 Summaries of important ecological factors for wild animal species

3.2.1 Bats (*Chiroptera*)

Bats belong to the order Chiroptera, which is divided into two suborders, the Megachiroptera and the Microchiroptera.

The Megachiroptera includes not only the larger bats, such as flying foxes or fruit bats, but also several small blossom bats. All Megachiroptera are fruit, blossom, or nectar feeders. They have large eyes and simple oval ears, and their facial features resemble small foxes or dogs. They use their excellent night vision and sense of smell to find food.

The four largest species are called flying foxes and belong to the genus *Pteropus*. The Australian range of the flying foxes extends from temperate eastern and coastal Australia into the eastern tropics, around the tropical northern coastline, and down as far as the subtropical west coast. The most common species—the little red flying fox—can be found in camps that include over 100 000 individuals, a factor that would readily facilitate the transmission of disease agents.

The Microchiroptera are small bats, which in Australia are all insectivorous, with one species being carnivorous as well. They are found in many parts of Australia, from the cold southern regions to the arid inland and the tropical north. The southern species are mostly insect eaters that roost in tree hollows or under bark, mostly near water. Most insect-feeding bats in tropical Australia live in caves or in old mines. The bent-winged bat has been known to migrate several hundred kilometres during colder months to warmer areas.

The role that native Australian bats might play in an exotic or emergency disease outbreak is undefined. The great mobility of bats gives them the potential to transmit viruses thousands of kilometres. Bats are responsible for the majority of rabies infections occurring in terrestrial mammals outside enzootic areas, but the disease does not appear to become established in these populations.

Several novel viruses have been discovered in Australia in the last decade. Two, and possibly three, of these are human pathogens. They include Hendra virus (formerly known as equine morbillivirus), which has been the cause of death in horses and humans, Menangle virus (formerly known as pig paramyxovirus, which causes foetal pig wastage and influenza-like illness in humans, and Australian bat lyssavirus, a rabies-related virus that has caused two human deaths. Australian bats are considered to be natural hosts for all three viruses.

KEY FACTORS — BATS

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- They have a long lifespan (most bats live for about 10 years but some may live up to about 25 years).
- The colonial habits of many bat species provide a highly efficient arena for the transmission of viruses from bat to bat.
- Fruit bats are largely restricted to tropical forests where succulent fruits can be found throughout the year. However, those living in temperate regions may engage in considerable seasonal migration in search of food.

Other factors

- Most of the 22 genera of Australian bats also occur in New Guinea and Asia.
- Bats play a very important role in controlling insect populations, in plant pollination and in spreading plant seeds.
- Eradication of bats, except through habitat destruction in a confined location is not feasible.

3.2.2 Buffalo *(Bubalis bubalis)*

Feral buffalo, once widely distributed near permanent water in the Northern Territory, have had their distribution and density drastically reduced by the Brucellosis and Tuberculosis Eradication Campaign. By 1990 buffalo only existed in large numbers in Arnhem Land and as tuberculosis-free domestic stock. Their numbers are expected to increase when the campaign ends in the near future (Henzell et al 1999).

KEY FACTORS — BUFFALO

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral buffalo have a distribution that overlaps with domestic cattle and other feral animals.
- They occur along the Northern Territory coast, placing them at risk of contact with unauthorised boat landings.
- They are able to breed all year round where food and water is abundant.
- Their wallowing habits are likely to increase the probability of disease transmission to other species that drink from or share the wallows, especially pigs.
- Bulls and cows congregate (up to 500 animals) in the wet season for breeding which may increase the probability of disease transmission.
- Under stress, groups may leave their home range and move into another group’s home range.
- Control operations may alter the behaviour of surviving buffalo (eg feeding at night and retreating to cover during the day, and possibly hiding from aircraft) making it difficult to locate residual animals.

Factors that reduce the risk

- Their distribution is limited, being confined to the ‘Top End’ of the Northern Territory.
- They do not tend to move great distances and have stable, relatively small home ranges (200–1000 ha).
- Dispersal is restricted by the availability of permanent fresh water to wallow in and drink.
- The Judas animal method has been highly successful in locating residual buffalo.

3.2.3 Camels (*Camelus dromedarius*)

In Australia feral camels are irregularly distributed throughout the arid zone of central Australia. They tend to live in the most remote areas away from habitation (Siebert and Newman 1989) in sand dune and spinifex (*Triodia* spp) country (Short et al 1988).

KEY FACTORS — CAMELS

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- During periods of drought, large numbers of feral camels (up to 500 animals) congregate near watering points, where they have been observed to interact with domestic livestock.
- They can travel great distances (50–70 km per day and up to 5500 km per year).
- They compromise the security of other animals by damaging cattle fences.

Factors that reduce the risk

- Feral camel populations have low densities.
- They inhabit very remote areas, away from habitation.

3.2.4 Cats *(Felis cattus)*

Moodie (1995) defines feral and stray cats as follows:

- *feral cat*—a free-living cat that has minimal or no reliance on humans; it survives and reproduces in self-perpetuating populations

- *stray cat*—a cat that relies on humans for some of its ecological requirements

Feral cats are distributed Australia-wide in most terrestrial habitats. They are a highly adaptable species and few environmental factors limit their distribution in Australia (Wilson et al 1992). They are very susceptible to rabies and are becoming the principal source of infection for humans in some countries (Bunn 1991).

KEY FACTORS — CATS

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral cats are widely distributed across Australia.
- They are highly adaptable and can survive and reproduce in almost all habitats.
- The density of feral cats is often highest where they are associated with humans (stray cats).
- They have a high potential rate of increase (feral cats in south-eastern mainland Australia have, on average, two litters per year) so that maintaining low population densities will be expensive and require ongoing efforts.
- No feral cat control techniques have been shown to be effective in substantially reducing numbers over large areas.
- While the home range of a feral cat tends to be stable, movements and dispersal that may contribute to disease spread occur, for example:
  - moving out to find prey and sometimes living commensally with people;
  - exploratory or migratory movements; and
  - movement away from the natal home range (settle some 4–8 km away) by young males before breeding (other immature animals may move in to take their place).

Factors that reduce the risk

- The home ranges of urban/stray cats tend not to overlap.
- Restricting the movements of urban cats at night would reduce the likelihood of their contact with other wild animals.
- Feral cats are largely solitary animals.
- They tend not to move great distances and have stable, relatively small home ranges.

3.2.5 Cattle *(Bos taurus* and *Bos indicus)*

Feral European cattle (*Bos taurus)*, zebu cattle *(Bos indicus)* and their hybrids have formed wild populations. These are largely limited to northern Australia, where they occur in many rugged and remote areas where it is difficult to muster. Their numbers in northern Australia have been greatly reduced during the Brucellosis and Tuberculosis Eradication Campaign (Wilson et al 1992). Feral cattle often occur in areas where domestic animals have been allowed to free-range (Strahan 1995). These cattle do not remain wild for long as once their existence is known they are captured or killed for economic and/or disease control purposes. They are neither widespread nor abundant.

KEY FACTORS — CATTLE

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral cattle share the same pathogens as domestic cattle and may interact with domestic stock.
- They are usually located in inaccessible terrain.
- Apart from bulls, they are gregarious, tending to run in groups (10–30 animals in northern Australia).
- They have a wary and skittish temperament.

Factors that reduce the risk

- Feral cattle populations are neither widespread nor abundant due to their economic value, and are largely limited to northern Australia.
- They are usually easily detected, mustered and captured or killed.

Note: Banteng cattle have only a limited and remote distribution on the Cobourg Peninsula in the Northern Territory. Nevertheless, outbreaks of screw-worm fly, an insect-borne virus, or any disease readily transmitted between banteng and horses or pigs, would constitute a significant threat.

3.2.6 Deer

Six species of feral deer occur in Australia: chital (*Axis axis)*, sambar *(Cervus unicolor)*, rusa *(Cervus timorensis)*, hog *(Axis porcinus)*, red *(Cervus elaphus)* and fallow *(Dama dama)*. These species are usually found only in small, fragmented colonies in isolated areas over much of Australia, except in semiarid and arid areas and Western Australia. Individually and collectively, the distribution of these species is much more restricted than those of the other feral herbivores. Deer are generally found in vegetated hilly areas interspersed with agricultural land, although they have little contact with domestic animals (Henzell et al 1999). However, in Tasmania deer may graze in close proximity to domestic stock.

KEY FACTORS — DEER

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral deer have gregarious, social behaviour (with the exception of sambar and hog deer) and form large groups (up to 100 animals), which increases the probability of disease spread.
- They travel long distances and have cryptic behaviour.
- Their ability to become nocturnal in response to human disturbance, making control more difficult.
- They often live in rugged inaccessible terrain, which makes aerial and ground shooting difficult.

Factors that reduce the risk

- The distribution of feral deer is limited to small, localised populations so deer are unlikely to play an important role in an emergency disease.
- Sambar and hog deer, in particular, are solitary or live in small groups.
- Their dispersal is limited by hunting pressure and lack of suitable habitat.

3.2.7 Dogs *(Canis familiaris dingo* and *Canis familiaris familiaris)*

Wild dogs in Australia can be separated into three groups: the dingo (*Canis familiaris dingo*); the wild domestic dog (*Canis familiaris familiaris*) and a hybrid of these two.

In addition there is the stray urban dog, which may also play a role in the spread of canine rabies.

The dingo was originally distributed throughout mainland Australia. Today, pure dingoes are most commonly found in the northern part of Australia, hybrid dogs on the south-east coast and in the south-western corner, and wild domestic dogs near towns and cities. Wild dogs are absent in Tasmania (Wilson et al 1992).

KEY FACTORS — DOGS

Factors that increase the risk of maintaining, transmitting and dispersing canine rabies

- The distribution of wild dogs is widespread. Of particular concern are populations on the outskirts of towns and cities that are in contact with humans and domestic stock.
- Urban stray dogs on the outskirts of towns make frequent/sporadic forays into the surrounding bush and countryside, which could provide a link between urban and wild animals.
- Wild dogs have a potential high rate of increase because they can breed all year in cooler temperate climates (eastern highlands) and produce up to two litters of 4–5 pups per year.
- They form packs/groups, which increases the risk of disease transmission between the animals.
- Dingoes disperse when food availability is limited, potentially spreading disease over large areas.

Factors that reduce the risk

- High temperatures and lack of water/prey in many parts of Australia restricts the breeding and distribution of wild dogs.
- Dingoes that occur in packs have relatively stable territorial boundaries so that protection of areas using buffer zones is a viable option (forays of dingoes out of their territory or range is rare).
- The presence of natural (escarpment) and constructed (dingo fencing) barriers limit their dispersal.

3.2.8 Donkeys *(Equus asinus)*

Feral donkeys occur predominantly in open country, in northern Western Australia, the Northern Territory and northern South Australia, and in isolated pockets of Queensland and New South Wales. Most of these areas are arid or semiarid. Donkeys are more sure-footed than horses and are often found among hills (Henzell et al 1999).

KEY FACTORS — DONKEYS

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral donkeys are widely distributed over pastoral districts in the Northern Territory and Western Australia, and in scattered locations in South Australia and Queensland, where they are considered to be an agricultural and environmental pest.
- They have a relatively high reproductive potential regardless of food availability, although survival of foals is greatly reduced when food is limited.
- They are able to survive dry periods better than other ungulates, tolerating exposure to high temperatures and the absence of surface water.
- They lack territoriality and have a habit of congregating around residual waterholes during the dry season in large groups (up to 500 animals).

Factors that reduce the risk

- Although feral donkeys are widely distributed, they tend to be only found in remote locations.
- A successful removal method has been developed involving continual ‘mustering up’ and killing of animals during control campaigns and not allowing surviving animals to disperse from the area during control (Wheeler 1987).
- Judas donkeys aid the location of residual animals.

3.2.9 Foxes *(Vulpes vulpes)*

Foxes have established throughout the southern half of Australia, with the exception of Tasmania and Kangaroo Island (Wilson et al 1992). Their distribution appears to be limited in some, but not all, areas by the presence of dingoes and the absence of rabbits (Saunders et al 1995). Their distribution also appears to be limited in the north by humid tropical conditions (Wilson et al 1992). In the north their distribution is not continuous, and they occur in isolated pockets, for example in the Kimberley region of Western Australia and the Victoria River and Barkly Tablelands of the Northern Territory (King and Smith 1985).

KEY FACTORS — FOXES

Factors that increase the risk of maintaining, transmitting and dispersing rabies

- Feral foxes are widely distributed throughout the southern half of Australia.
- Their high densities in urban habitats bring them into contact with humans and domestic animals.
- They form family groups where food and other resources are abundant, which favours disease transmission.
- Subadult foxes, particularly males, disperse between late summer and the onset of breeding in winter, with two distinct phases of movement: a sudden, quick movement involving straight line travel; followed by slower, less directed movements persisting until new territories are established.
- They disperse over long distances (up to 300 kilometres for adult males).
- Surveillance and control operations may be difficult because:
  - density estimates of foxes are often difficult to obtain and may be inaccurate due to the nocturnal and elusive nature of the fox, and cyclic changes in their density;
  - the variable nature of fox behaviour and home ranges invalidates extrapolations from one area to another, and necessitates careful planning for specific areas;
  - there is continuous distribution in many areas;
  - there is rapid reinvasion of an area following intensive control operations;
  - bait shyness may occur in populations in areas regularly baited.

Factors that reduce the risk

- The risk of the fox strain of rabies entering Australia is very low.
- Foxes do not appear to leave their home range in response to intense control activities.
- Although fox densities are higher in urban areas, their home ranges are smaller.

3.2.10 Goats *(Capra hircus)*

Feral goats occur in all states, in the Australian Capital Territory. and on several islands off the Northern Territory coast. They are most prevalent in hilly or scrubby parts of the sheep-grazed dingo-free areas of Queensland, New South Wales, South Australia and Western Australia, and in isolated colonies in scrub patches in the agricultural areas of these states (Henzell et al 1999). Within these areas their numbers are limited by one or a combination of the following factors: food availability, water, predation and disease (Parkes et al 1996).

KEY FACTORS — GOATS

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral goats breed all year round where food and water is abundant.
- The large size of their groups (up to 1000 animals observed) increases the probability of disease spread.
- Their large home ranges (up to 600 sq km for males and 200 sq km for females) and ability to move large distances (up to 30 km in 6 weeks in arid areas) means control areas for feral goats would have to be large.
- Feral goats readily move through most stock fences, making containment difficult.
- They sometimes intermingle with sheep while grazing and at water, which would facilitate disease spread between the species.
- Control and containment of disease may be difficult as control operations may cause goats to become wary and relocate to inaccessible areas.
- The enormous variation in feral goat densities, both between and within regions, further compound survey and control operation difficulties.

Factors that reduce the risk

- Populations of feral goats can be quickly reduced by a concerted mustering effort.
- Dispersal is limited by access to water, and interaction with dingoes, dogs or humans.
- The Judas goat method has been effective for locating and removing recalcitrant goats.

3.2.11 Horses *(Equus caballus)*

Feral horses are widely distributed in arid and semiarid northern and central Australia, predominantly in flat to rolling open country (Henzell et al 1999), often associated with cattle-raising areas. Smaller, isolated populations occur in wetter areas of southern Australia, especially the Australian Alps. There are no feral horses in Tasmania or the ACT (Dobbie et al 1993).

KEY FACTORS — HORSES

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral horses are widely distributed, particularly in northern Australia, and their habitat overlaps with that used for cattle raising.
- They live in overlapping home ranges, in harems or bachelor groups and their congregation in large cross-social groups (up to 100 animals) to share food and water resources would increase the probability of disease spread.
- They move large distances (up to 50 km from water to feed) and hence they have the potential to spread disease over large areas.
- They use hilly country to escape capture, which may hamper control operations and there may be difficulties removing residual animals that have become wary after being shot at but missed during control operations.

Factors that reduce the risk

- Feral horses tend not to be found where domestic horses are kept.
- They have a low reproductive capacity, mares generally only having a foal every two years.
- They do not disperse under control pressure and their dispersal is limited by human habitation and access to permanent water.
- In drier areas, control operations can be centred around waterholes with a high degree of success.

3.2.12 Pigs (*Sus scrofa)*

Feral pigs are widely distributed throughout a range of habitats in Queensland, the Northern Territory, New South Wales, and the Australian Capital Territory. Isolated populations occur in Victoria, South Australia, Western Australia and on Flinders Island in the Bass Strait. In mainland Tasmania, accidental releases led to small, temporary populations. In inland and seasonally dry areas of Australia, they are restricted to the vicinity of watercourses and associated floodplains. Populations are, however, still spreading in the more forest-covered parts of eastern and south-western Australia where access to daily water and shelter are not limited (Choquenot et al 1996).

KEY FACTORS — PIGS

Factors that increase the risk of maintaining, transmitting and dispersing diseases

- Feral pigs are distributed over a wide range of habitats, including agricultural areas, where they mix with other feral animals and domestic animals.
- They are scavengers — feeding on refuse and carcases.
- They have a potentially high rate of population growth where food, water and shelter is abundant (producing 2 weaned litters every 12–15 months, with an average of 5–6 piglets/litter), which means reducing and maintaining low population densities will be difficult, expensive and ongoing.
- They are occasionally found in large groups, particularly in tropical Australia (>100 observed around waterholes) and the interaction between individuals from groups in different litters early in life would facilitate disease transmission.
- The ability of boars to move great distances daily and over a period of time would facilitate disease spread.
- Their wallowing habits may increase the probability of disease transmission to other species that drink from or share the wallows, especially buffalo.
- Feral pigs may become wary and nocturnal if they are subjected to intensive or prolonged disturbance. Under these circumstances, they may shift home range or disperse over large distances to remote areas, thereby complicating control and containment operations.

Factors that reduce the risk

- Restricted access to water and shelter, particularly in hot environments, limits dispersal.
- Effective control techniques for pigs are well established.
- The Judas animal method may be successful with recalcitrant pigs.

3.3 Distribution, density, home range and social organisation of wild animals

Table 2 Biological and ecological attributes of feral herbivores (where known)

Attribute	Goat	Camel	Buffalo	Donkey	Horse	Cattle	Deer
Density							
– max (km^{-2}) over 100 km^2	40[a]	3[a]	15[a]	10[a]	10[a]	10[a1]	3(fallow)[a]
– range (km^{-2})	0.6 to 26[b] 1 to 3[c] 9[d] 0.6 to 7.5[e]	0.12[h] 0.78[i]		0.13[o]			8.7 (males) and 5.9 (females)[t]
Australian pop. (thousands)	2000 to 3000[a]	100[j]	10[a]	2000 to 5000[p]	350 to 600[a]		≤20 (fallow)[a] 5 (sambar)[a]
Home range (km^2)	100[f]; 2[g] ≤600 (♂)[a] ≤200 (♀)[a]	10000 to 58000[h]	200 to 1000 ha[n]	?	70 (52 to 88)[q] 100[r]		60 (fallow stags)[a], 13 (females)
Movement (km)	30km/6wks	5500/yr[h] 50 to 70/day[k]	small				
Social organisation							
– common group sizes	10 to 40[a]	1 to 5[l] 2 to 45[i]	30 to 50[a]	5 to 30[a]	5 to 7[q1]; 1 to 4[q2]; 1 to 3[q3]	10 to 30[m] 3 to 12[m]	1 to 20[a,t] 5 to 12 (chital)[s]
– max group sizes	1000[a]	500[j]	500[a]	500[a]	100[a]		400 (fallow)[a] 100 (chital)[a]

[a] Henzell et al 1999, [a1] feral and domestic, in pastoral areas; [b] Lord Howe Is; [c] arid/semiarid rangelands Western Australia (Southwell and Pickles 1993); [d] western/rangelands NSW (Maas and Choquenot 1995); [e] NSW (Mahood 1985); [f] arid areas; [g] high rainfall areas; [h] Wurst (1996); [i] Short et al 1988; [j] Dorges and Heucke (1995); [k] Siebert and Newman (1989); [l] Wilson et al (1992); [m] McKnight (1976); [n] Corbett (1995a); [o] Bayliss and Yeomans (1989) — northern limit of their range; [p] Choquenot (1995); [q] harems (Dobbie et al 1993), [q1] central Australia, [q2] eastern Australia [q3] bachelor groups; [r] Mitchell et al (1982); [s] Bentley (1995), [t] Statham and Statham (1996).

Table 3 Biological and ecological attributes of feral pigs[a]

Density (pigs per km^2)	
– highest (wetlands, swamps and floodplains)	1 to >20
– lowest (forests and semiarid regions)	0.1–4
Australian population	13.5 million[b]
Home range (km^2)	
(where food supply is poor, home ranges are larger)	
– male	1.4–43
– female	1.5–19.4
Social organisation	
– common group size	1–10
– maximum group size	>100[c]

[a] Refer to Choquenot et al (1996) for detailed information and references for research across Australia;

[b] Hone (1990) recommended that current estimates should be treated with caution; [c] in severe drought in tropical northern Australia.

Table 4 Biological and ecological attributes of feral cats, wild dogs, and foxes where known

Attribute	Feral cats	Wild dogs	Foxes
Density (km^{-2}) [a]			
–Highest	In association with rabbits and humans; insular populations; open habitats	Increases in watering points; increases in food supplies; accidental release accompanied by human settlement	4.6–7.2[g] 0–12[h]
–Lowest			0.2[i]
	Mainland populations; closed forest or wet heath		0.6–0.9[j]
Australian population			
Home range (km^2)			
–male	6.2[bc], 4.1[bd]	Males larger than females	
–female	1.7[c]	10[e]–77[f]	
–range			340[k]–610[l]
Social organisation		Highly flexible	
– common group size	1	(1) form packs to hunt large prey (2) solitary when small prey dominant	A male, a female and cubs
–maximum group size	1 adult with young		One male, several females and cubs

[a] There are few estimates of feral cat densities in Australia; comparison between studies is difficult due to differences in methodology and seasonal effects; [b] diurnal range; [c] semiarid SE Australia (Jones and Coman 1982); [d] Macquarie Island (Brothers et al 1985); [e] moist areas — Nadgee Nature Reserve (Corbett 1995); [f] arid regions — Fortescue River, north-western Australia (Corbett 1995); [g] temperate grazing, northern tablelands NSW (Thompson and Fleming 1994); [h] urban, Melbourne (Marks in Saunders et al 1995); [i] dry sclerophyll forest, south coast NSW (Newsome and Catling 1992); [j] semi-arid grazing, south-west Western Australia (from Saunders et al 1995); [k] farmland /woodland, Western Australia (from Saunders et al 1995); [l] farmland, Victoria (Coman et al 1991).

4 PRINCIPLES OF DISEASE CONTROL

4.1 Introduction

This section aims to help disease controllers develop a plan of action to deal with an emergency disease outbreak involving (or possibly involving) wild animals. It provides an overview of a systematic approach to the objectives, methodology and constraints of establishing disease status, conducting disease control and containment operations and demonstrating disease freedom in wild animals.

4.2 The challenges wild animals present to disease controllers

Wild animals often live in areas where their control and containment are both difficult and expensive. These objectives could take months to achieve, and in some cases might prove impossible. Wild animals can often pass through fences designed for livestock, and their movements could frustrate attempts to contain or eliminate an emergency disease. Infected wild animals might evade and disperse a considerable distance away from attempts to contain and eliminate them. Few elements in an emergency disease outbreak will be less tractable or predictable. In some cases a disease may change the normal behaviour of wildlife. There should be no false expectations about the ability to control wild animal populations should they become involved in an emergency disease outbreak.

The susceptibility of most Australian native species to natural infection with many emergency diseases remains untested, and, although this wild animal manual primarily concentrates on introduced species (feral animals), epidemiologists should be mindful of the possible involvement of native species in emergency disease epidemiology.

4.3 Principles of disease control in wild animals

The first requirement is to ascertain what susceptible wild animal species are present in the area and whether infection is present in them. If disease is present, the initial aim should be to control or restrict those species that are most likely to transmit disease.

In the longer term, wild animal carriers or reservoirs of disease will make it more difficult to demonstrate disease eradication. Thus the long-term aim should be to eradicate disease from these species. This may necessitate local elimination of the entire population or, if this is not feasible, containment and reduction of the population to levels where infection is unlikely to persist. Increasing population immunity by the use of vaccine may also eliminate infectious agents or reduce the spread of infection. However, threshold densities for disease persistence in wild animal populations will rarely be known in advance, and where two or more susceptible species live in the same area (that is, are sympatric) they might interact to lower their respective individual threshold densities.

In the case of rabies, the time taken for detection of development of sylvatic disease will be a determinant of the required control zone and probability of eradication.

Techniques used against one or a number of sympatric susceptible species should avoid prejudicing operations directed at another. If only one of a pair of sympatric species is infected, operations should be conducted in such a way as to minimise the risk of disease crossover.

In any particular outbreak the following sequence describes the steps to be followed. Not all the steps may be required, and they may be truncated or used in a different sequence. The selection of strategies and techniques will be determined using the decision-making key in Section 5. Also refer to Part 2 (Operational Guidelines) of this manual.

Step 1 Determine the distribution and density of susceptible wild animals

Obtain local knowledge of the distribution and habits of the wild animal species in the area. Where required, a wildlife biologist familiar with the species should also conduct appropriate surveys to obtain information on abundance of wild animals. The survey area should encompass all animals likely to have been exposed to infection, based on available information. Take account of home range sizes, but consider that exceptional movements may have spread the disease further. For information on species home range, refer to Section 3. Take into account natural barriers, topographical features and, where appropriate, watering points. Avoid drawing domestic stock into the population survey.

Step 2 Disease surveillance in wild animals

The epidemiologist and wildlife biologist should, if appropriate, determine the area and intensity of disease sampling, following the population survey. In some situations (eg for species known to be fairly uniformly distributed over wide areas) sampling may commence before the population survey or be carried out at the same time. The aim is to determine whether infection has spread to wildlife and to give an indication of the extent of its spread.

Sampling techniques are described in Section 7 of this manual (also refer to the relevant AUSVETPLAN **Disease Strategies**).

Step 3 Contain wild animals that may transmit the disease

If disease is detected in wild animals, the primary aim is to stop infection spreading, by preventing contact between animals in the infected area and the rest of the population.

Containment of the disease will usually involve defining a wild animal control area by surrounding the known extent of disease with a buffer area, the width of which is based on the estimated role of lateral spread, allowing for the incubation period of the disease. Techniques are defined in Section 9 of this manual.

Containment may involve the use of natural barriers to restrict the inward and outward movements of people and animals. Outward movements risk disease dissemination and inward movements seriously compromise the ability to demonstrate the effectiveness of depopulation and the absence of potential carrier species. Alternatively, containment may involve rapidly destroying all susceptible animals within the buffer area to establish an animal-free zone. If rapid depopulation is not possible, disease spread may be stopped by starting depopulation in the buffer area's outer margins. In some situations, disease eradication may involve doing nothing — that is, if the area is well contained, allowing the disease to run its course and die out naturally.

Containment may be impractical for diseases where insect vectors are involved.

Step 4 Control susceptible wild animals to eradicate disease and prevent its transmission

Eradicating the disease could entail the depopulation of some or all susceptible hosts within the wild animal control area. This would require the use of appropriate population reduction techniques (see Section 8). Because of the possibility that control measures could cause dispersal, disease surveillance should be undertaken to allow early detection of any disease spread outside the wild animal control area.

Step 5 Demonstration of freedom from disease

The State chief veterinary officer in conjunction with the Consultative Committee on Emergency Animal Diseases will determine whether demonstration of freedom from the disease in wild animals is appropriate; if so, a wildlife biologist and epidemiologist will determine the most suitable methods to apply. Principles involved in demonstrating freedom from disease are considered further in Section 7 of this manual. This depends on the type of disease (also see AUSVETPLAN **Disease Strategies**).

5 DECISION-MAKING KEY

5.1 Strategic planning

The objective of the decision-making key is to provide a guide to strategic planning for decision making whilst activating a response to an emergency animal disease, where wild animals may be implicated or pose a risk to disease transmission. Subsequently, it may be used by an advisory group of animal health and wildlife/vertebrate pest officers to guide decision making on operations involving wild animal species.

There are four parts/time-scales to this process:

(a) Risk assessment—immediate/short term

(b) Surveillance—short to medium term

(c) Operational decisions—medium to long term

(d) Evaluation—long term.

The checklist is not definitive; rather it is a logical sequence, which should be followed to its ultimate conclusion. There are various grey areas and many of the operations and decisions may be concurrent and are often not mutually exclusive, for example, population survey and disease sampling.

5.2 Decision-making key

PART A — RISK ASSESSMENT
Steps 1 and 2 are immediate to short-term actions.

<u>1 Is there any reasonable probability of the disease occurring in wild animals?</u>

In making this decision, consider reliable knowledge on factors such as known relationships between the disease and wildlife (worldwide) and distribution of wildlife within the vicinity of the disease outbreak.

Yes. Go to 2

No. Go to.. 5

Do not know. Go to 3

<u>2 Has a presumptive diagnosis of the disease been made in wild animal hosts?</u>

Yes. Go to 8

No. Go to.. 5

PART B — SURVEILLANCE
Steps 3 to 8 are short to medium-term actions.

3 Determine the distribution and abundance of susceptible wild animal hosts

Determine the distribution and abundance of potential wild animal host species on the basis of local and other existing knowledge, and, where deemed necessary, a reconnaissance of the area using an aerial or ground survey. Based on survey results (numbers of wild animals, contact with domestic animals), are wild animals likely to pose a risk?

Yes. Go to 4

No. Go to.. 5

4 Do we know if wild animals and/or domestic animals are infected?

Disease thought to be present only in domestic animals. Go to 5

Disease thought to be present in domestic animals, with the status of wild animals unclear. Go to.. 5

Disease thought to be present in both wild animals and domestic animals. Go to 5

Disease thought to be present in wild animals, with the status of domestic animals unclear. Go to.. 6

Disease thought to be present only in wild animals. Go to.. 6

5 Should we ignore wild animals?

Consult with a wildlife/vertebrate pest expert in the wild animal species implicated. Decide whether or not to take action against wild animals, taking into account the decision factors (Section 5.3).

The perceived/real consequences of inaction are of little importance. Go to.......................... 13

Wildlife cannot be ignored. Go to 6

6 Sample wild animals for the presence of the disease agent

The time involved in this process may be prolonged until adequate data are obtained. Very dependent on circumstances and the consequences of getting it 'wrong'.

Consult experts* to consider/initiate the following:

- a detailed population survey, using decision-making factors (Section 5.3); and/or

- disease sampling.

*Consider establishing an advisory group of wild animal experts and epidemiologists.

Also consider establishing a wild animal section at the local disease control centre (LDCC).

Refer to Part 2 (Operational Guidelines) of this manual.

If disease is detected in wild animals, go to 8

If no disease is detected in wild animals, go to 7

In some situations consider conducting operational procedures concurrently with disease sampling.

7 Relevance of wild animals

Where there are inadequate data:

If disease control in domestic animals does not proceed as quickly as expected consider increasing the intensity and range of testing of wild animals. Go to 6

It may be necessary to wait for a period taking into account the decision factors (Section 5.3). Go to.. 6

Consider whether to control and contain wild animals as a precautionary measure, taking into account the decision factors (Section 5.3). Go to 9

Where there are reliable data and:

No disease is detected in wild animals during sampling. Go to 5

Disease is detected in wild animals during sampling. Go to 8

PART C — OPERATIONAL DECISIONS
Steps 8 to 11 are medium to long-term actions. These steps are likely to continue simultaneously for a prolonged period.

8 Select appropriate control and/or containment strategies

Disease has been detected in wild animals. Select the appropriate methods to contain and control wild animals and/or the disease depending on all the decision factors (Section 5.3).

No targeted action against wild animals. Go to 9

Non-lethal disease control measures (including vaccination). Go to 10

Lethal disease control measures for wild animals, and containment. Go to 11

Modify control and containment methods depending on outcomes/assessment.

Disease is no longer detected in susceptible hosts. Go to.. 12

9 Continue to monitor wild animals

Continue to monitor wild animals for the presence of disease during and after domestic animal operations. The procedures will be developed in consultation with an advisory group of epidemiologists and species experts, who will refer to Part 2 (Operational Guidelines) of this manual — and the relevant part of AUSVETPLAN **Disease Strategies**.

If there is continuing or increasing concern over disease in wild animals. Go to 8

If there is a decrease in, or no concern over, disease in wild animals. Go to 12

10 Non-lethal disease control measures for wild animals

Implement appropriate methods, including vaccination and nonlethal population control methods, taking into account the decision factors (Section 5.3). Refer to Part 2 (Operational Guidelines) and the relevant part of AUSVETPLAN **Disease Strategies**.

Disease is still detected in susceptible hosts. Go to 9

Disease is no longer detected in susceptible hosts. Go to.. 12

11 Lethal disease control measures for wild animals, and containment

Implement appropriate methods to control and contain wild animals, taking into account the decision factors (Section 5.3). Refer also to Part 2 (Operational Guidelines) and the relevant part of AUSVETPLAN **Disease Strategies**.

Modify control and containment methods depending on outcomes assessment.

Disease is no longer detected in susceptible hosts. Go to 12

Susceptible hosts eradicated. It may be necessary to exclude wild animals from the wild animal control area until any remaining virus etc is inactivated. Go to 12

Wild animals reduced below disease threshold level and disease no longer detected. Go to 12

Wild animal disease control operations fail to prevent expansion of outbreak and disease declared endemic. Go to 14

12 Monitor for residual disease

Disease detected. Go to 5

Disease undetected. Go to 14

13 No action to be taken against wild animals

Periodically review the situation.

Developing concern. Go to 5

No concern. Go to 14

Factors to consider in making this decision:

- no wild animal species present is important in the maintenance and transmission of the disease; **and**
- wild animals, even if infected, are unlikely to be a source of infection for domestic animals and/or people; **and**
- any disease in wild animals will not persist after infection has been eliminated from domestic animals; **and**
- disease control in domestic animals (if commenced) is proceeding as expected; **and**

- action to test for the presence of disease in wild animals or to control wild animals is likely to have adverse consequences, for example:
  - spread disease by dispersing wild animals; **or**
  - lead to wild animals reinfecting domestic animals; **or**
  - unduly slow down disease control or other operations.

14 Cease operations — no further action

The disease has been declared:

- endemic; or
- eradicated; or
- unresolved.

5.3 Decision factors

The following factors should be considered when deciding what action, if any, will be taken against wild animals. They are to be used in conjunction with Section 5.2 — (decision-making key). They will help to choose the techniques, or combination of techniques, to be used for surveying, sampling, containing and reducing the wild animal population(s). The factors are grouped under four areas:

- epidemiology
- ecology
- resources
- sociopolitical

Some factors are relevant to more than one area and therefore appear under more than one heading.

5.3.1 Epidemiological factors

Disease control can be achieved by drastic population reduction or by mass immunisation of the host species. In both cases the aim is to reduce the number of susceptible animals to below the threshold density (K_t) of animals that is necessary to maintain the disease in the wild. The main epidemiological factors that need to be taken into consideration are shown below.

1) Characteristics of the disease

- mode of spread
- infectivity
- incubation period
- mortality and morbidity
- rate of spread, and
- carrier status

These characteristics will all have an effect on the type of operation (eg with rabies, vaccination of susceptible wild animals may be a more viable option than population reduction, particularly if the disease appears to have been in the population for a considerable period).

2) Epidemiological importance of wild animals

- potential role in spreading the disease to other animals (wild and domestic)
- potential role in spreading the disease to people

- persistence of the disease in wild animal populations after elimination from domestic animals

3) Density sought after control

The population reduction required will depend on:

- the disease
- the susceptible species present
- the epidemiological situation

4) Need for carcase disposal

This could influence:

- the choice of control method, as well as
- the decision whether or not to control wild animals

5) Control of the disease by vaccination or other non-fatal methods?

This could depend on:

- the effectiveness of conventional control techniques, as well as
- the availability of and authority to use vaccines

5.3.2 Ecological factors

1) Location

The topography, remoteness, ease of access, and density of vegetation will affect all operations, especially containment.

2) Season

The season will affect wild animal movement patterns, social behaviour, contact rates, drinking behaviour, and the extent of inundation and ease of human access to the habitat.

3) Initial density of susceptible species

The higher the density of susceptible animals, the more likely disease is to spread. Also, the density of susceptible species will influence the techniques used. Different techniques might be employed in sequence as the density falls.

4) Desired density sought after control

See Section 5.3.1 (3).

5) Attainability of desired density

Depends on the species being controlled, and other factors listed in this section. For example, it may not be possible to reduce feral pig populations to a predetermined or desired density in many habitats. Achieving target reductions to desired pig densities has proven difficult in full-scale simulated emergency disease exercises in Australia (Choquenot et al 1996).

6) Other susceptible species present in the same area

If several sympatric species are susceptible, techniques used against one should not prejudice the elimination of disease from others. Try to use the same technique against all species.

7) Likely movements of susceptible animals

These might be altered by operations to survey, control or contain wild animals. The likelihood of dispersal of wild animals will influence whether to intervene against wild animals at all, the techniques used, and the width of buffer areas.

5.3.3 Resource factors

1) Availability of resources

Are sufficient human and material resources available to mount the operation? There may have to be a compromise between the intensity of control and the area covered.

2) Attainability of target density

See Section 5.3.2 (5). This can be related to the availability of resources and rate of response.

3) Need for carcase disposal

The ability to locate and dispose of carcases will be resource dependent. This could influence the choice of control method, as well as the decision whether or not to control wild animals.

4) Cost–benefits of different techniques

The relative capabilities and estimated costs of different survey, control and containment techniques will influence which one/s are chosen.

5) Availability of expertise and knowledge

The availability and number of technical (species experts, wildlife biologists) and operational (wildlife and vertebrate pest control officers) resources could influence the scale and type of operation.

6) Availability of vaccine

The decision to vaccinate large numbers of wild animals will be dependent on whether vaccine is available in Australia or can be obtained in a reasonable time from overseas.

7) Availability of distribution method for vaccines

It is likely that there will be minimal, if any, experience in the distribution of vaccine baits in Australia. There will be considerable experience in the delivery of toxic baits, the technology from which is transferable. There will also be considerable expertise available from overseas which should be drawn on as the need arises.

8) The impact of control measures against a particular species may need to be measured against the potential impact on other non-target species.

5.3.4 Sociopolitical factors

1) Cost–benefit considerations

Operations to control and contain wild animals should cost less than the benefits they produce. An awareness of the costs of alternative operations, including inaction, will assist in the decision-making process.

2) Economy

What will be the likely effect on the local, regional and national economies?

3) Attainability of desired density

See Section 5.3.2 (5).

4) Legal ramifications

The State and Commonwealth legislation (see Appendix 4), likelihood of litigation, and legal powers/licences required of control officers, may influence the choice of strategy and techniques.

5) Public opinion

This could influence the choice of control technique and carcase disposal, and the decision whether or not to control wild animals.

6) Public safety

This could influence the choice to use certain control or capture methods, particularly in an urban area.

7) Occupational health and safety of operational staff

This could influence the choice of technique.

8) Government policy

The current State and/or Commonwealth policies on emergency diseases, wildlife and/or feral animals, rural assistance etc, together with related policies, will influence the scale and type of operation.

Part 2 OPERATIONAL GUIDELINES

Part 2 of this manual provides operational guidelines that briefly describe procedures and techniques for:

- **population survey** **(Section 6)**
- **disease sampling** **(Section 7)**
- **population reduction** **(Section 8)**
- **population containment** **(Section 9)**

These are only guidelines. When planning operations, it is important that appropriate local knowledge and technical expertise is consulted.

6 POPULATION SURVEY

6.1 General information

Some States have geographic information systems (GIS) of wildlife distribution and density estimates.

Estimates of wild animal density and distribution can be used with local knowledge to:

- identify whether wild animals pose a risk to disease transmission, and provide an indication of the intensity of disease sampling required
- plan an appropriate strategy for wild animals
- determine the size, location and type of operation and the resource requirements
- assess the progress of an operation, that is the extent of population reduction and/or containment achieved
- demonstrate, if required, in conjunction with disease sampling, freedom from disease or minimal risk of disease transmission in wild animals

The survey may only require collation of local knowledge.

6.2 Planning the survey strategy

6.2.1 Determination of area to be surveyed

The area surveyed should be large enough to encompass all animals likely to have been exposed to infection, based on available information. The areas to be surveyed should aim to provide the maximum information in the time available, taking into account the species ecology. The area may be too large in the first instance, increasing the time required for the survey and placing excessive demands on available resources. Also refer to Section 3 of this manual to ensure that operational areas are determined in an integrated manner.

Small outbreak in domestic animals, with wild animals uninfected

If there is no evidence of infection in wild animals and the outbreak in domestic animals is small (much smaller than the largest home range of any susceptible wild animal present), the area surveyed should be a circle of radius at least equal to the maximum likely length of the largest home range of any susceptible species present (allow for the marked asymmetry of some home ranges). For information on species home range see Section 3 of this manual. In the absence of this information, the radius should equal the incubation period of the disease multiplied by the likely daily rate of its spread (**Note**: This information is unlikely to be known for Australian conditions). A non-circular survey area may be more appropriate if indicated by the terrain or local knowledge of wild animals.

Large outbreak in domestic animals, with wild animals uninfected

For a larger outbreak in domestic animals only, the survey should include the infected premises (IPs) and dangerous contact premises (DCPs) and a buffer area around them (likely to be non-infected) at least as wide as the radius given above. If the disease might have entered wild animals, estimate the area likely to be infected from the maximum likely rate of disease spread and the length of time the disease is thought to have been present in wild animals, and survey an area including this area and a buffer area of a width similar to that given above.

Wild animals infected

Where disease is present in wild animals, survey an area that includes the likely limits of spread (**Note**: At the time the situation will be very unclear and it will probably not be known how long the disease has been in Australia, or even if we are dealing with the index cases). Estimate this area by surrounding the known extent of disease with a buffer area the width of which is based on the disease's incubation period and estimated rate of lateral spread (the zone might need to be made wider to allow for animal movement). The likely rate of spread should be estimated by the epidemiologist and a wildlife biologist (if possible they should both be familiar with the relevant species). Surveying may be more circumspect, with a more detailed survey being implemented later.

6.2.2 Population assessment teams

Population assessment teams should generally consist of:

- local vertebrate pest control and/or wildlife officers where possible
- at least one officer experienced in wild animal survey techniques

If the workload is high, consider including a technical assistant to assist with counting, data recording and mapping.

Population assessment teams will be briefed at the local disease control centre (LDCC) on where they are to operate, what to look for, what techniques are to be used, reporting and data recording and decontamination procedures. Teams will report to the wild animal control and surveillance coordinator (see Section 11).

Population assessment teams will:

- complete a wild animal sampling form (Appendix 2), which will clearly show the location and number of animals sighted.
- use grid overlays on maps and, where appropriate, global positioning systems (GPS), to facilitate accurate recording of the distribution and density of wild animals; and
- ensure that the mapping officer records the location of animals on topographic maps at the LDCC. (Also refer to the AUSVETPLAN **Mapping Manual**.)

6.3 Techniques and species-specific information

The choice of technique will influence the accuracy of survey data (Table 5). Density can be measured in three ways (Caughley 1977):

- as the number of animals in a population;
- as the number of animals per unit of area (absolute density); and
- as the density of one population relative to that of another (relative density).

Techniques to survey populations of wild animals are common to many species. For example, aerial survey is the most rapid and preferred method for feral herbivores and feral pigs where the vegetation is relatively open and/or where the terrain is inaccessible or rough. Ground survey techniques such as track and dung counts are more appropriate for species such as dogs and feral pigs in closed forest. In many situations only estimates of relative density will be possible. For information on species-specific techniques, consult wild animal species experts/wildlife biologists.

The wild animal control and surveillance coordinator (see Section 11) and the epidemiologist should consult with an experienced wildlife biologist who will be responsible for developing and conducting a rapid survey (where possible) to suit the prevailing conditions and availability of resources. The wildlife biologist will be competent in the statistical design and analysis of population surveys for the relevant wild animal species.

Table 5 Survey techniques for distribution and abundance and considerations for wild animals

Technique	Species	Comments
Aerial survey **–** helicopter and fixed wing	Feral buffalo camel, cattle deer donkey, goat, horse, pig	Various methodologies (strip transect, double count, total count). Needs experienced personnel. Sightability affected by habitat, group size, weather and time of day.
Ground survey – spotlight and day counts	All species (variable). Depends on nocturnal/diurnal behaviour	Highly variable outcomes and accuracy. Dependent on habitat, vehicle access, species, previous control history (eg shooting makes animals wary of spotlights). Sample all habitats in area. Use line transect methodology wherever possible.
– trapping	All species (including rodents, wild birds, bats	Requires time (varies by species). Only to be used together with population reduction and/or disease sampling, or where other methods cannot be used.
– sign	All species	Various methodologies including dung count, track counts, den count, surveys of rooting, wallows, rub marks. Use initially only as crude index and follow up with other methods.
– free feeding	Most species (not well tested)	Select bait according to likely species; beware of non-target take. Requires time; sample all habitats. Use initially only as crude index and follow up with other methods.
Local knowledge	Most species	Consult land manager, local pest management authorities, survey information on pest animal distribution and local hunters, bushwalkers etc.

7 DISEASE SAMPLING

7.1 General information

Early detection and determination of the wild animal species involved, and the geographical extent of the disease, are key requirements for managing an outbreak. Disease sampling is used to test for the presence and geographical extent of the disease in wild animal populations, and in some cases to give an indication of prevalence (ie the proportion of the population affected). At the end of an eradication campaign, sampling of wild animals may be required to prove freedom from the disease.

Disease sampling will involve getting access to animals or faeces and the use of a test to diagnose the disease. Obtaining animals may involve:

- live capture techniques (eg trapping)
- lethal capture techniques (eg poisoning, shooting)
- sick animals encountered by hunters
- observation of animals at feeding or trapping sites
- fresh roadkills
- carcase collection

The test procedure may involve a simple inspection of animals for the presence of characteristic disease lesions, or it may involve the collection of blood or other tissue samples from which isolation of the disease agent may be attempted or the presence of antibodies demonstrated. Blood is one of the most common samples collected for diagnosing disease because serological testing (the measurement of serum antibody) is one of the most commonly used diagnostic tests to discriminate between exposed and non-exposed animals.

The diagnostic methods to be used and the specimens to be collected will depend on the disease in question, and will be determined by animal health authorities at the time of the outbreak (see Geering et al 1995 for details of recommended diagnostic samples and methods).

Sampling wild populations for evidence of disease poses several problems. Firstly, the epidemiological formulae used for determining the sample size required to draw conclusions about the level of disease in a population rely on random sampling. In random sampling, all animals in the population have the same chance of being sampled. Clearly, with wild populations the usual requirement for random sampling is unlikely to be met. Animals will vary in their ‘sightability’ and ‘trappability’ depending on such biological factors as age, size and behaviour, and environmental factors such as terrain and habitat. Care must be exercised when drawing inferences about the prevalence of disease based on a sample of the wild animal population.

Secondly, many tests, particularly serological tests, used for testing wild animals will be directly transposed from domestic species and these may not perform identically in wild animals. There may be differences in host responses, while wild species may be exposed environmentally to organisms with similar antigens that produce cross-reacting antibodies (Gardiner et al 1996).

7.2 Planning the sampling strategy

The sampling strategy to be adopted will depend on the objective of the sampling exercise. Three major reasons for sampling wild animals are:

- to test for the presence of the disease;
- to determine the extent of disease spread; and
- to prove freedom from the disease at the end of the eradication campaign.

The key issues that need to be considered are:

- how many animals need to be sampled;
- what areas to sample;
- how to obtain animals for sampling;
- what samples are required; and
- how to interpret the findings.

The LDCC controller and epidemiologist, in conjunction with the wild animal control coordinator and/or a species expert, will determine the wild animal, surveillance area and extent of sampling to be undertaken based on:

- the type of disease;
- the expected speed of spread;
- the density and distribution of susceptible animals present;
- the topography of the area;
- the capability of diagnostic facilities;
- expected prevalence; and
- specificity and sensitivity of the test available.

Refer to Section 5 of this manual to ensure that all factors have been considered in the decision-making process. Appendix 1 lists sources that should be consulted when planning wild animal operations.

In consultation with local wildlife and/or vertebrate pest control experts, the likely distribution of the wild animal species in the area should be determined (see Section 6). First determine if the disease is present. Sampling should be concentrated on areas where animals are considered most likely to have come in contact with the disease (eg due to potential contact with infected livestock, or because of the likely presence of vectors). If it is quickly demonstrated that the disease is present in wild animals, a more extensive structured survey should be implemented.

Surveillance (see Section 7.5.1) will be allocated responsibility for specific areas. They will be responsible for examining animals and collecting samples.

7.3 Looking for evidence of disease in wild animals

The main purpose of disease sampling will be to determine if the wild animal population has been exposed to, or is harbouring, the disease agent. Factors that need to be considered in setting the sample size are:

- performance of the test procedure used;
- the size of the population;
- prevalence of infection in the population; and
- extent of mixing in the population.

Tables (eg Cannon and Roe 1982) and various computer software packages (eg Epi Info, Win Episcope, FreeCalc) are available for determining appropriate sample sizes, although as discussed in Section 7.4.1 they rely on the assumption that random sampling is used. If population estimates are not accurate or cannot be readily obtained, as many animals as physically possible should be captured and sampled, particularly in the vicinity of IPs and within and surrounding the restricted area (RA).

7.3.1 Is the disease present?

From the emergency disease management point of view, the key issue is: *Is the disease present in wild animals or not?* (see the decision-making key in Section 5). To address this issue, random sampling is less important. In fact, sampling should be targeted to maximise the chances of finding disease. This will involve preferentially sampling those animals with the highest risk of having come into contact with the disease. Depending on the disease in question, this may involve sampling and testing those animals:

- closest to a known IP;
- downwind from an infected property (if airborne spread is likely to be involved);
- at locations where they are likely to have come into contact with infected stock (eg watering points);
- if vectors are implicated in spread, where vectors are likely to be found (eg along watercourses); and
- at 'highest' risk (eg bovines are considered indicator species for foot-and-mouth disease because of their extreme sensitivity to infection by the respiratory route).

Where the species is likely to be found in family or other social groupings, samples should be collected from all animals trapped or shot, recognising that it may only be necessary to test a few of these to be confident of finding disease.

7.3.2 Determining the extent of spread

Once the disease is found in the wild animal population, further information on the spatial extent of spread will be required to assess response options, for setting RA boundaries and for implementing movement controls. Sampling should shift from targeting high-risk locations to a more structured and systematic approach aimed at determining the extent of spread. For example, animals could be sampled in a radial pattern at fixed distances out from the known infected location (concentric ring pattern). Alternatively, a grid could be overlaid on a map of the surrounding area and grid cells sampled according to a predetermined, systematic or random pattern. Sampling efforts should be concentrated in areas of known or preferred habitat for the species being investigated.

7.3.3 Estimating disease prevalence

In some circumstances, it may be useful to estimate the level of disease in a population. This information can be used for assessing how long disease has been present and for estimating how quickly it is spreading, and can be useful for modelling studies to predict the likely future course of events.

Prevalence can be estimated from sampling results (refer to the epidemiologist) although the reliability of the findings will be questionable unless formal random selection techniques are used.

7.3.4 Multispecies testing

Where more than one susceptible wild animal species is present, the disease status of *all* susceptible populations should be assessed and sampling undertaken in a coordinated manner.

In the initial stages where the objective is to look for evidence of the disease, particularly if resources are limited, it may be appropriate to concentrate on the species that has the greatest risk of having been exposed. The sampling strategy can then be adjusted according to the initial findings.

7.3.5 Repeated sampling and ongoing surveillance

While initial sampling may provide information on the disease status of the population at that time, it is important to appreciate that disease is not static. Disease may be spreading (often rapidly) in domestic livestock, and an initially disease-free population or area may become infected. Ongoing surveillance for tested negative populations may be necessary for the duration of the outbreak. This could involve:

- repeated trapping and sampling of animals in the population (animals could be fitted with radio transmitters to assist in relocating them) and Judas animals could be used if appropriate (see Section 8.4.2); and

- use of sentinel animals (animals could be maintained in a central trap or pen and monitored for development of the disease).

7.3.6 Detecting residual disease following depopulation

Following control activities, it may be desirable to test the residual population for disease. This could pose problems since remaining animals may be very difficult to locate. Penned sentinel animals or closely monitored free-ranging Judas animals could be considered. Fitting Judas animals with two transmitters to guard against collar failure could be considered.

7.4 Proving that disease is not present

At the end of the outbreak, it will be necessary for Australia to demonstrate that the disease is no longer present in its wild animal populations. For proving freedom, a wide area survey is required rather than focusing on high-risk areas. While a true random sample may be impossible, it is important to use as random a process as possible to select animals for testing.

One approach, advocated by the World Organisation for Animal Health (Office International des Epizooties, OIE), for proving disease freedom is based on random selection of map coordinates. Further information is contained in *Recommended Standards for Epidemiological Surveillance for Rinderpest* (OIE 1993a).

7.4.1 Sample size

The size of the sample required to be tested for demonstrating freedom depends on:

- the size of the population
- the likely prevalence of the disease, if present
- the reliability required of the conclusions (ie the confidence level)
- the sensitivity of the test used

The larger the sample, the greater the confidence that can be placed in the results. Provided the above variables are known or can be estimated, tables (eg Cannon and Roe 1982) and various computer software packages (eg Epi Info, Win Episcope, FreeCalc) are available for determining sample size. Alternatively, having tested a random proportion of animals in a population and found no positives, the confidence level can be determined. For proving freedom from a disease, OIE guidelines for diseases such as rinderpest and contagious bovine pleuropneumonia (OIE 1993a, 1993b) suggest that the sampling strategy for domestic stock should be designed to have a 95% confidence of detecting the disease at a prevalence of 1% (refer to Cannon and Roe 1982).

Where the population distribution is not uniform, it may be necessary to stratify it into sections with similar risk of maintaining the disease. For wild animal populations, in most cases, stratification will be on geographical areas. This means that once the target sample size to provide the desired level of confidence has been calculated, the actual number of samples required, by area, will be proportional to the (estimated) numbers of animals present in these areas.

7.5 Field aspects of disease sampling

In many situations, disease sampling operations will be conducted as part of population surveys, and planning should be undertaken in a coordinated manner. Alternatively, the decision could be taken for a pre-emptive reduction of the population of wild animals in the vicinity of an outbreak, in which case disease sampling operations would be undertaken as part of a control operation.

If aircraft are to be used for sampling operations, the location of the nearest landing site or helicopter base should be determined. It will be necessary to obtain approval from the Civil Aviation Safety Authority to carry firearms on aircraft.

Surveillance teams will be briefed at the LDCC on where they are to operate, what to look for, what samples are required, decontamination procedures and how to deal with carcases.

7.5.1 Surveillance teams

Membership

Surveillance teams should generally consist of:

- one veterinary adviser, or officer trained in disease recognition and sample collection; and
- one officer experienced in wild animal capture/control procedures.

If the workload is high, a technical assistant to assist with counting, data recording and mapping could be included.

Duties

Surveillance teams will:

- complete specimen collection forms, together with a wild animal sampling form (Appendix 2) and maps which show the location of sampling sites and carcases;
- use grid overlays on maps and, where appropriate, GPS, to facilitate accurate recording of sampling sites;
- identify specimens individually and pack them in sealed bags or containers as directed, and deliver them to a designated collection point for dispatch to a diagnostic laboratory; and
- ensure that the mapping officer records the location of animals sampled on topographic maps at the LDCC. (Also refer to the AUSVETPLAN **Mapping Manual**.)

7.5.2 Specimen collection

The number and type of samples to be collected will be determined in consultation with animal health authorities. Detailed descriptions of sample collection methods, and specimen preparation and storage, are beyond the scope of this document. For further information consult Geering et al (1995) *Exotic Disease of Animals. A Field Guide for Australian Veterinarians* (see the AUSVETPLAN **Laboratory Preparedness Manual** and the relevant AUSVETPLAN **Disease Strategy**).

Once samples are taken, carcases should be treated or disposed of as directed by the LDCC. (Refer also to the AUSVETPLAN **Disposal Manual**).

7.6 Techniques for capturing animals

Techniques for capturing wild animals (Table 6) can be considered in two groups: those that return a live animal (live capture), and those that return a dead animal (lethal). Advantages and disadvantages of individual techniques are listed in Section 8.4.

Some of these techniques may cause animals to disperse. Alternatives that could be considered include:

- free feeding to facilitate good observations of animals for clinical signs;
- food trapping, using food as an attractant;
- collection of fresh roadkills;
- collection of carcases from other than roadkills;
- by request, submission of sick animals found by hunters;
- tranquillising with dart gun; and
- examination of fresh faeces for virus (see Section 7.7).

Consideration could also be given to the slightly more disruptive Judas animal operations for large, feral herbivores and feral pigs; water trapping for large, feral herbivores; and sedation for all species.

The wild animal control and surveillance coordinator and the epidemiologist will consult with wildlife and vertebrate pest control biologists and practitioners to determine the most appropriate techniques for the circumstances. A wildlife biologist experienced in the chosen technique must be consulted to design and evaluate the success of the operation.

7.7 Detection of disease in faeces

This could be especially useful for rapid surveys of large areas, or when animals are particularly difficult to trap or shoot. This method will only be suitable for some diseases.

Table 6 Disease sampling techniques and considerations for wild animals[1]

Technique	Species	Comments
Helicopter shooting	Feral buffalo, camel, cattle, deer, donkey, goat, horse, pig	The preferred method where samples are required quickly, and animals are not in heavy cover or grazing at night
Ground and spotlight shooting hunting[2]	All species[3]	At permanent water, where animals are in heavy cover, nocturnal and for carnivores. Unlikely to be used for sampling feral pigs unless (1) trapping is unsuccessful, or (2) pigs to be sampled are those surviving trapping or poisoning campaigns[4]. For birds, consider shooting at night with silenced rifles, using red light for illumination.
Trapping or netting[2] (mist and hand nets are also used for wild birds and bats)	All species[3](including rodents) Wild birds	For long-term disease monitoring and sentinels Only to be used together with population reduction, or where other methods cannot be used, with small numbers or in hot weather when birds are near water
Mustering	Feral buffalo, camel, cattle, deer, donkey, goat, horse	Consider using dogs
Judas animals	Feral buffalo, cattle, goat, pig	For long-term disease monitoring and observations
Helicopter net guns	Deer, goat	Where live animals are required
Free feeding, food trapping	Most species	Will facilitate observations of animals for clinical signs
Collecting fresh road kills	Feral cats, dogs, dingoes, foxes	Has been used overseas to facilitate detection of rabies
Observing sick animals (hunters, bushwalkers etc)	All species[3]	Has been used overseas to facilitate the detection of rabies. An inducement and/or extensive media coverage may be necessary

[1] refer to Section 8 (Population reduction) for details of techniques and advantages and disadvantages; bats, wild birds and rodents may need to be sampled;

[2] the type of equipment used (eg trap, gun etc, will be species specific and determined by the wildlife biologist);

[3] including birds and bats;

[4] Wilson and Choquenot (unpublished);

8 POPULATION REDUCTION

8.1 Objective

Population reduction or depopulation of wild animals to a predetermined level can be used to minimise the risk of disease transmission (also see Section 7, Disease sampling). If wild animals are considered to be a risk factor in the dissemination or persistence of infection, then programs aimed at reducing contact between infected domestic animals, wild animals and uninfected susceptible domestic animals should be instigated as soon as possible. For further information on determining whether to instigate a population reduction program, follow the guidelines in Section 4 of this manual.

In all disease situations, unrealistic expectations of wild animal control or depopulation operations must be avoided. Consider also that the removal of wild animals from an area may create a sink into which healthy and infected animals may immigrate. Furthermore, aerial and ground shooting, hunting, shooting drives and inordinate numbers of control personnel in an area may cause unnatural dispersal of the wild animals and spread the disease. Many of the AUSVETPLAN **Disease Strategies** indicate that in many instances wild animals should be left alone and their control limited to activities that will not cause their dispersal. In particular, where animals are being infected by domestic animals, it is possible that once this source is eliminated, infection might die out naturally in low-density wild animal populations. Another option is the use of vaccine, for example in the case of rabies with the trap–vaccinate–release (TVR) program as applied in Canada.

8.2 Planning the control strategy

The LDCC controller, epidemiologist and wild animal control coordinator, together with appropriate species experts and local wildlife and/or vertebrate pest control officers, will determine the type and extent of control operations to be undertaken. Refer to Section 5 of this manual to ensure that all factors have been considered in the decision-making process. Appendix 1 lists sources of information that should be consulted when planning wild animal operations.

Consider that most techniques (eg poisoning and trapping) will take weeks to achieve the target density.

Consider the sequential use of different techniques. Vary the technique as the population density falls; the technique used first will depend on the starting density. Objectives and priorities for control operations should be set so that progress can be assessed. Areas where wild animals are (or are suspected to be) infected or have the greatest risk of contact with infected domestic animals should be preferentially targeted. This is referred to as the *wild animal control area*.

Determination of the population reduction to achieve a threshold density where disease will not be maintained or spread will be difficult when the dynamics of the disease can only be predicted and there is great variation in density between regions.

Disease sampling may be undertaken with population reduction to monitor the spread of the disease (see Section 7).

8.2.1 Control teams

Membership

Control teams should generally consist of:

- local vertebrate pest control and/or wildlife officers where possible; and
- at least one officer (two is desirable) experienced in wild animal capture/control procedures.

If the workload is high, consider including a technical assistant to assist with counting, data recording and mapping.

Briefing

Control teams will be briefed at the LDCC on where they are to operate, what to look for, what techniques are to be used, reporting and data recording procedures, decontamination procedures and how to deal with carcases. Teams will report to the wild animal control team leader and/or wild animal control and surveillance coordinator (see Section 11) depending on the size of the outbreak.

Duties

Control teams will:

- use safe practices to humanely destroy target wild animal species
- complete a wild animal control form (Appendix 3) that will clearly show the location and number of animals destroyed and number of animals escaped
- use grid overlays on maps and, where appropriate, GPS to facilitate accurate recording of the area of control
- ensure that the mapping officer records the location of animals destroyed on topographic maps at the LDCC. (Also refer to the AUSVETPLAN **Mapping Manual**.)

Note: Carcases should be treated or disposed of as directed by the LDCC. (Refer to AUSVETPLAN **Disposal Manual**.)

Coordination of control efforts is critical to the success of any operation. Ensure that proper planning, recording of information and debriefing are maintained at all times.

8.3 Techniques and species-specific information

For further information on techniques relevant to a specific disease refer to the relevant part of AUSVETPLAN **Disease Strategies.** References to wild animals are generally found at **Sections 2.2.10 and 3.2.8**.

Selection of technique will depend on:

- technique efficiency (that is, the proportion of wild animals killed, and how quickly given levels of reduction in the wild animal density are achieved);
- factors affecting the efficiency of the technique in different habitats;
- availability of carcases for disease sampling; and
- the effect of the technique on movement and dispersal of wild animals from the wild animal control area (Wilson and Choquenot, unpublished).

The techniques specific to each species are presented in Table 7. It will be necessary to tabulate the performance targets achievable with each technique for each species, taking into account density, dispersal, ease of carcase disposal, use of resources available and cost.

If aircraft are used, it will be necessary to obtain approval from the Civil Aviation Safety Authority to carry firearms on aircraft.

There is the potential for some control techniques to cause changes in behaviour of target populations (eg helicopter shooting of feral pigs). This may result in dispersal of surviving individuals. The likelihood of dispersal for deer caused by different control techniques is as follows (highest to lowest): helicopter shooting, dogging, ground shooting, spotlight shooting, mustering, trapping, fencing, ground poisoning, aerial poisoning. The potential risk this may create for disease spread must be considered.

Table 7 Population reduction and disease control techniques and considerations for wild animals

Technique	Species	Comments
Lethal control		
Helicopter shooting	Buffalo, camel, cattle, pig, donkey, goat, horse	Rapid control with concurrent control of sympatric species possible in open floodplain, grassland and swamp habitats; inaccessible/uneven terrain; not suitable in heavy cover May utilise Judas animals
Ground shooting	All species	Spotlight shooting for most species; from a hide for deer and birds May utilise Judas animals
Poisoning	All species	Achieved from ground and/or air depending upon the habitat Poisoning using 1080 for all species[2]; warfarin for pigs[2]; strychnine for foxes and wild dogs[3]; cyanide for foxes[3]; has been used with variable results in Australia. Check on current legal status and conditions of use before using these poisons. Licensed, experienced vertebrate pest control officers must be used to mix and distribute baits.
Gassing	Foxes	Not labour efficient and only appropriate during the denning season
Live capture		
Trapping[1]	All species	Use at water, with lures, food or baits
Judas animals[4]	Feral buffalo cattle goat, pig	Characteristics that make for the best Judas animals vary between species: for cattle and buffalo, use young animals; for goats, avoid extremes of age. Use both sexes. Eliminate unhelpful Judas animals, but persevere with at least some animals of both sexes for species where segregation of the sexes occurs. Method has had limited success for pigs. For goats use dogs to hold animals for capture or while they are shot (unproven for other species). Although local animals are most suitable, it may be necessary to use disease-free animals from outside the area and introduce in pairs or small groups. Replace animals and test them for disease regularly.

Mustering	Feral buffalo camel, cattle deer donkey, goat, horse, pig	Muster each species separately, and minimise disturbance to other species. Take care not to disperse animals, back up with shooters (usually in helicopters) to immediately destroy recalcitrant animals.
Other		
Bait vaccination for rabies	Foxes	Oral vaccination is effective and more desirable than population reduction as it is less disruptive to species population dynamics, and because foxes are generally resilient to persecution[3]. Do not attempt population reduction while vaccinating.
Urban control of rabies	Urban and stray dogs	'Managed population' and 'immunised population' approaches[3]
Large-scale burning off	Feral buffalo camel, cattle deer donkey, goat, horse, pig	Use only under exceptional circumstances
Small-scale burning off	Feral buffalo	To produce green pick during dry season
Human sweep line	Feral buffalo, camel, cattle, deer, donkey, goat, horse, fox	Use only under exceptional circumstances
Sedatives	Feral goats	Unproven for other species
	Birds	Alpha-chloralose has been used
	Fallow deer	Diazepam used successfully in Tasmania

[1] trap design differs between species, nets will also be used for wild birds and bats, a wildlife biologist or wildlife/vertebrate pest control officer will design or advise on traps

[2] see Wilson and Choquenot (unpublished) for feral pig poisoning methods

[3] see Saunders (1999) for information on methods and bait types

[4] see Henzell et al (1999) and Section 8.4.2 for information on Judas animals

8.4 Capture and control techniques for wild animals

8.4.1 Lethal control techniques

These methods rely on shooting (helicopter or ground shooting) or poisoning.

Helicopter shooting

Advantages:

- useful to obtain samples quickly;
- can cover large areas rapidly;
- rapid control of large number of animals with concurrent control of sympatric species possible;
- suitable for a wide range of larger species such as horses, donkeys, cattle, buffalo, goats, camels, deer and pigs; and
- reduces mechanical disease spread by minimising ground contact.

Disadvantages:

- only suitable where vegetation density permits good visibility and where animals are not grazing at night; and
- may cause dispersal (possibly mainly in high-density populations).

Samples will be required early in the outbreak so generally the quickest retrieval method is recommended. This is most commonly helicopter shooting.

Ground shooting

Advantages:

- can be used where terrain and vegetation cover preclude the use of helicopters;
- spotlight shooting suitable for nocturnal animals such as deer, foxes, cats and pigs; and
- may be useful for follow-up surveys, particularly if animals have learned to hide.

Disadvantages:

- relatively slow and time-consuming compared with helicopter shooting; and
- will need many teams to cover large areas.

Poisoning

Routine poisoning of vertebrate pests (feral pigs, rabbits, wild dogs, foxes) is conducted throughout Australia using 1080. This is carried out by government pest management agencies in each State or Territory using similar methods. Other poisons such as warfarin (pigs) and cyanide (carnivores) are used under licence mostly for research activities. In any instance where poisons are to be used in emergency disease control, local pest management agencies must be consulted. There are legal restrictions on who can mix and distribute baits.

This manual does not deal in detail with rodents (see Section 1.1), and does not recommend widespread destruction of wild birds (see Section 2.1). **Strict conditions apply to the use of poisons in these situations and prospective users should consult with State/Territory department chemicals coordinators before use**.

Advantages:

- minimised disturbance; and
- reduced risk of dispersal.

Disadvantages:

- need to allow for a period of free feeding if poison bait is used;
- non-specific and may kill non-target species;
- unless a quick-acting poison such as cyanide is used, it may be difficult to locate carcases;
- efficacy is variable, particularly with 1080; and
- may be difficult to get fresh tissue samples.

8.4.2 Live capture techniques

These methods will generally involve some form of trap or snare. With larger animals, tranquilliser guns should be considered, and in the case of animals such as deer, net guns can be used. Nets (mist and hand nets) are also useful for capturing wild birds and bats.

Trapping

Advantages:

- minimised disturbance;
- reduced risk of dispersal; and
- live animals being then available for sentinels or as Judas animals.

Disadvantages:

- may take a few weeks to achieve results; and
- need to allow a period for free feeding and/or familiarisation.

Note: Trapping is more likely to be effective when food or water are in short supply.

For traps at water, minimise dispersal by using separate one-way devices (ramps or spear gates) for entry and exit. Habituate the animals to using them, then close exit device. Place traps close to suspected refuge areas, on permanent water, in association with barrier or temporary fencing, along frequently used paths and pads.

Judas animals

In Australia, this method has been successfully tested on feral goats (Henzell 1987) and has proven highly cost-effective in Brucellosis and Tuberculosis Eradication Campaign control operations for cattle and buffalo in the Northern Territory (Carrick et al 1990, Caple, P., unpublished data). It has had mixed results with feral pigs (Wilson and Choquenot, unpublished, McIlroy and Gifford 1997).

Judas animals obtained from among the population to be controlled are no more likely to disperse than any other members of the population. Some Judas animals obtained from elsewhere are more likely to disperse, and for this reason Judas animals should preferably be obtained from within the restricted area, possibly at an early stage of control operation when they can be caught easily. If necessary they could be held until eventual deployment. If dispersal does occur, Judas animals allow it to be readily monitored.

Advantages:

- it minimises the disruption caused by human intervention in animal populations;
- because it is cheap, eradication is affordable in situations where it would not otherwise be contemplated;
- a population estimate can be calculated from the numbers of Judas animals and wild animals seen;
- Judas operations do not cause animals to disperse (see above); and
- free-ranging Judas animals can be used as sentinel animals, to test for the presence of residual or reinvading animals and of disease, making them an ideal method of demonstrating freedom from disease at the end of a campaign.

Disadvantages:

- setting up Judas operations takes time and specialised equipment;
- for a population of a few animals it might take weeks or even months for a Judas animal to join up with them; and
- some radio transmitters fail and Judas animals must be double collared if it is essential that the animal be traced.

9 POPULATION CONTAINMENT

9.1 Objective

Containment aims to prevent or minimise the risk of disease transmission by preventing infected or potentially infected animals making contact with disease-free animals. Containment may be achieved by:

- natural physical or environmental barriers (eg rivers, mountains, deserts etc);
- artificial barriers (eg fencing, bird-proofing); and
- surrounding the infected population with an ‘animal-free’ zone or a vaccinated buffer zone.

Many of the AUSVETPLAN **Disease Strategies** indicate that improved fencing, or bird-proofing, around domestic animal industries will reduce the risk of disease agent contact between domestic and wild animals.

When deciding whether to attempt containment, follow the guidelines in Section 4 of this manual. Also refer to the relevant part of AUSVETPLAN **Disease Strategies**.

9.2 Planning the containment strategy

Appendix 1 lists sources of information that should be consulted when planning wild animal operations.

The LDCC controller, epidemiologist and wild animal control coordinator, together with appropriate species experts/wildlife biologists will determine the type and extent of containment operations to be undertaken.

A variety of techniques can be used to contain wild animals. The most important criteria for deciding if, or what, containment techniques are appropriate are:

- the nature of the disease;
- availability of existing natural or man-made barriers;
- time-frame, as it may take some time to fully implement a containment strategy; and
- availability of resources.

9.2.1 Containment teams

Membership

Containment teams should generally consist of:

- local vertebrate pest control and/or wildlife officers where possible

- at least one officer experienced in wild animal capture/control procedures

If the workload is high, consider including a technical assistant to assist with counting, data recording and mapping.

Briefing

Containment teams will be briefed at the LDCC on where they are to operate, what to look for, what techniques are to be used, reporting and data recording procedures, decontamination procedures and how to deal with carcases. Teams will report to the wild animal control team leader and/or wild animal control and surveillance coordinator (see Section 11) depending on the size of the outbreak.

Duties

Containment teams will:

- establish and maintain physical barriers, if used;
- use safe practices to humanely destroy target wild animal species, ensuring that dispersal does not occur;
- complete a wild animal control form (Appendix 3) that will clearly show the location and number of animals destroyed and, importantly, number of animals escaped;
- immediately report the dispersal or escape of wild animals out of the wild animal buffer area;
- use grid overlays on maps and, where appropriate, GPS, to facilitate accurate recording of the area of operation (within the wild animal buffer area); and
- ensure that the mapping officer records the location of animals destroyed on topographic maps at the LDCC. (Also refer to the AUSVETPLAN **Mapping Manual**.)

Where feasible, carcases should be treated or disposed of as directed by the LDCC. (Refer to AUSVETPLAN **Disposal Manual**.) Note that although the time and resources required to dispose of carcases may compromise the speed of population containment, disposal may be necessary to ensure disease containment.

9.3 Techniques and species-specific information

An outline of species-specific techniques is listed in Table 8.

Table 8 Containment techniques and considerations for wild animals[1]

Technique	Species	Comments
Depopulation	All species	Use one or more of the techniques in Section 8 (Population reduction) to create a buffer area around the wild animal control area or the infected area
Helicopter patrol	Feral buffalo, camel, cattle, deer, donkey, goat, horse, pig	Patrol the perimeter of the wild animal control area; clearing lines of vegetation may be useful
Fences[2]	All species	Expensive, resource-intensive, and inflexible; useful to contain a relatively undisturbed wild animal population while being tested for disease presence or while Judas animals are released and allowed to join up with local wild animals. Most effective against small species; large herbivores, if agitated, will penetrate fences, so disturbance in the vicinity should be minimised. For very large species, consider fences that alter dispersal paths and allow passage to be detected (eg electric fences to funnel buffalo to movement detectors)
Lure traps	Feral buffalo	Especially oestrous females baited in movement corridors; not successful for feral pigs
Cordon of armed personnel	Likely all species although not tested	Resource-intensive and inflexible; use only where 100% containment vital; combine with illumination

[1] Consider that many of these techniques will be resource and time consuming

[2] Consult experts in feral animal and wildlife fencing

10 SYMPATRIC SPECIES OPERATIONS

If operations are required against more than one species in an area, where possible the chosen techniques should be applicable to all species. Operations are then likely to be less disruptive and quicker to apply and enable more efficient use of resources. If this is not feasible, then the techniques selected for one species should not compromise operations against others (see Tables 5, 6 and 7).

When resources are limited, those species with a demonstrated ability to amplify or spread the disease should be targeted first. Later, when the situation is better under control, the emphasis may be shifted to those species that can maintain the disease (ie are reservoirs of infection). Such a situation could arise, for example, in an outbreak of foot-and-mouth disease where both feral pigs and feral goats may be infected. Pigs pose the greatest threat of spreading the disease to other animals, and where control operations are contemplated it is logical to target these first because of their potential to excrete large amounts of virus.

In other situations, controlling infection in one species may be sufficient to bring the disease under control in the other species. This is frequently the case with rabies where, although a range of species may be affected, only one species is usually responsible for maintaining the disease in an area.

In some situations, different types of operations may be considered against sympatric species. For example, if two susceptible species are present in an area, but disease is only present in one, then control operations may be directed at that species, while the other may be subjected to surveillance only. The situation should be kept under review.

A special problem arises where one species may feed on the carcases of other species (eg feral pigs, foxes, wild dogs/dingoes). Where the former are at risk of becoming infected or of spreading disease, then control operations that leave contaminated carcases may be contraindicated. Alternatively, consideration may need to be given to disposing of or treating carcases.

11 ROLE DESCRIPTIONS

The number of managers/coordinators will depend on the scale of the outbreak and level of involvement of wild animals. Even if there is no person dedicated to undertake these functions in a small outbreak, they still need to be carried out, either by someone in the control centre with other management roles or by a wildlife officer who may have other responsibilities as well.

As a guide, the different levels are:

Extensive outbreak

In addition to the managers/coordinators listed below a *wild animal operations manager* would be appointed to the LDCC operations section to manage and determine the effectiveness of all wild animal control and surveillance operations. The main tasks are in the **Control Centres Management Manual *Part 2*, Role descriptions** LRD 400.

Medium-scale outbreak

A *wild animal control and surveillance coordinator* will be appointed to the LDCC operations section. The responsibilities of this position are similar to those of the wild animal control team leader (see below) with broader responsibilities beyond the infected premises (IPs), including to:

- allocate/define operational areas; and
- coordinate and manage all wild animal control and surveillance activities within the restricted area and on IPs/dangerous contact premises (DCPs).

The main tasks are in the **Control Centres Management Manual *Part 2*, Role descriptions** LRD 401.

A **wild animal control coordinator** may also be appointed to the State disease control headquarters (refer to **Control Centres Management Manual *Part 2*, Role descriptions** SRD 105).

Small-scale outbreak

A **wild animal control team leader** will be appointed to the IP and may have the dual role of control and surveillance for the restricted area (RA). The responsibilities of this position are to:

- identify all important wild animals capable of spreading disease, on the IP/DCP and, where appropriate, in the RA; and
- plan and coordinate an effective population reduction/containment, disease surveillance and/or population survey program to minimise the risk of disease transmission, by coordinating activities of field staff.

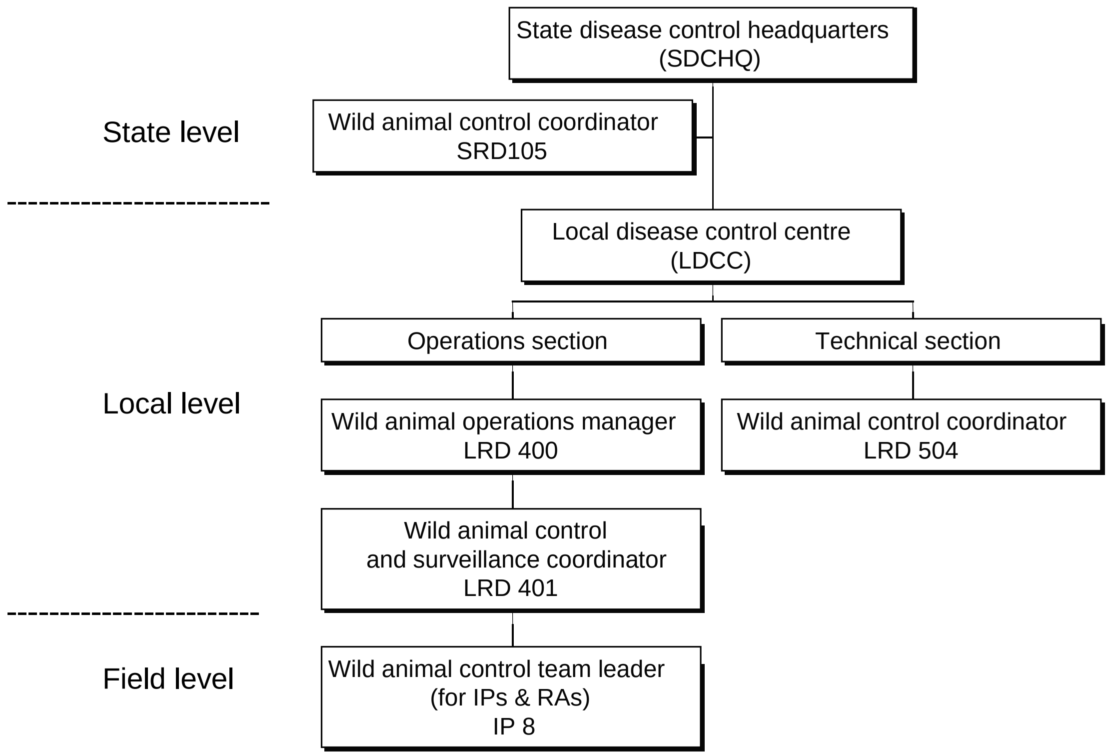
The main tasks are in the **Control Centres Management Manual *Part 2*, Role descriptions** IP 8.

A **wild animal control coordinator** may also be appointed to the technical section. The responsibilities of this position are to:

- develop an overall picture of the distribution, abundance and possible movement of wild animals throughout the RA and possibly the control area (CA); and
- provide advice on the potential for wild animal disease spread, and effect on the size of the RA and the need for disease surveillance.

The main tasks are in the **Control Centres Management Manual *Part 2* Role descriptions** LRD 504.

Figure 1 Structure of wildlife manager/coordinator roles



NOTE

Actual structure will depend on the scale of the outbreak, as follows.

- Wild animal operations manager (role description LRD 400) should only be created for extensive outbreaks.
- Wild animal control coordinator (SRD 105) attached to State disease control headquarters and the LDCC wild animal control coordinator (LRD504) may be necessary for medium and small-scale outbreaks.
- Wild animal control and surveillance coordinator (LRD 401) may be required for a small-scale outbreak .

Appendix 1 Sources of information

Species	Sources of information
All species	Consult local/State vertebrate pest control authorities[1] and control officers, National Parks rangers, landholders, local hunters and the wildlife biologist to determine the likely location and density of species. Also refer to the key documents listed below[2]
Bats	Consult museums, universities, carer groups
Buffalo	Consult the most recent aerial survey of the NT Also Northern Australia Quarantine Strategy staff and buffalo catchers/harvesters
Deer	The Australian Deer Association Inc should be able to recommend hunters with local knowledge who can provide information on deer control and live capture; evaluate deer numbers from tracks and spotlight counts; advise on feeding areas and seasonal movements
Dogs/dingoes/feral cats	Consult local doggers and, where appropriate, the local/State authority responsible for wild dog destruction
Feral goats	Consult commercial harvesters as to the location and number of goats shot and mustered in the area
Feral horses/donkeys	As for all species (above)
Feral pigs	Also consult harvesters and chiller operators as to the location and number of pigs shot in the area
Marsupials	In addition to National Parks rangers, consult local field naturalist and wildlife conservation organisations
Wild birds	Consult local and state ornithologist groups, Birds Australia, and domestic bird producers as to the location and species of wild birds in the area

[1] Refer to the State or Territory emergency disease management manual for contact details of organisations

[2] Parkes et al (1996), Dobbie et al (1993), Choquenot, McIlroy and Korn (1996), Saunders et al (1995), Saunders (1999); Henzell et al (1999)

Appendix 2 Wild animal sampling form

Date					**Operator name or ID**			
Geographical area/zone					**Location ID**			
Animal ID	**Location (GPS)**	**Time**	**Species**	**Age**	**Sex**	**Group size**	**Clinical signs**	**Sampled Y/N**

Appendix 3 Wild animal control form

Date	**Operator name/ID**
Geographical area/Zone	**Location ID**

Operation type (circle)

Aerial shooting Ground shooting Baiting Trapping Other

Location **(GPS)**	**Time**	**Species**	**Number in group**	**Number destroyed**	**Number escaped**	**Comments**

Appendix 4 Legislation relevant to wild animal control during an emergency disease outbreak

Jurisdiction	Act or Regulations	Provisions of legislation
ACT	*Animal Welfare Act 1994*	Prevention of cruelty and ill-treatment of animals.
	Rabbit Destruction Act 1919	Declaration of rabbit infested areas. Duty of owners and occupiers to destroy rabbits and noxious animals.
Commonwealth	*Agricultural and Veterinary Chemicals Code Act 1994*	Covers registration of agricultural and veterinary chemicals Australia-wide.
	Agricultural and Veterinary Chemicals (Administration) Act 1994	Importation of chemicals.
	Quarantine Act 1908	Prevention of introduction or spread of pests and diseases affecting humans, plants and animals.
New South Wales	*Aboriginal Lands Rights Act 1983*	Access to Aboriginal land.
	Prevention of Cruelty to Animals Act 1979	Prevention of cruelty and ill-treatment of animals.
	Pesticides Act 1978	Control use of agricultural chemicals
	Rural Lands Protection Act 1989	Animals declared noxious, required to be continually suppressed.
	Threatened Species Conservation Act 1995	Protection of endangered fauna and their habitat
Northern Territory	*Aboriginal Land Rights (Northern Territory) Act*	Control of Aboriginal land.

Northern Territory (cont)	*Pastoral Land Act*	Regulates appropriate use of pastoral land with emphasis on a cooperative approach through property plans. Power to require pest management.
	Poisons and Dangerous Drugs Act	Control of use of poisons.
	Prevention of Cruelty to Animals Act	Control of pest animals is exempted, provided humane methods are used.
	Territory Parks and Wildlife Conservation Act	Declares animals that are pests or prohibited entrants. Permits may be issued for the possession or import of exotic animals. Authority to declare pest control areas and issue notices to landholders to control pests.
Queensland	*Animals Protection Act 1925*	Prohibits cruelty and regulates animal experimentation: welfare aspects.
	Health (Drugs and Poisons) Regulations 1996	Control of poisons.
	Lands Act 1994	Conditions require control of declared animals.
	Rural Lands Protection Act 1985	Owner or occupier of land bound to control declared animals.
South Australia	*Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986*	Owner/occupier of land responsible for control of proclaimed animals (including rabbits). Regulation of the keeping, import and export of exotic animals.
	Controlled Substance Act 1984	Controls use of poisons
	Dangerous Substances Act 1979	Regulations for transport, storage and use of dangerous substances.
	National Parks and Wildlife Act 1972	Required to manage pests on reserved land.

South Australia (cont)	*Pastoral Land Management and Conservation Act 1989*	Controls the use of land in arid areas. Limits amount of stock (including feral animals) that can be carried.
	Prevention of Cruelty to Animals Act 1985	Provides for the prevention of cruelty and ill-treatment of animals.
Tasmania	*Agricultural and Veterinary Chemicals (Control of Use) Act 1995*	Imposes controls on the manufacture, sale, use and application of agricultural chemicals.
	Animal Welfare Act 1993	Prevention of cruelty and ill-treatment of animals.
	Dog Control Act 1997	Poison and baiting of dogs.
	National Parks and Wildlife Act 1970	Rabbit-proof fencing of reserved crown land. Issue of permits and licences to take native animal pests. Prohibition on introduction of certain animals.
	Vermin Destruction Act 1950	Duty of occupiers to destroy and suppress vermin (rabbits). Power to enter land and destroy vermin. Suppression of vermin on crown land.
Victoria	*Agricultural and Veterinary Chemicals (Control of Use) Act 1992*	Imposes controls on the manufacture, sale, use and application of agricultural chemicals.
	Catchment and Land Protection Act 1994	Provides for a system of controls on noxious weeds and pest animals.
	Dangerous Goods (Storage and Handling) Regulations 1989	Provides standards and procedures for the storage and safe handling of dangerous substances.
	Dangerous Goods (Transport) Regulations 1987	Determines the standard safe methods for the transport of dangerous substances.

Victoria (cont)	*Drugs, Poisons and Controlled Substances Act 1985*	Classifies poisons and controlled substances and sets conditions on their keeping.
	Flora and Fauna Guarantee Act 1988	Provides the basic legal powers and the management systems needed for the protection of the State's native species.
	National Parks Act 1975	Responsibility for destruction of 'exotic' fauna in national parks.
	Prevention of Cruelty to Animals Act 1985	Provides for the prevention of cruelty and ill-treatment of animals
	Wildlife Act 1975	Provides for the conservation, protection and management of wildlife. Provides for proclaiming 'noxious wildlife'.
Western Australia	*Agriculture and Related Resources Protection Act 1976*	Provides for the management of pest animals, and the introduction, spread and keeping of certain animals.
	Agricultural and Veterinary Chemical (Control of Use) Act 1995	Controls use of pesticides.
	Animal Welfare Act 1993	Provides for the prevention of cruelty and ill-treatment of animals.
	Conservation and Land Management Act 1984	Provides for use, protection and management of public lands, water, flora and fauna.
	Dog Control Act 1987	Covers control of feral dogs.
	Explosives and Dangerous Goods Act 1961	Regulates the classification, marking, storage, carriage and sale of dangerous goods.
	Land Act 1933	Power to undertake pest control on crown land.

Western Australia (cont)	*Mining Act 1978*	Defines responsibility for pest control on mining tenements
	Poisons Act 1971	Limits use of poisons.
	Police Offences Act 1935	Controls use of poisons.
	Soil and Land Conservation Act 1945	Conservation of soil and land resources, and the mitigation of the effects of erosion, salinity and flooding. May include management of land degradation caused by pest animals. Powers include prohibition of animals on any soil conservation reserve.
	Wildlife Conservation Act 1950	Provides for the conservation and protection of wildlife. Includes management programs for capture, breeding, keeping and import/export of fauna.

GLOSSARY

Australian Chief Veterinary Officer	The nominated senior Commonwealth veterinarian in the Department of Agriculture, Fisheries and Forestry – Australia who manages international animal health commitments and the Commonwealth's response to an animal disease outbreak.
AUSVETPLAN	Australian Veterinary Emergency Plan
Buffer zone	An area surrounding or abutting a wild animal control area within which susceptible wildlife can be eradicated, reduced in density or physically contained in order to prevent transmission and further spread of the disease.
Chief veterinary officer	The veterinary officer of a State or Territory animal health authority who has responsibility for animal disease control in that State or Territory.
Consultative Committee on Emergency Animal Diseases	A committee of Commonwealth and State/Territory CVOs, and CSIRO/AAHL, chaired by the Australian CVO (AFFA), to consult in emergencies due to the introduction of an exotic disease of livestock, or serious epizootics of Australian origin.
Control	The process of reducing either the population density of wild animals or threshold density of the disease by lethal (eg poison, shoot) and non-lethal (eg trap, vaccinate) methods.
Containment	The process of containing a wild animal population within a defined area or buffer zone by the use of natural or artificial barriers and/or depopulation.
Dangerous contact premises	Premises (a defined area) that contain a dangerous contact animal or animals or other serious contact.
Dispersal	Movements of animals (usually permanent migrations) outside normal home range area. Can be associated with annual re-allocation of territory ownership (eg carnivores), events involving search for resources or disturbance from control.
Emergency animal disease	Includes exotic animal diseases and endemic diseases that warrant a national emergency response.
Exotic fauna	Non-domestic animal species that are not indigenous to Australia.
Feral animals	Domestic animals that have ‘gone wild’.

Feral herbivores	These include buffalo, cattle, camels, deer, donkeys, feral goats and horses, that is, the large herbivores only.
Infected premises	A defined area (which may be all or part of a property) in which an emergency disease or agent exists, or is believed to exist.
Home range	The area used by an animal in the course of its normal activities. Generally proportional in area to the amount of resources it contains (ie animals in resource-rich environment has a smaller home range than the same species in a resource-poor environment).
Judas animals	This method exploits the social behaviour of large herbivores and pigs. Animals carrying radio transmitters are released into the area and join up with local wild animals. The entire group is then tracked down, and the non-Judas animals shot. The Judas animals are allowed to escape and the process is repeated.
Local disease control centre	An emergency operations centre responsible for the command and control of field operations in a defined area.
Monitoring	Routine collection of data for assessing the health status of a population (see also *Surveillance*).
Native wildlife	Term used to denote native fauna that may be susceptible to emergency disease, including bats, dingoes and marsupials.
Prevalence	Proportion (or percentage) of animals in a particular population affected by a particular disease at a given point of time.
Restricted area	A relatively small declared area (compared with a control area) around an infected premises that is subject to intense surveillance and movement controls.
Sensitivity	The probability that a test will correctly identify animals that have been exposed to the disease (true positives). Exposed animals that do not give a positive test response are referred to as false negatives (see also *Specificity*).
Sentinel animal	Animals used for the express purpose of detecting the presence of a specific emergency disease agent.

Specificity	The probability that a test will correctly identify animals not exposed to the disease (true negatives). Non-exposed animals that test positive are referred to as false positives (see also *Sensitivity*).
State disease control headquarters	The emergency operations centre that directs the disease control operations to be undertaken in the State/Territory.
Surveillance	A systematic program of inspection and examination of animals to determine the presence or absence of a disease. It is a more active process than monitoring, and usually implies that directed action will be taken if disease levels exceed a threshold (see also *Monitoring*).
Survey	An investigation involving the collection of samples or information.
Susceptible species or hosts	Animals that can be infected with the disease.
Sylvatic cycle	Term used to denote a cycle of rabies infection involving wildlife (derived from *sylvan* [adj] – pertaining to or inhabiting the woods.
Sympatric species	Two or more species having common or overlapping geographical distributions.
Threshold density	Population density below which a disease dies out in a population.
Vector	Carrier of disease or infection.
Vertebrate pest control officer	An officer employed by a State or Commonwealth authority who conducts operations to control noxious and feral animals (vertebrate pests); usually has excellent knowledge of the distribution and abundance of most species of wild animals within their local area.
Wild animals	Term used to include feral animals (of which many are declared 'noxious' under State legislation), and native wildlife (see *Feral animals*, *Native wildlife).*
Wildlife biologist	A specialist in the biology and ecology of one or a number of wildlife and/or vertebrate pests, who is competent in the design and analysis of population surveys.
Wild animal control area	An area where wild animals are (or are suspected to be) infected with an emergency disease agent or have the greatest risk of contact with infected domestic animals.

Abbreviations

AAHL	Australian Animal Health Laboratory
AFFA	Commonwealth Department of Agriculture, Fisheries and Forestry — Australia
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AUSVETPLAN	Australian Veterinary Emergency Plan
BTEC	Brucellosis and Tuberculosis Eradication Campaign
CA	Control area
CCEAD	Consultative committee on emergency animal diseases
CVO	Chief veterinary officer
DCPs	Dangerous contact premises
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FMD	Foot-and-mouth disease
GIS	Geographic information system
GPS	Global positioning system
ID	Identification
IPs	Infected premises
LDCC	Local disease control centre
OIE	World Organisation for Animal Health Office International des Epizooties
RA	Restricted area
TVR	Trap–vaccinate–release
1080	Sodium monofluroacetate

REFERENCES

Bayliss, P. and Yeomans, K.M. (1989). Distribution and abundance of feral livestock in the 'Top End' of the Northern Territory (1985–1986), and their relation to population control. *Australian Wildlife Research*, 6:651–76.

Bentley, A. (1995). Fallow Deer (*Dama dama*), red deer (*Cervus elaphus*), sambar deer (*Cervus unicolor*), chital (*Axis axis*), hog deer (*Axis porcinus*). In *The Mammals of Australia* (ed *R. Strahan*), Reed Books, Chatswood, pp 732–41.

Braysher, M. (1993). *Managing Vertebrate Pests: Principles and Strategies,* Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Brothers, N.P., Skira, I.J. and Copson, G.R. (1985). Biology of the feral cat, *Felis catus* (L.), on Macquarie Island. *Australian Wildlife Research,* 12:425–36.

Bunn, T.O. (1991). Cat rabies. In *The Natural History of Rabies* (ed *G. M. Baer*). 2nd edition. CRC Press, Boston, pp 379–87.

Cannon, R.M. and Roe, R.T. (1982). *Livestock Disease Surveys. A Field Manual for Veterinarians,* Australian Government Publishing Service, Canberra, 35 pp.

Carrick, P., Thomson, D. and Calley, G. (1990). The use of radio transmitters for tracking and shooting feral buffalo. *Australian Rangeland Journal,* 12:84–90.

Caughley, G. (1977). *Analysis of Vertebrate Populations,* John Wiley and Sons, Chichester, United Kingdom.

Choquenot, D. (1995). Donkey (*Equus asinus*). In *The Mammals of Australia* (ed *R. Strahan*), Reed Books, Chatswood, pp 712–13.

Choquenot, D., McIlroy, J. and Korn, T. (1996). *Managing Vertebrate Pests: Feral Pigs*, Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Coman, B.J., Robinson, J. and Beaumont, C. (1991). Home range, dispersal and density of red fox (*Vulpes vulpes* L.) in central Victoria. *Australian Wildlife Research,* 18:215–23.

Corbett, L.K. (1995). *The Dingo in Australia and Asia,* University of New South Wales Press, Sydney.

Corbett, L.K. (1995a). Swamp buffalo, *Bubalis bubalis,* In *The Mammals of Australia* (ed *R. Strahan*), Reed Books, Chatswood, pp 723–25.

Dobbie, W.R., Berman, D.McK. and Braysher, M.L. (1993). *Managing Vertebrate Pests: Feral Horses*, Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Dorges, B. and Heucke, J. (1995). One-humped camel (*Camelus dromedarius*). In *The Mammals of Australia* (ed *R. Strahan*). Reed Books, Chatswood, pp 718-20.

Gardiner I.A., Hietala S. and Boyce W.M. (1996). Validity of using serological tests for diagnosis of diseases in wild animals. *Science Technical Review Office International des Epizooties* 15(1):323–35.

Geering, W.A., Forman, A.J. and Nunn, M.J. (1995). *Exotic Disease of Animals. A Field Guide for Australian Veterinarians*, Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Henzell, R. (1987). Methods of controlling feral goats in special situations — a progress report. *Australian Vertebrate Pest Control Conference* 8:264–67.

Henzell, R., Caple, P. and Wilson, G. (1999). *Wildlife and Exotic Disease Preparedness in Australia—Feral Herbivores.* Wildlife and Exotic Disease Preparedness Program, Department of Agriculture, Fisheries and Forestry – Australia, Canberra.

Hone, J. (1990). Note on seasonal changes in population density of feral pigs in three tropical habitats. *Australian Wildlife Research,* 17:131–34.

Jones, E. and Coman, B.J. (1982). Ecology of the feral cat, *Felis catus* (L.), in South-eastern Australia. II Home ranges and population ecology in semi-arid north-west Victoria. *Australian Wildlife Research,* 9:111–19.

King, D.R. and Smith L.A. (1985). The distribution of the red fox in Western Australia. *Records of the Western Australia Museum*, 12:197–205.

Maas, S. and Choquenot, D. (1995). *Feral Goats in Outcrop Areas of the Semi-Arid Rangelands: Aerial Survey Techniques and the Cost of Helicopter Shooting.* Final report to The Wildlife and Exotic Diseases Preparedness Program, Bureau of Resource Sciences, Canberra.

Mahood, I.T. (1985). Some aspects of ecology and the control of feral goats (*Capra hircus* L.) in western New South Wales. MSc Thesis, Macquarie University, Sydney.

Moodie, E. (1995). The potential for biological control of feral cats in Australia. Report to Australian Nature Conservation Agency, Canberra (unpublished).

McIlroy, J.C. and Gifford, E.J. (1997). The Judas pig technique: a method that could enhance control programs against feral pigs. *Wildlife Research*, 24 (4):483–91.

McKnight, T.L. (1976). *Friendly Vermin: a Survey of Feral Livestock in Australia*. University of California Press, Berkeley, p154.

Mitchell, J., Merrell, P. and Allen, L. (1982). *Vertebrate Pests of Queensland*. Stock Routes and Rural Lands Protection Board, Department of Lands, Queensland.

Newsome, A.E. and Catling, P. (1992). Host range and its implication for wildlife rabies in Australia. In *Wildlife Rabies Contingency Planning in Australia* (eds *P. O'Brien and G. Berry*). Bureau of Rural Resources Proceedings No. 11, Australian Government Publishing Service, Canberra, pp 97–107.

OIE (Office International des Epizooties) (1993a). *Recommended Standards for Epidemiological Surveillance for Rinderpest* (an update of the OIE (1989) *Report of the Expert Consultation on Rinderpest Surveillance Systems*).

OIE (1993b). Ad Hoc Group on Contagious Bovine Pleuropneumonia (CBPP) Surveillance Systems. *Recommended Standards for Epidemiological Surveillance for Contagious Bovine Pleuropneumonia*.

Parkes, J., Henzell, R. and Pickles, G. (1996). *Managing Vertebrate Pests: Feral Goats*, Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Saunders, G. (1999). *Wildlife and Exotic Disease Preparedness in Australia—Rabies.* Wildlife and Exotic Disease Preparedness Program, Department of Agriculture, Fisheries and Forestry — Australia, Canberra.

Saunders, G., Coman, B., Kinnear, J. and Braysher, M. (1995). *Managing Vertebrate Pests: Foxes.* Bureau of Resource Sciences, Australian Government Publishing Service, Canberra.

Siebert, B.D. and Newman, D.M.R. (1989). Camelidae. In *Fauna of Australia. Vol. 1B Mammalia* (eds *D.W. Walton and B.J. Richardson*). Australian Government Publishing Service, Canberra, pp 1050–53.

Short, J., Caughley, G., Grice, D. and Brown, B. (1988). The distribution and relative abundance of camels in Australia. *Journal of Arid Environments* 15:91–97.

Southwell, C.J. and Pickles, G.S. (1993). Abundance, distribution and rate of increase of feral goats in Western Australia. *Rangeland Journal,* 15(2):334–48.

Statham, H.L. and Statham, M. (1996). *Movement of fallow deer (*Dama dama*) in Tasmania and the effect of population sampling on dispersal*. Research on behalf of the Wildlife and Exotic Disease Preparedness Program, Bureau of Resource Sciences.

Strahan, R. (1995). *Complete Book of Australian Mammals*. Australian Museum, Reed Books, Chatswood.

Thompson, J.A. and Fleming, P.J.S. (1994). Evaluation of the efficacy of 1080 poisoning of red foxes using visitation to non-toxic bait as an index of fox abundance. *Australian Wildlife Research,* 21:27–39.

Wheeler, S.H. (1987). A model disease control exercise using feral donkeys in the east Kimberley district. *Vertebrate Pest Control Conference No 8,* Coolangatta, pp 339–43.

Wilson, G., Dexter, N., O'Brien, P. and Bomford, M. (1992). *Pest Animals in Australia: A Survey of Introduced Wild Mammals*, Bureau of Rural Resources, Canberra.

Wilson, G. and Choquenot, D. *Review of Feral Pigs and Exotic Disease Preparedness.* Report on behalf of the Wildlife and Exotic Disease Preparedness Program, Bureau of Resource Sciences, internal document.

Wurst, D. (1996). *Distribution, movement, environmental impact and management of the feral camel in central Australia*. A report to the Australian Nature Conservation Agency, Canberra, pp 15.

Further reading

Caughley, J., Bomford, M., Parker, B., Sinclair, R., Griffiths, J. and Kelly, D. (1998). *Managing Vertebrate Pests: Rodents.* Bureau of Resources Sciences and Grains Research and Development Corporation, Canberra.

Corbett, L.K. (1995). Dingo, *Canis lupus dingo*. In *The Mammals of Australia* (ed *R. Strahan*). Reed Books, Chatswood, pp 696–98.

Fleming, P., Thomson, P., Corbett, L. and Harden, B. (in press). *Managing the Impacts of Wild Dogs and Dingoes*. Bureau of Resource Sciences, Canberra.

Groves, C.P. (1989). Equidae. In *Fauna of Australia Vol. 1B Mammalia* (eds *D.W. Walton and B.J. Richardson*). Australian Government Publishing Service, Canberra.

Murray, M.D. and Snowdon, W.A. (1976). The role of wild animals in the spread of exotic diseases in Australia. *Australian Veterinary Journal,* 52: 547–54.

Newsome, A. (1995). Cat, *Felis catus*. In *The Mammals of Australia* (ed *R. Strahan*). Reed Books, Chatswood, pp 700–2.

Olsen, P. (1998). *Australia's Pest Animals: New Solutions to Old Problems*, Bureau of Resource Sciences and Kangaroo Press, East Roseville.

Rolls, E.C. (1969). *They All Ran Wild*. Angus and Robertson, Sydney.

INDEX