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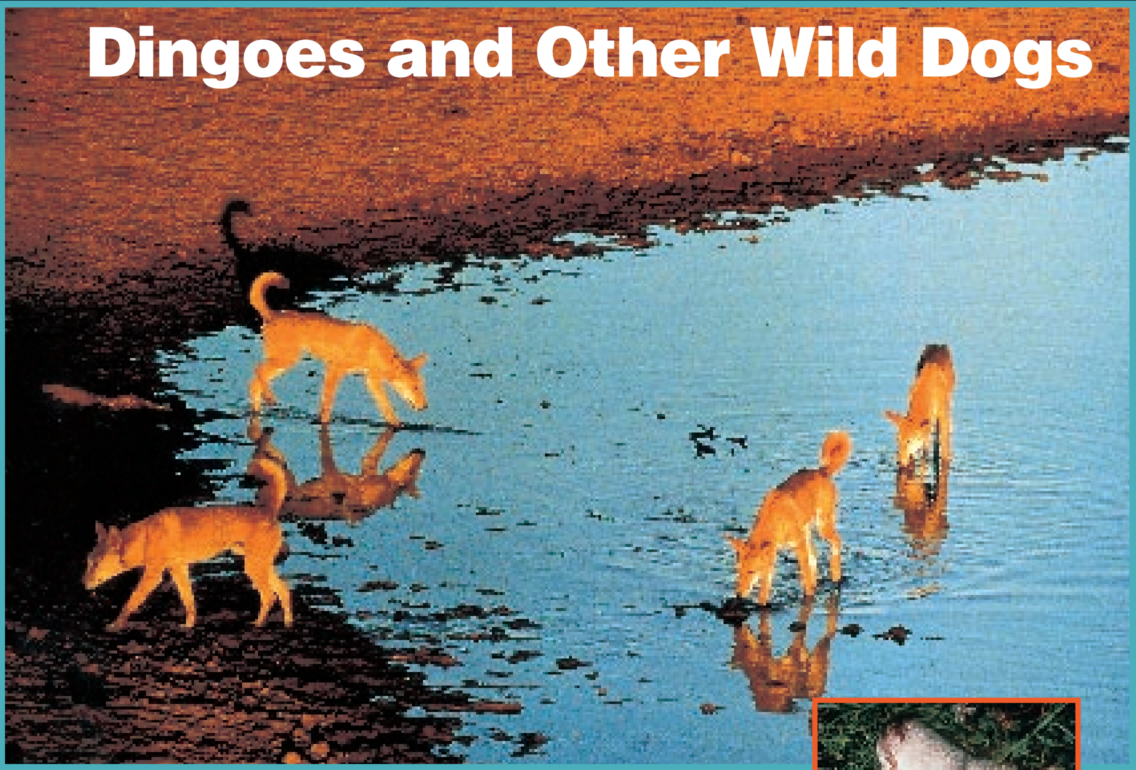
Managing the Impacts of
Dingoes and Other Wild Dogs



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AGRICULTURE, FISHERIES AND FORESTRY - AUSTRALIA

Managing the Impacts of Dingoes and Other Wild Dogs

Peter Fleming, Laurie Corbett,

Robert Harden and Peter Thomson

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Credits for cover photographs: Main: Laurie Corbett. Inset: NSW Agriculture.

Affiliations:
Authors: Peter Fleming, NSW Agriculture – Vertebrate Pest Research Unit
Laurie Corbett, EWL Sciences Pty Ltd
Robert Harden, NSW National Parks and Wildlife Service – Biodiversity Research Group
Peter Thomson, Agriculture Western Australia – Vertebrate Pest Research Section

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AGRICULTURE FISHERIES FORESTRY

Foreword

Wild dogs, which include feral domestic dogs, dingoes and their hybrids, are a problem in Australia because their predation and harassment of stock causes millions of dollars worth of losses to sheep, cattle and goat producers each year. There are also opportunity costs in areas where sheep are not grazed because of the high risk of wild dog predation. Yet dingoes are also valued as a native species and their conservation is important to many people. The survival of pure dingoes on mainland Australia is threatened by hybridisation with feral domestic dogs.

There is little reliable information about the cost of wild dog predation or the benefits of wild dog control. The relationship between dog abundance and livestock predation is often complex and variable and sometimes stock losses can be high even when wild dog numbers are low. Although spending on pest control should be justified in terms of economic returns on such investments, this is clearly difficult when changes to livestock productivity in response to dog control are often poorly quantified. This can be further complicated where pastoral properties abut government lands where dingo conservation is a management objective and dogs move between these areas.

This book is one in a series produced by the Bureau of Rural Sciences as part of the National Feral Animal Control Program — a Natural Heritage Trust initiative. Others in the series include guidelines for managing feral horses, rabbits, foxes, feral goats, feral pigs, rodents and carp. The principles underlying the strategic management of vertebrate pests have been described in *Managing Vertebrate Pests: Principles and Strategies* (Braysher 1993) and in *Australia's Pest Animals: New Solutions to Old Problems* (Olsen 1998). The emphasis is on the management of pest damage rather than on simply reducing pest density. The guidelines recommend that, wherever practical, management should concentrate on achieving clearly defined economic or conservation benefits.

To ensure the guidelines are accepted as a basis for wild dog management, comment has been sought from State, Territory and Commonwealth Government agencies and from land managers and community and research organisations. The Standing Committee on Agriculture and Resource Management has endorsed the publication of these guidelines.

These guidelines provide natural resource users, managers, advisers and funding agencies with 'best practice' national guidelines for managing the economic and environmental damage caused by wild dogs. They will help land managers reduce harm to livestock caused by wild dogs and assist in the conservation of pure dingoes through the use of scientifically based management that is humane, cost-effective and integrated with ecologically sustainable land management.

Peter O'Brien

Executive Director

Bureau of Rural Sciences

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Acknowledgments

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Several individuals from the Bureau of Rural Sciences deserve mention. Quentin Hart managed the overall publication production process and assisted with editing, design and print management. Lisa Curtin incorporated the numerous modifications to the final drafts, assisted with copy editing, compiled the index, typeset the document and had major responsibility for final production. Dana Bradford helped collate earlier drafts of the manuscript. Kim Tatnell redrew the figures.

The draft manuscript was circulated to the following organisations for comment:

- Animals Australia
- Australian Conservation Foundation
- Australian Veterinary Association
- Central Land Council
- Commonwealth Department of Agriculture, Fisheries and Forestry
- CSIRO
- Land and Water Resources Research and Development Corporation
- National Consultative Committee on Animal Welfare
- National Farmers' Federation
- Rural Industries Research and Development Corporation
- Standing Committee on Agriculture and Resource Management
- Standing Committee on Conservation
- Vertebrate Pests Committee

We thank these groups and hope that this document will facilitate their involvement in more strategic management of wild dog impacts.

Summary

Wild dogs are widely distributed throughout Australia and are pests in agricultural areas, particularly in areas dominated by sheep enterprises. Predation of sheep and cattle threatens the economic viability of some properties and the costs of wild dog control can be substantial. At the same time, in unoccupied lands and areas of extensive cattle grazing wild dogs are often tolerated and dingoes are actively conserved in parts of their range.

These guidelines are a comprehensive review of the origins of dingoes and other wild dogs in Australia, their biology and ecology, the damage they cause, and past and current management. The attitudes of various community groups to wild dogs and the damage they cause through predation of livestock, and to the conservation of dingoes were sought during the production of these guidelines. A strategic approach to management is recommended to reduce predation on livestock by wild dogs and to allow conservation of dingoes. This approach is illustrated by case studies. Deficiencies in knowledge, management and legislation are identified.

These guidelines have been prepared primarily for State and Territory management agencies as a basis on which to consult with land managers and relevant interest groups and to prepare state, regional and local strategies for managing wild dogs and reducing the damage they cause to livestock industries. Their purpose is to assist in developing the most cost-effective strategies to reduce wild dog damage to production. Ideally, such strategies are based on reliable quantitative information about the damage caused by dogs, the cost of control measures and the effect that implementing control has on reducing damage. In developing these guidelines the authors have used all such available information. In some instances, however, where reliable information is not yet available, land managers responsible for wild dog management will still have to make assumptions about impacts and the efficacy and cost-effectiveness of control techniques.

Biology, ecology and taxonomy

The wild dog population comprises two subspecies of canid, dingoes (recommended nomenclature, *Canis lupus dingo*) and feral dogs (recommended nomenclature, *C. l. familiaris*) and hybrids of the two. Dingoes were first introduced to Australia some 4000 years ago and domestic dogs have been present since first European settlement in 1788. Dingoes and other wild dogs are widely distributed throughout the country and are present in most environments. However, dingoes and other wild dogs have been removed from much of the agricultural zone over the past 200 years and hybridisation between the subspecies over that time has resulted in a lesser proportion of pure dingoes, especially in south-eastern Australia.

The average adult dingo in Australia weighs 16 kilograms and, although feral dogs and hybrids may weigh up to 60 kilograms, most are less than 20 kilograms. Pure dingoes are distinct from similar-looking domestic dogs and hybrids because they breed once a year and have some different skull characteristics. The present distribution of dingoes and other wild dogs covers most of the mainland, except for the sheep and cereal growing areas of south-eastern Australia. Wild dogs live in small groups or packs in territories where the home ranges of individuals vary between 10 and 300 square kilometres. Packs are usually stable but under certain conditions some wild dogs, usually young males, disperse.

Although wild dogs eat a diverse range of foods, from insects to buffalo (*Bubalus bubalis*), they focus on medium and large vertebrates. Hunting group size and hunting strategies differ according to prey type to maximise hunting success. Larger groups of wild dogs are more successful when hunting large kangaroos (*Macropus* spp.) and cattle and solitary animals are more successful when hunting rabbits and small macropods.

Female dingoes become sexually mature by two years and have only one oestrus period each year, although some do not breed in droughts. Female feral dogs of a similar size to dingoes have the potential to have two litters each year but this is rarely achieved because of the high nutritional demands of raising young. Litters average five pups and are usually whelped during winter.

Agricultural impacts

Wild dogs prey on livestock and predation on sheep and cattle can threaten the economic viability of properties in some areas. Sheep are the most commonly attacked livestock, followed by cattle and goats.

Some individual wild dogs cause far more damage than others, although many individuals will attack or harass sheep, sometimes maiming without killing. Wild dogs sometimes chase sheep without attacking them. Even when wild dogs kill sheep, they often leave carcasses uneaten. Wild dogs that frequently kill or maim sheep often eat other prey, indicating that predation of livestock may be independent of the abundance of other prey. Surplus killing, where more sheep are killed than are needed for food, means that stock losses can be high even when wild dogs are at low densities.

Wild dogs are implicated in the spread of hydatids, a risk to human health and the cause of losses of production associated with hydatidosis (causal agent *Echinococcus granulosus*) in cattle and sheep. They also provide a reservoir for heartworm (*Dirofilaria immitis*) infection and dog diseases such as parvovirus (causal agent Parvovirus). Wild dogs pose the greatest potential risk of maintaining and spreading dog rabies (Rhabdoviridae) if it were to be introduced to Australia.

Conservation of dingoes

The dingo is usually considered a native Australian mammal. Dingoes are an intrinsic part of natural ecosystems and they also have aesthetic value. There is some public expectation that dingoes should be conserved and dingoes are legally protected in some States and Territories. In Australian wildlife communities, wild dogs are top order predators, and as such probably have a major influence on the abundance of the species they compete with or prey on. The interactions between wild dogs and foxes (*Vulpes vulpes*) are not well understood. It is unknown whether the presence wild dogs reduces fox abundance and hence whether wild dogs reduce the impact of foxes on native animal prey.

The greatest threat to the survival of dingoes as a protected sub-species is hybridisation with other dogs. In the more settled coastal areas of Australia and increasingly in outback Australia, the barriers to mating between domestic dogs (feral and owned) and dingoes are rapidly being removed. Hence hybridisation is becoming more common and the pure dingo gene pool is being swamped. In south-eastern Australia, more than half the wild dogs are hybrids. Changes to policies on wild dog management and people's attitudes would be needed to prevent the extinction of pure dingoes on the mainland. The main hope for conservation is to educate people about the plight of dingoes and to manage pure dingoes on large islands such as Fraser Island and Melville Island.

Community attitudes affecting management

Opinions vary as to the pest status of dingoes and other wild dogs. People in the agricultural sector often view wild dogs as a pest to be removed from the environment. In contrast, Aboriginal peoples, urban people and conservationists often view dingoes as native wildlife that should be conserved. Public opinion influences not only the type of management strategies that are developed but also the type of control methods that are used. Wider public attitudes rightly demand that the techniques used for wild dog control be as humane as possible and minimise risks to non-target animals and other environmental values. Management strategies that do not address or acknowledge broad community attitudes are susceptible to disruption or interference.

Past and current management

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

The dingo is extinct in much of the sheep and cereal production zones of eastern and southern Australia because of habitat modification and the success of early poisoning campaigns. The areas that are largely without wild dogs are separated from areas where they are still present by dog-proof fences that were erected around the turn of the century and are still maintained.

In most States and Territories, there is a legal requirement to destroy wild dogs in sheep and cattle grazing zones. Poisoning programs form the basis of lethal control efforts although trapping and shooting are also important.

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

Policy and legislation to encourage the conservation of pure dingoes is required in some States and Territories and a concerted nation-wide effort is needed to ensure that dingo conservation is not thwarted by conflicting legislation. Simultaneously, the control of wild dogs, including dingoes, must be permitted where predation of livestock occurs.

Techniques to measure and manage impact and abundance

To formulate wild dog management plans, it is necessary to measure the level of predation inflicted by wild dogs and to measure changes in wild dog abundance. These two measures enable an assessment of when wild dog control is required and how effective it is.

The principal techniques to control wild dogs are exclusion fencing, shooting, trapping and poisoning. Poisoning using 1080 is the most cost-effective means of reducing populations of wild dogs over large areas of remote or inaccessible country. Various bait types are used and methods of placement range from burying individual baits to dropping baits from aircraft. Trapping is still used for wild dog control and will probably always be needed to target particular dogs that cannot be removed by other means. New techniques such as the use of livestock-guarding dogs, poison ejecting devices and toxic collars have been suggested as alternatives to current methods.

Strategic approach to management

The strategic approach to wild dog management allows improvements at both the local and regional scale. The strategic approach has four components: defining the problem; developing a management plan; implementing the plan; and monitoring and evaluating progress and outcomes.

Defining the problem involves the identification of who has a wild dog problem, what harm the dogs cause, where, when and why damage occurs and how much it costs.

The development of a management plan requires setting management objectives that should include interim and long-term goals, a time frame for achieving them and indicators for measuring performance. Options for wild dog control include local eradication, strategic management, reactive management or no dog control.

Economic frameworks are needed for assessing the value of alternative strategies to manage wild dogs. In some situations, management plans that include conservation strategies for dingoes are required so that potentially conflicting goals can be encompassed. Consultation between stakeholders and clear identification of the goals is critical for avoiding potential conflicts between stakeholder groups with different legal obligations and objectives.

Wild dogs have large home ranges and often traverse boundaries between lands managed by different stakeholders. Action by groups, including government agencies, is therefore an essential element of planning and implementation. By pooling resources, wild dog control groups and boards have been better able to manage wild dog problems. Management programs must be flexible enough to account for the different objectives of stakeholders.

Monitoring and evaluation occur at different levels throughout the implementation and on completion of actions. Operational monitoring records and reviews the costs of actions during the program and ensures that the management plan is executed in the most cost-effective manner. Performance monitoring assesses the effectiveness of the management plan in meeting the agricultural production or conservation objectives that were established initially. Evaluation of data from both forms of monitoring enables the continuing refinement of the management plan. Strategic management of wild dogs is based on the concept of adaptive management, in which the management plan is flexible, responding to measured changes in economic, environmental and pest circumstances. By adopting the strategic approach, predation by wild dogs should be minimised while the conservation of the dingo proportion of the wild dog population will be enhanced. Under such an approach, limited resources will be better allocated and the scale of management will be more appropriate for wild dog problems.

Deficiencies in knowledge and practice

Although there is much knowledge about the ecology, behaviour and effects of predation by dingoes and other wild dogs, some topics require further research to enable best practice management to be implemented. These include better definition of the agricultural impacts of wild dogs and control programs for different enterprises in different regions, study of the interactions between the control of rabbits and wild dog predation of livestock and the effects of wild dog control on the abundance of kangaroos and wallabies (*Macropus* spp.), and the effects of this on agriculture and forestry. There are also knowledge deficits relating to the conservation of dingoes, the effects of wild dog control programs on persistence of pure dingoes, the interactions between predation by wild dogs and the conservation status of non-target animals, and the interactions of wild dogs with feral cats, foxes and native carnivores.

Introduction

These guidelines for managing the impacts of dingoes (*Canis lupus dingo*) and other wild dogs (*C.l. familiaris*) are the eighth in the Managing Vertebrate Pests series being published by the Bureau of Rural Sciences (BRS) in cooperation with the Vertebrate Pests Committee of the Standing Committee on Agriculture and Resource Management (SCARM). These guidelines were funded under the agricultural component of the National Feral Animal Control Program (NFACP) of the Natural Heritage Trust (NHT). A fundamental difference between these guidelines and the preceding publications exists because dingoes hold a legal position unique amongst Australian mammals. Unlike most of the other species addressed by the series, dingoes are simultaneously a protected native species and declared vermin. The dingo and some native birds and rodents are both protected and declared according to their occurrence and situation.

Other guidelines in the series include those for managing feral horses (Dobbie et al. 1993), rabbits (Williams et al. 1995), foxes (Saunders et al. 1995), feral goats (Parkes et al. 1996), feral pigs (Choquenot et al. 1996), rodents (Caughley et al. 1998) and carp (Koehn et al. 2000). A companion volume, *Managing Vertebrate Pests: Principles and Strategies* (Braysher 1993), which explains the principles on which best practice pest management is based, can be read in conjunction with all of these guidelines. There is also an overarching publication (Olsen 1998), designed for general reading, which reviews past management of pest animals in Australia and promotes a more strategic approach for future management. The benefits of focusing on the damage caused by a pest and not the pest itself are explained. Olsen (1998) also explains the need to take into account the links between different feral animal species and other aspects of land management, consistent with the holistic approach advocated under the Ecologically Sustainable Development (ESD) Strategy and Landcare.

A single publication considering the main vertebrate pests would be desirable and consistent with the holistic approach to land management advocated under the ESD Strategy and Landcare objectives. Such a publication would take into account links between pests and links between pests and other aspects of land management. However, the complexities posed by such an approach and current limited knowledge of interspecific interactions has made this impractical. All the guidelines, including these, consider interactions between species and the relationships with other aspects of land management.

These guidelines are principally for State and Territory land management agencies, to assist them to better coordinate, plan and implement regional and local programs that can more effectively manage adverse impacts of wild dogs. The Commonwealth Government has an interest in improving strategies, techniques and approaches to manage the damage caused by wild dogs, both through its responsibilities as a manager of Commonwealth lands and resources, and through programs such as NFACP and the National Landcare Program (NLP) of the NHT, and the National Strategy for the Conservation of Australia's Biological Diversity (Commonwealth of Australia 1992).

Vertebrate pests in Australia: species or situations?

The definition of pest status can be contentious. Some species are regarded as pests all the time in all situations because of their current detrimental impacts or their potential adverse impacts, given their biology, behaviour and historical performance as pests in similar or other habitats. Other animals are generally regarded as having either beneficial or neutral net impact in most situations. Some species, such as the dingo and the feral goat, may be both a significant pest and a significant conservation or economic resource. Perhaps the most useful criterion for evaluating the status of an animal is to evaluate it in terms of its value in a particular situation. For example, cats are valued highly as pets by many people and some pedigree cats have a high market price. Conversely, predation by feral cats is regarded as a process threatening some endangered native vertebrates with extinction (Dickman 1996).

The National Feral Animal Control Program

NFACP is working with State, Territory, and local governments to reduce damage by pest animals to agriculture and the environment. The agricultural component of NFACP is administered by BRS; the environmental component by Environment Australia.

Under its component of NFACP, BRS is producing these national management guidelines for the main pest species of agricultural production and supporting projects to address the information, management and extension deficiencies they identify and to demonstrate the strategic management approaches they advocate.

Applying a strategic approach to the management of the impacts of wild dogs involves the establishment of four essential components (Figure 1) This approach has been adopted in the development of each set of national guidelines.

The strategic management approach

Problem definition and planning of management strategies

There are two problems requiring management. The first problem is predation of livestock by dingoes and other wild dogs. Although there are no estimates of the Australia-wide losses to livestock production caused by wild dogs (including dingoes), the estimated annual expenditure on control activities of $7 million is second only to that for rabbits. The historical threat of predation by wild dogs has largely determined the distribution of sheep and cattle in Australia. A barrier fence stretching from the Great Australian Bight through South Australia and Queensland and ending in north-eastern New South Wales has been built and maintained by government agents and graziers to exclude wild dogs from sheep grazing lands.

Secondly, the dingo has been in Australia long enough to be regarded as part of the native fauna. The existing dynamics of Australia's fauna have evolved with the dingo and the conservation of dingoes within non-agricultural environments is a legitimate aim. Since European settlement, the increasing presence in the population of genes from feral and domestic dogs has reduced the dingo population's integrity. If this trend continues it is predicted that the increasing occurrence of domestic dog genes in wild populations will effectively lead to the extinction on the mainland of the dingo as a subspecies by 2100 (Corbett 1995a).

Strategies to conserve pure dingoes can conflict with strategies to control wild dogs to reduce their impacts on livestock enterprises. Developing approaches to satisfactorily address both problems requires clarification of issues and knowledge of the biology and status of dingoes and other wild dogs. Thus, Chapter 1 discusses the taxonomy of dingoes and other wild dogs, and details their origins, distribution and abundance, and Chapter 2 reviews their biology and ecology. In Chapter 3, the impacts of wild dogs on human activity and environments are discussed. Public attitudes can strongly influence the perceived nature of dingoes and other wild dogs as a resource or as a problem, and these issues are addressed in Chapter 4. The legal status of dingoes and other wild dogs, and past and current management practices, are reviewed in Chapter 5.

The objective of the national guidelines is to stimulate a widespread change in approach to the management of dingoes and other wild dogs from ad hoc measures to a strategic management approach based on cooperative action and the most recent knowledge. An integrated approach on a regional or total catchment scale is advocated because the problems associated with dingoes and wild dogs usually extend past the boundaries of individual land holdings.

The primary aim of a land manager is to meet their desired conservation and/or agricultural production goals using practical and cost-effective means. This must be done as humanely as possible and without degrading other natural resources on which the long-term sustainability of agriculture and biodiversity depend. There is great variability within and between the environments in which wild dogs occur and this influences management activities. The factors that affect the desired outcomes include fluctuating commodity prices, legal constraints, climatic variability including drought, interactions of wild dogs with prey, grazing pressure, livestock genetics, conservation objectives, animal welfare considerations and social factors.

Legislative constraints and the extensive nature of wild dog predation problems have resulted in a strategic approach being manifest in many areas. These guidelines will have achieved their purpose if the advocated strategic approach is widely accepted and implemented. Strategic management requires the measurement of the impacts and abundance of wild dogs, and this can be achieved in a number of ways which are detailed in Chapter 6. Many people and agencies, including governments and community groups, jointly own wild dog problems and need to work cooperatively to find strategic solutions (Chapter 4 and Chapter 7). In some cases, inadequacies in available knowledge may prevent identification of the best strategy. A flexible approach, where the implementation of management actions are continually monitored and evaluated and modified if necessary ('learning by doing' or 'adaptive management') is often the best approach. Strategic approaches to the management of dingoes and other wild dogs are described in Chapter 7.

Implementation, monitoring and evaluation of strategic programs

A group approach to the implementation of management programs reflecting cooperation between individuals and agencies at the local and regional level is encouraged throughout the guidelines and Chapter 7 outlines features to aid the implementation of management plans. A group approach involves all affected landholders and others with a significant interest in the management and conservation issues associated with dingoes and other wild dogs from early planning stages through to implementation, monitoring and evaluation.

At a national level, such an approach requires that the various roles and responsibilities of government agencies, individuals and interest groups are taken into account and integrated. State and Territory governments provide the legislative and regulatory infrastructure, and conservation and pest control agencies administer the appropriate Acts and regulations. Responsibility for local management of wild dogs rests with the owners and occupiers or administrators of land. The active participation of the Vertebrate Pests Committee (VPC) and all associated government agencies in developing these guidelines is thus important in obtaining their acceptance and support for implementation by both agricultural and conservation interests.

For a strategic management program to be successful, it must be continually monitored and evaluated so that modifications and improvements can be incorporated. Such monitoring, evaluation and re-evaluation is an ongoing process and techniques for assessing impacts and monitoring management practices and programs are detailed in Chapter 6.

Strategic management at the local and regional level

The management of wild dogs is a complex issue because the pest status and conservation status of the species must be balanced. This document presents the best practices for the management of dingoes and other wild dogs. Management must attempt to reduce the adverse impacts of wild dogs while maintaining viable populations of genetically pure dingoes and these guidelines amalgamate the best available information on effective approaches. These guidelines consider the conservation values of dingoes and the influence of hybridisation on their genetic integrity. Conservation priorities affect management decisions for wild dogs, particularly at the interface of developed agricultural lands and land managed for conservation. The emphasis in these guidelines is therefore to concentrate on managing the impacts of wild dogs on agricultural and environmental resources while conserving the dingo as a sub-species. At the local and regional level, land managers need to use the information in the book to develop and apply their own strategies. Examples of successful strategic approaches, both hypothetical and real, involving private and government land managers are given in Chapter 7.

These guidelines outline best practices based on present knowledge. A number of deficiencies in that knowledge are identified in Chapter 8. It is expected that best practices will evolve through adaptive management and that community-based groups will become more involved in the strategic management of wild dogs. These guidelines allow local groups to own the pest or conservation problem as well as management strategies derived from the guidelines. It is intended that these guidelines will also assist State and Territory governments in their role of providing legislative, technical and policy support for the management of dingoes and other wild dogs.

All dollars have been converted to 1999–2000 Australian dollars unless otherwise stated in the text.

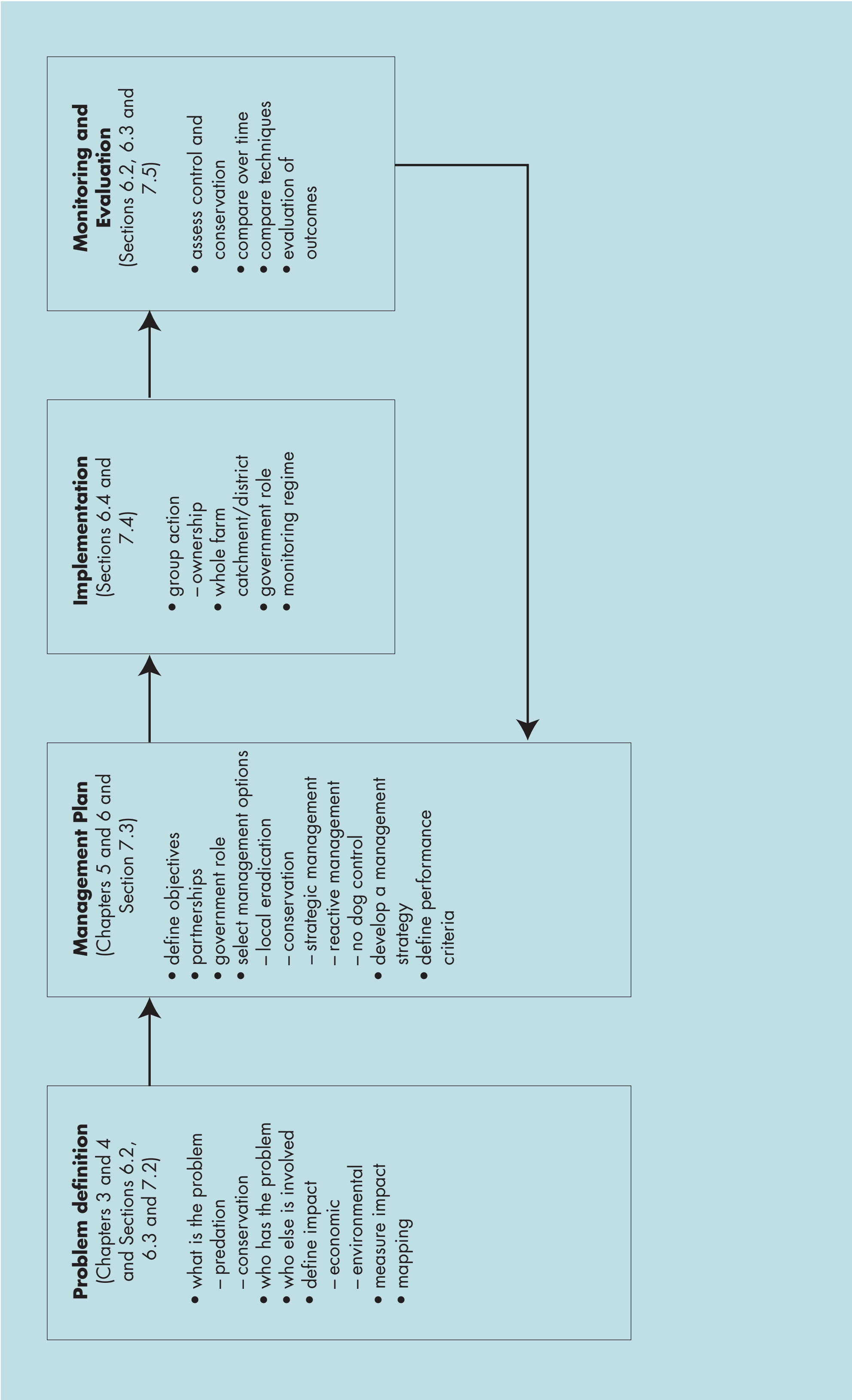


Figure 1: Strategic approach to managing the impacts of wild dogs (after Braysher 1993).

1. Nomenclature, history, distribution and abundance

Summary

*There is currently debate about the correct taxonomy of dingoes and other wild dogs. Both are derived from wolves (*Canis lupus ssp.*). In this book, the scientific names* Canis lupus dingo *and* Canis lupus familiaris *are recommended for the subspecies dingo and domestic dog respectively.*

Dingoes were brought to Australia from Asia about 4000 years ago. They were present in Asia possibly 10 000 to 14 000 years ago and were derived from wolves. The dispersal of dingoes throughout Australia was aided by Aboriginal people who used dingoes for food, companions, hunting-aids and bed-warmers. The dingo never reached Tasmania. Domestic dogs were brought into Australia by Europeans as early as 1788 and their release into the wild has continued since then.

The distribution of dingoes in Australia has decreased since European settlement, although the abundance of wild dogs in some areas may have increased due to the provision of permanent water. Food, water and cover are probably the most important factors affecting the distribution of wild dogs in areas without intensive control. Dog-proof fences that protect sheep from predation also limit the distribution of wild dogs.

1.1 Nomenclature

The scientific names applied to animals that have been selected by domestication are at present the subject of much debate in taxonomic circles (Gentry et al. 1996; Brisbin 1998). Wild-living dogs of Australia are members of the family Canidae, belonging to the order Carnivora. The dog, *C. familiaris*, is the type species for the genus *Canis*, although it is not considered a natural species but rather one developed by humans from grey wolves (*C. lupus*) (Stains 1975). Analyses of chromosomes have shown that the karyotypes of *C. lupus* and *C. familiaris* cannot be differentiated (Chiarelli 1975). While this does not assist in the differentiation of *Canis* species, it demonstrates recent or close common evolutionary lineage.

The name 'dingo' is probably a European corruption of the word 'tingo', used by Aboriginal people at Port Jackson to describe camp dingoes (Thomson 1870). Other Aboriginal names for dingoes include 'warrigal', 'maliki' (camp dogs) and 'wantibirri' (wild dingoes) (Breckwoldt 1988). The scientific name of the dingo has undergone much synonymy but in 1982, the specific designation *Canis lupus dingo* was recommended (Honacki et al. 1982). This name was proposed to reflect their wolf ancestry, the uniformity of dingo populations throughout their huge distribution in Asia and Australia and 'universal usage'; however, *C. l. dingo* is not in common usage. Of 109 documents in a search for the keyword 'dingo' in the Wildlife Worldwide database, 1935 to June 1995 (National Information Services Corporation), none used this nomenclature. *Canis familiaris dingo* was the most commonly used name for dingoes. Domestic and feral dogs were usually grouped as *C. f. familiaris*. The name *C. f. dingo* has not been suppressed and is still in common usage (Dr J. Clutton-Brock, British Museum, London, pers. comm. 1997).

The names *C. f. dingo* for the dingo proportion of the wild dog population and *C. f. familiaris* for both wild-living and commensal domestic dogs have the greatest use in scientific literature. It logically follows from the derivation by human selection of both dingoes and dogs from wolves and the genetic similarities that all three animals should be *C. lupus*. Wolves are morphologically separable from both dingoes and domestic breeds of dog (Lawrence and Bossert 1967) and have such morphological and behavioural dissimilarities (Newsome et al. 1980) for all three to be considered separate subspecies allocated sub-specific names, *lupus, dingo* and *familiaris* respectively. This delineation of the classification of dingoes and other wild dogs has the potential to affect management strategies through acts of law (Brisbin 1998).

Corbett (1995a) concludes that wild-living dogs in Australia are subspecies of *C. lupus,* that is *C. l. dingo* and *C. l. familiaris*, but these designations are yet to be formally accepted (Corbett 1995b). However, because of genetic similarities that indicate common lineage with wolves and sufficient differences that they justifiably be regarded as distinct sub-species, the recommended nomenclature is: dingoes, *C. l. dingo*; and domestic dogs, *C. l. familiaris*. Recent evidence, based on skull morphology, size, coat colour and reproduction, indicates the existence of regionally distinct populations of dingoes between Australia and Thailand (Corbett 1985; 1995a) but not within Australia (Corbett in press).

'Delineation of the classification of dingoes and other wild dogs has the potential to affect management strategies through acts of law'.

The terms wild dog, feral dog, dingo and hybrids mean different things. We define the various meanings as follows:

Dingoes: native dogs of Asia. Dingoes were present in Australia before European settlement and still occur in the wild here. Pure dingoes are populations or individuals that have not hybridised with domestic dogs or hybrids.

Domestic dogs: dog breeds (other than dingoes) selectively bred by humans, initially from wolves and/or dingoes, that usually live in association with humans. Introduced to Australia by European settlers.

Hybrids: dogs resulting from crossbreeding of a dingo and a domestic dog and the descendants of crossbred progeny.

Wild dogs: all wild-living dogs (including dingoes and hybrids).

Feral dogs: wild-living domestic dogs.

Free-roaming dogs: dogs that are owned by humans but not restrained so they are free to travel away from their owner's residence.

Commensal dogs: wild dogs (including dingoes and free-roaming domestic dogs) living in close association with but independently of humans.

Where we were unable to ascertain the status of animals in the publications consulted, we have followed the original authors' usage. Whether this usage is in accordance with the above definitions is unknown.

1.2 Origin, spread and distribution of dingoes throughout the world

Recent work using molecular techniques (DNA fingerprinting) indicates that a dingo-like canid existed perhaps 100 000 before present (BP) and that it was distinctly dingo-like about 10 000–14 000 BP (Gentry et al. 1996). However, the earliest known dingo-like fossils are from Thailand (dated at 5500 BP) and Vietnam (5000 BP) (Higham et al. 1980). Based on skull morphology, these early canids evolved from the pale-footed (also known as the Indian) wolf (*C. l. pallipes*) and/or the Arabian wolf (*C. l. arabs*) between 6000 and 10 000 years ago (Corbett 1995a).

'The dingo's general morphology has remained virtually unchanged for the past 5500 years, although this situation is now rapidly changing through hybridisation with domestic dogs.'

This phase of rapid evolution coincided with the time when people in southern Asia changed their nomadic hunter-gatherer lifestyle to a settled agricultural subsistence that allowed commensal relationships to develop between wild animals and people (Clutton-Brock 1989; 1992). Effectively this was the start of the evolution of the early dingo-like canids into dingoes and other dogs, but subsequent evolution proceeded along different pathways in western and eastern Asia, and at different rates.

In western Asia and southern Europe, people selectively bred these primitive canids to improve the characteristics of dogs for hunting, herding, hauling, guarding, scavenging and

Thai dingo, which has similar morphology to the Australian dingo (Source: L. Corbett).

fighting, as well as for therapeutic, companion, symbolic and novelty values (that is, domestication). The outcome is the immense range of size, shape, colour and temperament found in the 600 or so modern domestic breeds of dogs.

In eastern Asia, people used the early canids for food, hunting, alerting and perhaps for cultural reasons, but they were not selectively bred. Morphological comparisons of skulls of the early Asian fossils show a close similarity with modern dingoes from Thailand and Australia, but a clear difference to modern domestic dogs (Corbett 1985; 1995a). There are also close similarities in body shape, breeding pattern, coat colour and social behaviours between dingoes in southeast Asia and Australia. This indicates that the dingo's general morphology has remained virtually unchanged for the past 5500 years, although this situation is now rapidly changing through hybridisation with domestic dogs (Section 2.9).

The early dingo became cosmopolitan through its association with the movements of early humans as their populations expanded (Bellwood 1978, 1984; Thorne and Raymond 1989). It was during this expansion that dingoes were transported to Australia where the most recent introductions were by the Macassan trepangers (90–350 years ago) (Macknight 1976), and the 'boat people' from Vietnam and Indonesia.

Dingoes probably accompanied the Asian seafarers mainly as a source of fresh food during long sea voyages, or as guard dogs during stopovers. There were also cultural reasons for transporting dingoes (Clutton-Brock 1977; Medway 1977;Corbett 1995a).

The primitive dogs of most Pacific islands (Titcombe 1969), the ancient kirri dog of New Zealand (Colenso 1877; Bay-Petersen 1979), the basenji in the African Congo (Coe 1997), and the New Guinea singing dog (Troughton 1957) are descended from southeast Asian dingoes. According to fossil evidence, the primitive dogs of the Americas were also morphologically very similar to dingoes and they probably arrived there together with people via the Bering Strait (Olsen and Olsen 1977). The Carolina dog is the remaining descendent of the early Amerindian canids (Brisbin 1989).

1.3 Introduction, spread and distribution of dingoes and other wild dogs in Australia

1.3.1 Introduction to Australia

The oldest reliably dated dingo remains in Australia are from 3450 ± 95 years BP (Milham and Thompson 1976) and fossils of about this age have been found throughout mainland Australia (White and O'Connell 1982). This suggests that, having reached this continent, dingoes colonised the mainland and many offshore islands quickly and completely, although they never inhabited Tasmania.

This dispersal was probably assisted by Aboriginal people who had arrived on the continent at least 40 thousand years earlier. Some Aboriginal tribes used dingoes to hunt game, especially kangaroos and wallabies (*Macropus* spp.), possums (Phalangeroidea) and echidnas (*Tachyglossus aculeatus*). Some Aboriginal people suckled pups and slept with dingoes for warmth (Lumholtz 1889; Finlayson 1935; White 1972; Dixon and Huxley 1985; Pickering 1992). Dingoes are well-represented in Aboriginal mythology and rock art (Breckwoldt 1988).

Domestic dogs were first introduced into Australia in 1788 (Australian Geographic Society 1996) and dispersal into the wild (both deliberate and accidental) has been continuing since then. The assumed source of feral dogs in Australia is the abandonment, neglect, loss or deliberate release into the wild of domestic dogs by humans since 1788 (Gould 1863; Corbett 1995a). Although there are few records of such releases, their occurrence is supported by reports of free-living dogs of specific breeds being seen or captured in remote areas (Newsome and Corbett 1985; Jones 1990; Corbett 1995a). Some of the larger feral dogs may have been bred to hunt feral pigs and other game and become lost on hunting expeditions. The incidence of *C. l. familiaris* and hybrids in wild dog populations is higher in south-eastern Australia than in inland and north-western Australia (Newsome and Corbett 1982; 1985; Jones 1990; Thomson 1992a).

1.3.2 Distribution in Australia

The distribution of dingoes in Australia (Figure 2) has been reduced since European settlement in 1788, when dingoes occurred throughout the mainland. For example, in South Australia they now occupy about 60% of their former range (P. Bird, Primary Industries and Resources, South Australia, pers. comm. 1999). However, the abundance of dingoes is likely to have increased over much of their remaining range (Corbett 1995a) as a result of increases in watering points and food supplies. Dingoes and other wild dogs are widely distributed through mainland Australia to the north and west of the barrier fence (Breckwoldt 1988; Thomson and Marsack 1992). Most populations throughout Australia comprise pure dingoes, although in south-eastern Australia the majority are hybrids (Figure 2) (Newsome and Corbett 1985; Jones 1990).

'Control by humans has had significant impact on the distribution and abundance of wild dogs since European settlement.'

In Queensland, most wild dogs occur outside the Dog Fence (Figure 2 and Chapter 6) which surrounds the sheep grazing areas of central and southern Queensland although there is no information about relative dog densities either side of the fence (Fleming et al. 1992). Although wild dogs sporadically occur in the Western Division inside the Dog Fence that runs along the north-western borders of New South Wales, wild dogs are most abundant and most commonly occur in tableland and coastal environments in the east of the State. The highest densities and greatest impact of wild dogs are in the Northern and Southern Tablelands, the latter being contiguous with the Eastern Highlands of Victoria which is the location of most wild dogs in that State (Mitchell 1986). The activities of free-roaming dogs are most commonly centred near towns and cities (Coman and Robinson 1989; Meek 1999).

The absence of wild dogs from most of the more closely settled and agriculturally developed areas, and areas within the exclusion fence, indicates that control by humans has had a significant impact on the distribution and abundance of wild dogs since European settlement.

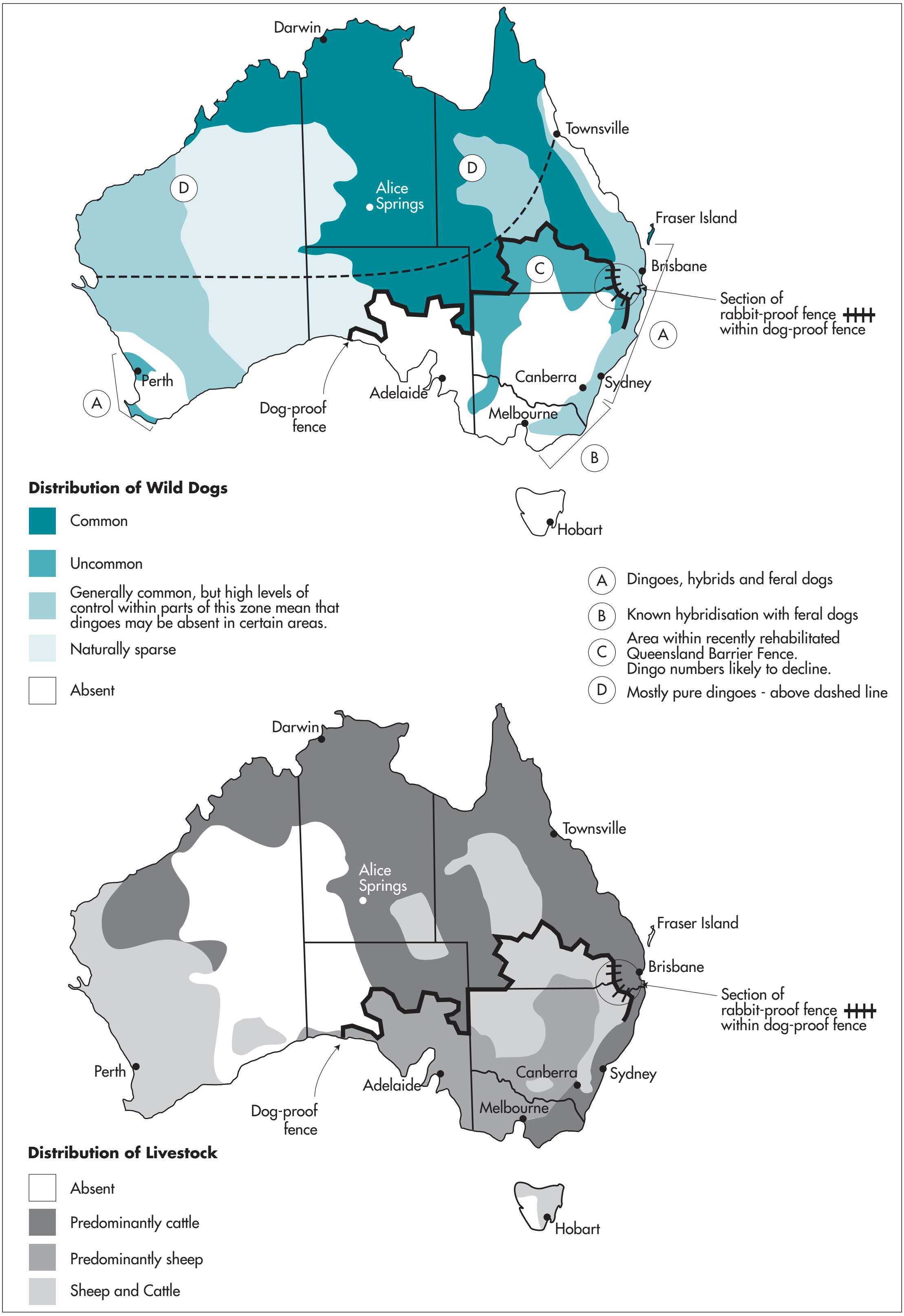


Figure 2: Distribution of wild dogs and livestock (after Breckwoldt 1988; Corbett 1995a; Fleming 1996b)

2. Biology and ecology

Summary

The average adult dingo in Australia stands 57 centimetres at the shoulder, is 123 centimetres long from nose to tail tip and weighs 16 kilograms. Dingoes are smaller in Asia. Feral dogs of up to 60 kilograms have been recorded but most are less than 20 kilograms and their height and length are similarly variable.

The coat of dingoes is typically ginger but varies from sandy-yellow to red-ginger and is occasionally black-and-tan, white or black. Most dingoes have white markings on the feet, tail tip and chest, some have black muzzles and all have upright ears and bushy tails. Coats with a dark dorsal strip or dappling in the white areas usually indicate hybrids. Both hybrids and feral dogs have highly variable coat colours and patterns.

Pure dingoes have only one oestrus cycle in a year whereas hybrids and domestic dogs may have two cycles. Dingoes also differ from hybrids and domestic dogs in some skull characteristics and dingoes usually do not bark whereas most hybrids and domestic dogs do. Hybridisation between dingoes and other wild dogs is becoming more common.

The present distribution of dingoes and other wild dogs covers most of the mainland except for the sheep and cereal growing areas of south-eastern Australia. They prefer habitats that have adequate free water and cover for concealment. Wild dogs live in small groups or packs in territories where the home ranges of individuals vary between 10 and 300 square kilometres. However, there is considerable overlap in the home ranges of pack members. Wild dogs eat a diverse range of foods, from insects to buffalo. Hunting group size and hunting strategies differ according to prey type to maximise hunting success. Larger groups of wild dogs are more successful when hunting large kangaroos and cattle and solitary dogs are more successful when hunting rabbits and small macropods. The main prey are: magpie geese, rodents and agile wallabies in the Top End (Kakadu National Park); rabbits, rodents, lizards and red kangaroos in central Australia; euros and red kangaroos in north-west Australia; rabbits in the Nullarbor region; and wallabies, possums and wombats in eastern Australia. In Asia most dingoes have a commensal relationship with humans and mainly eat rice, vegetables and other table scraps.

Female dingoes become sexually mature by two years, although some do not breed in droughts. Males in arid Australia also have a seasonal breeding cycle of about six months. Gestation takes about 63 days and litters of 1–10 pups (the average is 5) are whelped in winter, usually in an underground den. Dingo pups usually forage independently of their parents at 3–4 months or, if in a pack, when the next breeding season begins. In eastern Australia pups may become independent at 6 months or stay in the family group for up to 12 months.

2.1 General description

2.1.1 Size and coat colour

The average measurements of a mature dingo in Australia are: total length, 123 centimetres; shoulder height, 57 centimetres; head length, 22 centimetres; ear length, 10 centimetres; hindfoot length, 19 centimetres; tail length, 31 centimetres; and weight, 16 kilograms (Thomson 1992a; Corbett 1995a;). Males are universally larger and heavier than females. Dingoes from northern and north-western Australia are larger than dingoes in central and southern regions. All Australian dingoes are heavier than their Asian counterparts (Corbett 1995a). Feral dogs may weigh up to 60 kilograms (Korn and Fleming 1989) but are usually 11–24 kilograms (males), and 10–22 kilograms (females) (Jones 1990). Free-roaming domestic dogs in Meek's (1998) study near Jervis Bay ranged from 15–31 kilograms.

Hybridisation may be obvious as in this case, but other hybrids may be hard to distinguish from pure dingoes, posing management problems in conservation areas (Source: L. Corbett).

Feral dogs may weigh up to 60 kilograms (Source: P. Fleming).

In order of frequency of occurrence, the coat colours of pure dingoes are: ginger (red to sandy), black and tan, white and black (Newsome and Corbett 1985). Most dingoes have white points (white toes, white feet or white socks and a white tail tip) (Newsome and Corbett 1985; Thomson 1992a). According to early explorers' reports, solid black dingoes, widespread throughout Asia, may once have been widespread in Australia ('Collin's Voyage', undated c. 1790 and 'Mr Gilbert's note', undated, cited in Gould 1863) but they have been rarely recorded in Australia in recent times. However, animals from a population in the Victorian and South Australian mallee are consistently black with white points (P. Bird, Primary Industries and Resources, South Australia, pers. comm. 1999).

All other colours including sable (sandy with black shoulders and back, commonly seen in German Shepherd breeds), brindle, patchy ginger and white and patchy black and white indicate hybrids or domestic dogs. Ginger-coloured hybrids, usually resulting from hybridising with heelers, kelpies or collies, appear very similar to pure dingoes and are often impossible to distinguish on external features (Figure 3).

2.1.2 Longevity and methods to assess age of wild dogs

In the wild, dingoes can live for 10 years and feral dogs for at least 12 years, but most die at about 5–7 years. Methods to estimate the age of wild dogs use: head length and eye-lens weight (Catling et al. 1991); the weight or length of bacula (penis bones — juvenile, immature and mature adult age classes); the eruption pattern of adult teeth (useful up to 6 months); tooth wear (6–12 months), and the annular cementum bands in the root tissue of teeth (dogs older than 12 months) (Jones 1990). Alternative methods use closure of the foramen at the root tip of canine teeth to distinguish juveniles from older animals; and for dingoes with closed root tips on all canines, the width of the pulp cavity of canine teeth distinguishes yearlings from adults (Thomson and Rose 1992). Direct observation is also used to distinguish juveniles from older animals.

2.1.3 Water needs

Wild dogs generally drink water every day, about one litre in summer and half a litre in winter (Newsome et al. 1973). In winter in

Figure 3: The pelts of wild dogs, showing a variety of colours (Source: NSW Agriculture).

arid areas, when prey such as long-haired rats (*Rattus villosissimus*) are plentiful, dingoes may live solely by absorbing water from prey (Green 1973). Also, in arid central Australia, many weaned pups obtain most of their water from food. Females have sometimes been observed to carry water in their bellies to dens and regurgitate it for their pups (Corbett and Newsome 1975).

During lactation, captive females have almost no increase in their water intake because they ingest the faeces and urine of their small pups, thus recycling the water they contain as well as keeping the den clean (Green 1973). Wild-living dogs probably have higher rates of water turnover than dogs fed by people because they need to pursue and catch their own food.

2.2 Habitats

Prior to the arrival of Europeans, dingoes occurred across all of mainland Australia but were absent from Tasmania. They probably occupied all habitats, although at various densities. Today, the overall distribution of dingoes has been reduced by the long history of control and exclusion fencing, particularly in the sheep grazing areas of the continent (Figure 2). They are absent from the majority of New South Wales and Victoria except for the eastern highlands and coast of both States, from the south-east third of South Australia, and from most of the south-west tip of Western Australia (Figure 2).

'Dingo numbers may have increased greatly in some arid areas since European settlement as a result of the pastoral industry, more watering points and the introduction of rabbits.'

Habitat use by wild dogs has not been studied in detail. Their present distribution covers the majority of mainland habitat types, and they are considered common across this range except for the arid eastern half of Western Australia and adjoining parts of South Australia and the Northern Territory where they are thought to be naturally sparse (Figure 2). Corbett (1995a) has suggested that dingo numbers may have increased greatly in some arid areas since European settlement as a result of the pastoral industry, more watering points and the introduction of rabbits (Section 2.8.4).

On a smaller scale, wild dogs favour some habitats more than others. These preferences appear to be related to habitat features such as prey distribution, presence of cover or other shelter and presence of water. In the hot, semi-arid Fortescue River region of Western Australia, for example, packs of dingoes spend proportionately more time in riverine areas than in other parts of their range (Thomson 1992d). This is likely to be associated with the presence of water, thicker cover and greater prey abundance in the riverine areas.

2.3 Diet and hunting strategies

2.3.1 Diet of wild dogs in Australia

The diet of wild dogs has been studied more extensively than any other aspect of their biology. Over the past 30 years or so, almost 13 000 stomach and faecal samples from six major climatic regions have been analysed. Of 177 prey species identified, most were mammals (72.3% by occurrence, 71 species); others were birds (18.8%, 53 species), vegetation (3.3%, mainly seeds), reptiles (1.8%, 23 species) and an assortment of insects, fish, crabs and frogs (3.8%, 28 species) (Table 1; Corbett 1995a).

'Dietary information may be misleading because wild dogs will kill stock without eating them and conversely because canids often take livestock carrion.'

Despite the large range of prey eaten by wild dogs throughout Australia, almost 80% of the diet comprised only ten species. In order of greatest frequency these were: red kangaroo (*Macropus rufus*), rabbit, swamp wallaby (*Wallabia bicolor*), cattle, dusky rat (*Rattus colletti*), magpie goose (*Anseranas semipalmata*), brushtail possum (*Trichosurus*

Table 1: The occurrence of major food groups (% of samples) in the diet of dingoes and other wild dogs in Australia (adapted from Corbett 1995a). f = faecal samples, s = stomach samples. Size categories from Brown and Triggs (1990).

	Wet–dry tropics	Central Australia	Nullarbor Plain	Fortescue region (WA)	South-east Australia	North-east New South Wales
Samples	6722 (f)	1480 (s)	131 (f/s)	413 (f/s)	2063 (f/s)	1993 (f)
Large mammals[a]	12.5	36.4	39.7	100	22.9	0.4
Medium mammals[b]	26.6	41.7	69.5	4.8	72.6	85.5
Small mammals[c]	34.3	28.0	0	0.2	13.2	20.6
Reptiles	0.1	14.1	1.5	3.4	1.0	1.3
Birds	33.8	11.9	2.3	5.6	21.7	2.7
Insects	1.3	4.1	0.8	2.9	2.2	<0.1
Plants	7.3	0.1	0	0	1.2	0.2
Others	0.4	0.5	0.8	0.2	16.3	1.4

[a]Animals > 10 kilograms mean adult body weight.

[b]Animals 750 grams to 10 kilograms mean adult body weight.

[c]Animals < 750 grams mean adult body weight.

vulpecula), long-haired rat, agile wallaby (*Macropus agilis*) and common wombat (*Vombatus ursinus*). Of these, only cattle (mostly as carrion) were eaten in each of the six regions reported in Corbett (1995a). This narrow range of major prey indicates that wild dogs are specialists and not the opportunistic generalists they are often assumed to be. However, wild dogs do use a broad range of hunting tactics involving solitary and cooperative hunting in groups (Section 2.3.4).

Fresh sheep and cattle rarely occur in the diets of wild dogs (Robertshaw and Harden 1985a; Lunney et al. 1990; Corbett 1995a). However, this may reflect the relatively low abundance of livestock in many of the areas where samples were taken, sheep in particular being few or at low density in most studies. For arid and semi-arid cattle country, the absence of cattle in the diets of wild dogs may reflect the abundance and ease of procurement of native prey rather than the density of cattle. Thomson (1992c) found that sheep were an important component of the diet of dingoes on a pastoral lease in northwest Western Australia where merino sheep were the main livestock enterprise. In contrast, livestock were a minor component of the diet of dingoes at two other sites where the land was vacant government land or unimproved pastoral leases running cattle (Thomson 1992c). Both Corbett (1995a) and Thomson (1984a, 1992c) caution that dietary information may be misleading, in relation to attacks on livestock, because wild dogs will kill stock without eating them (Section 3.6.1). Conversely, the occurrence of the remains of livestock in the digesta and faeces of predators does not necessarily implicate them as serious pests (Ginsberg and Macdonald 1990) because livestock kills can be revisited and conversely because dogs often take livestock carrion (Corbett 1995a).

2.3.2 Regional differences in diet

In tropical coastal regions of the Northern Territory, dusky rats, magpie geese and agile wallabies together form over 81% occurrence in the diet (Corbett 1989) and there is a seasonal pattern of predation on them. Most geese are eaten as fledged young during the dry season. Dusky rats are eaten when in high abundance, about every fourth year. Agile wallabies are eaten throughout the year but mainly in the wet season.

In arid central Australia, rabbits, small mammals and lizards are the main prey during sequences of good rainfall years whereas during droughts, dead cattle provide most of the diet (Corbett and Newsome 1987). On the Barkly Tableland, Northern Territory, where rabbits do not occur, no single native species predominates in the diet except for long-haired rats when they form huge plagues, about once every nine years (Newsome and Corbett 1975; Corbett 1995a).

In north-west Australia, the large native mammals, red kangaroos and euros (*Macropus robustus*), predominate in the diet, probably because of the paucity of small and medium-sized mammals, particularly rabbits (Thomson 1992c). However, on the Nullarbor Plains where both red kangaroos and rabbits are abundant, rabbit occurs twice as frequently as kangaroos (*Macropus* spp.) in the diet (Marsack and Campbell 1990).

In the Gulf region of Queensland, feral pigs and agile wallabies are important diet items. As in tropical Northern Territory, rabbits are absent from this region. Macropods, including eastern grey kangaroos (*Macropus giganteus*), red-necked wallabies (*M. rufogriseus*), rat kangaroos (Potoroidae) and brushtail possums were found commonly in samples collected in the Maranoa region of central Queensland (L. Allen, Department of Natural Resources, Queensland, pers. Comm. 1997; Allen et al. 1997).

'In the Gulf region of Queensland, feral pigs and agile wallabies are important diet items.'

In the cool temperate mountains of south-eastern Australia, the medium-sized wallabies (swamp wallaby and red-necked wallaby) predominate in the diet of wild dogs in the lower slopes, and the common wombat predominates at higher altitudes. Brushtail possums and ringtail possums (*Pseudocheirus peregrinus*) are also commonly eaten (Corbett 1995a).

2.3.3 Dingo diet in south-east Asia

Very few dingoes in Asia live totally independently of humans and the main food of Asian dingoes is carbohydrate (rice, fruit and other food scraps) supplied by people or scavenged. In rural areas of Thailand and north Sulawesi, dingoes have been observed hunting insects, rats, lizards and other live prey along roadsides, rice paddies and in forests (Corbett 1988a).

2.3.4 Hunting strategies, hunting success and anti-predator behaviour of prey

In Australia, as elsewhere, predation of livestock by wild dogs conflicts with human agricultural activity. The foraging behaviour and feeding ecology of wild dogs are of interest because they may affect the patterns of predation on livestock and the susceptibility of wild dogs to control practices. For example, an abundance of alternative food has been cited as a possible reason for the failure of strychnine baiting programs (Newsome et al. 1972).

The foraging behaviour of dingoes has been characterised differently by various authors (Whitehouse 1977; Robertshaw and Harden 1986; Corbett and Newsome 1987; Newsome and Coman 1989; Thomson 1992c). The availability of different prey species in different localities determines the dingo's hunting strategies. For example, the dingo may be:

- an opportunistic feeder (Whitehouse 1977)
- a selective predator of medium-sized macropods, such as swamp wallabies (Robertshaw and Harden 1986; 1989)
- a predator of large macropods (Thomson 1992c), or it may
- combine a staple diet of medium-sized mammals with a supplementary diet of larger mammals and an opportunistic diet of small mammals and carrion (Newsome et al. 1983a).

'Alternative food has been cited as a possible reason for the failure of strychnine baiting programs.'

When dingoes forage, the size of hunting groups is determined by the type and abundance of prey (Thomson 1992c; 1992d). If large prey such as kangaroos and cattle are being targeted, then dogs form large groups to hunt (Corbett and Newsome 1987; Thomson 1992d). Schoener (1971) postulated that hunting efficiency for large prey is increased through group formation and this hypothesis is supported by Kruuk's (1972a) study of spotted hyenas (*Crocuta crocuta*). Kruuk (1972a) found that individual hyenas benefited from hunting in groups because for every doubling in the weight of prey taken, the number of hyenas that were fed increased threefold. In addition, when canids hunt in groups they are able to capture larger prey (Van Valkenburgh and Koepfli 1993).

Hunting kangaroos and wallabies

Throughout Australia various species of macropods (mean adult weight 17–66 kilograms) are the most commonly killed prey (Corbett 1995a) and the tactics dingoes use to catch them are generally the same: they sight them, bail them up, then kill them. Groups of dingoes are more than three times as successful at bailing up kangaroos and more than twice as successful at killing them than dingoes hunting by themselves. For example, in the Fortescue River region in north-west Australia, the success rate for single dingoes bailing up and killing was 5.5% for red kangaroos and 33.3% for euros. The equivalent success rate for groups of three or more dingoes hunting together was 18.9% and 74.2% respectively (Thomson 1992c).

In contrast, Marsack and Campbell (1990) reported that all attacks on red kangaroos observed in the Nullarbor region of Western Australia (sample size = 10) were by solitary dingoes. However, this may have been unusual because the primary prey of dingoes in the Nullarbor region are rabbits and solitary wild dogs are more successful than groups when hunting rabbits. Therefore, dingoes were probably hunting alone for rabbits when they saw a red kangaroo and took the opportunity to hunt it.

Jarman and Wright (1993) reported observations of attacks on eastern grey kangaroos by wild dogs at Wallaby Creek in north-eastern New South Wales. The wild dogs they saw with grey kangaroos were more often in groups than the dogs seen without kangaroos. However, this does not mean that wild dogs usually formed groups to hunt large macropods in the area because wild dogs were seen in groups in only 21.3% of all observations of wild dogs hunting kangaroos (Jarman and Wright 1993). Solitary wild dogs were also observed hunting red-necked wallabies (Jarman and Wright 1993), the most abundant medium-sized macropod at Wallaby Creek (Southwell 1987).

The advantage of numbers when *pursuing* large kangaroos is that the leading dingo often makes the kangaroo change direction into the path of other dingoes involved in the chase, who in turn are skilled at cutting corners; the combined effort soon exhausts the quarry and it is easily bailed up (Thomson 1992c). This technique is similar to that used by wolves (*Canis lupus*) (Mech 1970), hyenas (Kruuk 1972a) and African hunting dogs (*Lycaon pictus*) (Bekoff 1975). Another variation that African hunting dogs and dingoes sometimes use is the 'relay hunt', in which exhausted leaders are replaced by following pack members.

The advantage of hunting in groups when *killing* large kangaroos is that wild dogs can maintain relentless pressure on the quarry after a successful chase. Since the leading wild dogs become exhausted during the chase, the killing is done by other members of the group coming along behind them. The quarry can also be attacked simultaneously from several directions. Autopsies of kangaroos killed by wild dogs (Thomson 1992c) suggest two patterns of attack: (1) nipping or hamstringing the hind leg to slow the kangaroo sufficiently to attack its throat (on adult and juvenile kangaroos), and (2) running alongside and biting the dorsal thorax and neck regions (on juveniles and small adult females).

Wild dogs are probably more successful at hunting large kangaroos in more open areas, particularly arid areas where kangaroos tend to concentrate around permanent sources of water, especially during droughts (Corbett 1995a). This can lead to surplus killing (Shepherd 1981). In contrast, hunting success is lower where kangaroos use the terrain to escape pursuing dingoes or hamper their attack. In the dissected ironstone ranges of the Fortescue River region in north-west Australia, 62.5% of unsuccessful attacks by groups of dingoes on adult kangaroos failed because the kangaroos backed up against natural barriers, preventing attack from the rear and reducing the attack to only one dingo at a time (Thomson 1992c).

Presumably, the success rate of dingoes and other wild dogs hunting grey kangaroos in the densely forested regions of eastern Australia is also low because of similar obstacles, but little information is available. However, the apparent differences between hunting success in open and closed habitats may be reflected in the alert and flight distances of kangaroos in these habitats. Eastern grey kangaroos (Jarman and Wright 1993) alert to dingoes sooner than red kangaroos (Shepherd 1981) (means: 121 metres and 150 metres respectively) but both flee at similar distances (means: 98 metres and 105 metres respectively).

'Hunting tactics developed for macropods pre-adapted wild dogs for hunting sheep and cattle.'

There are many anecdotal records of adult kangaroos and wallabies (*Macropus* spp.) taking to water to escape attack by dingoes (Bacon 1955). This ploy is unlikely to be successful if there is no escape route (as at a small dam or waterhole) because the dingoes often wait for the quarry to emerge and then continue the attack. Most reports of kangaroos drowning dogs that enter the water to attack them relate to domestic dogs rather than dingoes.

The tactics dingoes use to chase and kill small and medium-sized macropods (mean adult weight 3–15 kilograms) are similar to those they use for large kangaroos, but some differences are apparent. Dingoes hunting alone rely more on scent than sight to trail the quarry, so they are often several hundred metres behind them and the chase may last for several hours. The success rate of lone dingoes hunting medium-sized macropods is probably greater than it is for lone dingoes hunting large macropods, but there are no data to confirm this.

In north-eastern New South Wales, Robertshaw and Harden (1986) recorded that female swamp wallabies pursued by dingoes eject their pouch young (greater than approximately 800 grams), apparently because they are a burden when escaping predators. However, there are no data on whether or not more females escape by this ploy; it is only known that the population age structure of wallabies is altered.

Most studies indicate that wild dogs killed the young of large (mean adult weight >15 kilograms) and medium-sized macropods more frequently than they killed adults. For example, in arid north-western New South Wales, Shepherd (1981) recorded that almost all of the 83 red kangaroos killed by a group of five dingoes around a dam were juveniles less than 18 kilograms (96.4%) and most were females (81.3%). In the moist forested mountains of north-eastern New South Wales dingoes also indicated a strong preference for dependent juvenile swamp wallabies (32%), but not for gender (Robertshaw and Harden 1985b, 1986). Several studies have concluded that large male kangaroos are not routine prey for wild dogs (Shepherd 1981; Robertshaw and Harden 1989; Jarman and Wright 1993; Wright 1993).

Hunting tactics developed for macropods pre-adapted wild dogs for hunting sheep, cattle and other large animals. These tactics may also result in surplus killing of sheep and cattle.

Hunting rabbits and small prey

In central Australia, dingoes usually hunt alone to catch rabbits, often by sighting and running them down, or by scenting and pouncing on a rabbit in a grass hutch. Their greatest success apparently comes from knowing where to find rabbit warrens, especially warrens containing rabbit kittens; and dingoes, in groups or alone, include such warrens in their regular hunting circuit (Corbett 1995a). Hunting success is also likely to be related to rabbit density and age structure but there are few data; Corbett (1995a) observed a dingo hunting alone for one hour in a rabbit-infested area, with 80 holes investigated, and two successful kills from four attempts.

Dingoes mainly rely on their hearing and smell to find rodents, grasshoppers and other small prey moving about in grass and other vegetation. They capture these prey by pouncing on them.

Hunting birds

Many adult birds are captured when they are moulting and unable to fly. Dingoes also eat young nestlings and newly fledged birds that are easily captured. For example, at a coastal salt lake in south-east Australia, a dingo 'cornered' six moulting black swans (*Cygnus atratus*) in a small shallow inlet. When the swans made a break for open water, a second dingo rushed out of the fringing scrub and they swiftly dispatched all six swans with bites across the back behind the wings; but only four of the swans were eaten (Newsome et al. 1983a). In the coastal wetlands of northern Australia, fledgling magpie geese form a major part of the dingoes' diet (Corbett 1989) and are captured in much the same way as swans are. However, healthy adult geese (mean weight 2.4 kilograms) are also obtained by stealing the kills of large predatory birds such as white-breasted sea eagles (*Haliaaetus leucogaster*) (Corbett 1995a).

Hunting cattle, buffalo, horses and sheep

The formation of hunting groups is usually essential when wild dogs hunt large ungulates such as cattle (Corbett and Newsome 1987; Thomson 1992c), feral horses (Newsome and Coman 1989) and buffalo (*Bubalus bubalis).* Nearly all attacks on cattle and buffalo are aimed at young animals, from the newborn to subadults; healthy full-grown adults are rarely attacked. There are three basic attack tactics (Corbett 1995a):

1. Constantly harass a mother with a dependent calf. Solitary wild dogs or groups keep the prey constantly on the alert, so it eventually tires or relaxes its guard enough for a dingo to deliver a crippling bite.

2. Actively spook a mob of cattle to separate the calves from the adults, then focus on the calves.

3. Wait-and-watch tactic, observing and testing the most vulnerable members of a herd.

In the third tactic, a group of wild dogs, usually sits, sometimes for hours, and watches a herd from a distance. They watch for cattle or buffalo that exhibit unusual behaviour that might indicate vulnerability, such as disease or injury. Common examples of such behaviour are: cows giving birth; individuals that are stationary or not moving with the main body of the herd when grazing or drinking; and calves running and frequently bawling. Wild dogs will either attack or harass the targeted animal directly or wait until it dies. If the targeted individual turns out to be healthy, the wild dogs promptly retreat and may resume waiting and watching for other potential quarry.

Although wild dogs can kill cattle, there are few data on how successful they are. In the Fortescue River region of north-west Australia, Thomson (1992c) recorded only 73 interactions between cattle and dingoes over seven years. Most interactions (81%) involved cattle reacting defensively to dingoes and 26 (36%) involved attacks on calves. However, only four calves were killed, so the dingoes' success rate was at best 15% (4/26), or only 5% (4/73) if all interactions are counted.

'The formation of hunting groups is usually essential when wild dogs hunt cattle.'

Cattle have a greater tendency to defend themselves than do sheep, and trained cattle have been used to protect sheep from predators in New Mexico (Anon. 1987). The grouping exhibited by cattle acts as an antipredator behaviour that reduces the risk of an individual being taken and allows for animals on the outside of a group to aggressively defend the whole group (Alcock 1989). In some areas of Australia, predation of calves by wild dogs is believed to be minimised if horned cows are run instead of polled cows (E. Maskie, grazier, New South Wales, pers. comm. 1984).

Wild dogs evolved for running and they can outrun both sheep (Thomson 1992c) and cattle (Alexander 1993). There are many anecdotes about the dingo's prowess at hunting and killing sheep but the only detailed evidence is from Thomson's (1992c) study in the Fortescue River region in northwest Australia. Thomson (1984a, 1992c) found that both groups and solitary dogs killed sheep, that dingoes often attacked more than one sheep in a mob, and that in most attacks the sheep were not killed outright. From a total of 61 attacks, 26 sheep (43%) were seriously injured, but only eight (13%) were killed outright. In 69% of attacks, dingoes broke off the attack before the sheep was killed, although in 31% of attacks they then attacked another sheep. Sheep showed no aggressive defensive behaviour and in 11 (18%) of the attacks they struggled so little that dingoes began eating them before inflicting a killing bite.

The reaction of sheep to the appearance of a dog in their vicinity is to congregate in a mob (Kilgour 1985). Sheep chased by dogs often run in a circle, the leading animals being turned back to the mob by a pursuing dog. These behaviours make sheep more susceptible to surplus killing.

Scavenging and caching

Dingoes readily scavenge food, particularly cattle and kangaroo carcasses that become plentiful during drought in arid regions of Australia. For example, Corbett and Newsome (1987) studied dingo diet over seven years at Erldunda in central Australia and found overall that cattle carrion occurred in 6.3% of 285 stomachs compared to remains of live cattle in only 2.1%. More carrion was eaten in droughts (mean 10% occurrence) than flush periods (3%). Dingoes usually gorge themselves on the carcasses of large prey either in one feed or intermittently over several days until it is all eaten (P. Thomson, unpublished data 1976–1984). Sometimes rival dingo groups dispute over a carcass (Corbett 1995a).

'Cattle carrion occurred in 6.3% of stomachs compared to remains of live cattle in only 2.1%'.

Dingoes living on the coast regularly patrol the beaches and scavenge fish, seals, penguins and other birds that are washed up (Newsome et al. 1983a). In Kakadu National Park, dingoes regularly scavenge the remains of prey underneath the nests and feeding platforms of white-breasted sea eagles (Corbett 1995a).

In the Fortescue study, caching by dingoes of a small euro was observed (P. Thomson, unpublished data 1983). Captive dingoes at Alice Springs have also been observed caching excess food, especially dog biscuits. In central Australia, wild dogs frequently returned to carcasses, although these were not buried or covered. Food remains at dens were often abundant and always conspicuously placed (L. Corbett, unpublished obs.).

2.4 Home range and movements

2.4.1 Home range

In common with most terrestrial mammals, individual wild dogs spend the majority of their lives within discrete areas or home ranges. Data on the boundaries and size of home ranges are usually derived from radio-tracking studies of collared animals. Within discrete social groups or packs, the home ranges of individual pack members overlap considerably (Section 2.5). The sizes of home ranges appear to be determined to a large degree by the availability of resources. Where resources are plentiful, individuals do not have to roam far for food or water, and home ranges tend to be smaller. For example, radio-tracked adult wild dogs in the heavily forested escarpment areas of the northern tablelands of New South Wales had a mean home range size of 27 square kilometres, with considerable overlap in the ranges of different individuals (Harden 1985). McIlroy et al. (1986a) found similar sized home ranges (21.5 square kilometres) for wild dogs in a mountainous forest area of south-eastern Australia. These areas have a high rainfall, a temperate climate, and a large diversity of potential prey species (Newsome et al. 1983a; Robertshaw and Harden 1985a). In contrast, in the less productive arid environment of the Fortescue River in north-west Western Australia and the Simpson Desert in Central Australia, dingoes had larger home ranges, averaging 95.8 square kilometres (Thomson and Marsack 1992) and 67 square kilometres (Corbett 1995a) respectively. In the Nullarbor region of south-east Western Australia, where prey populations fluctuated widely and water was

The social organisation of dingoes has implications for predation dynamics (Source: L. Corbett).

sparse, home ranges were larger still, ranging from 90 to 300 square kilometres (Thomson and Marsack 1992).

'The sizes of home ranges appear to be determined to a large degree by the availability of resources.'

Home ranges are generally stable over time, although they may shift in response to changes in food availability or social organisation. Individuals that begin to separate from social groups or packs, prior to dispersing from their natal home range tend to roam over larger areas (Thomson 1992d). In South Australia, Bird (1994) estimated that 300–400 dingoes were sharing a single watering point in a particularly arid region. Eighty individual dingoes were simultaneously visible near another water source. These appeared to be merely aggregations of individuals rather than social groupings, and probably reflected the large area serviced by widely spaced waters, and that dingo numbers were high because of a recent rabbit plague.

2.4.2 Movements

Harden (1985) carried out an intensive study of short-term movements of dingoes in the escarpments of north-eastern New South Wales and showed that dingoes exhibited two distinctly different patterns of movement. The first was characterised by the intense use of a small area with many changes in direction and was believed to be associated with hunting. The second was a more directed movement that frequently traversed a large part of the home range. One of the functions of the latter might have been to maintain communication between individuals by regular visits to scent posts (Section 2.5.2).

In Harden's (1985) study, the wild dogs were active throughout the day with peaks of activity at dawn and dusk. Hourly rates of movement were equal for diurnal and nocturnal periods and the average distance moved in 24 hours was around 15 kilometres. Wild dogs spent 65% of the day active and 35% resting. Periods of activity were short (65% less than 60 minutes) and interspersed with shorter rest periods (70% less than 30 minutes). In contrast, in the hotter, less vegetated environment of north-west Western Australia, dingoes tended to be inactive during the middle of the day, with major peaks of activity and movement occurring around dawn and dusk (Thomson 1992b). Similar patterns of activity have been recorded for dingoes in the Simpson Desert (Corbett 1995a) and coyotes (*Canis latrans*) living in hot environments in North America (Andelt 1985).

'Dispersal appears to be related to food supply and mediated by social factors.'

In north-west Western Australia, dingoes did not regularly travel large distances across their ranges (mean maximum range width was 10.5 kilometres) (Thomson 1992d). Movements were localised, and packs tended to focus their activities in a particular section of their range for a time, with occasional forays into other parts of their range. This pattern was consistent through most of the year. The major seasonal factor influencing movement patterns was related to the raising of pups. This activity dramatically affected nursing individuals, restricting their movements, but other pack members were affected as well.

Dingoes displayed strong site fidelity, seldom engaging in forays far beyond their home ranges or territories (only 1.2% of all radio-locations represented foray movements) (Thomson et al. 1992a). Most foray movements were within four kilometres of the territory boundaries and rarely exceeded six kilometres. There was no seasonal pattern to these movements. Males were more likely than females to engage in forays and juvenile dingoes only engaged in forays in the company of older dingoes. Some forays appeared to be associated with subsequent dispersal movements.

Dispersal represents a move that places an animal permanently beyond the area that it normally occupied, and usually involves movement out of the natal home range.

Dispersal appears to be related to food supply and mediated by social factors. In north-west Western Australia, individuals as well as groups dispersed (Thomson et al. 1992a). Males tended to disperse further than females and had a higher incidence of dispersal. One male dingo in arid central Australia travelled 250 kilometres (Newsome et al. 1973). Dispersal distances in the study by Thomson et al. (1992a) ranged from 1–184 kilometres, with a mean of 20 kilometres. The incidence of dispersal was highest when the density of the dingo population was high and food supply low, and was facilitated by the availability of nearby vacant areas. On the Nullarbor Plain, dingoes tended to move further than those in north-west Western Australia particularly as dams dried up. Less than 10% of dingoes moved more than 50 kilometres and the longest movement was 250 kilometres (Thomson and Marsack 1992). In South Australia, the two largest males of 59 radio-collared individuals dispersed 150 and 225 kilometres respectively after a dam they were watering at dried up (Bird 1994). Dingo numbers were very high throughout the region at the time and food supply low.

Meek (1999) reported that radio-collared free-roaming dogs travel 8–30 kilometres to hunt macropods in bushland adjacent to the homes of their owners. Coman and Robinson (1989) reported that commensal dogs from the Victorian city of Bendigo travelled smaller distances, usually less than 6 kilometres. Most of these forays were into adjacent agricultural land where livestock were attacked in 51 of 84 forays. The management implications of wild dog movements are discussed in detail in Chapter 6.

2.5 Social organisation and behaviour

2.5.1 Wild dog society

Dingoes and other wild dogs, like their wolf (*Canis lupus* ssp.) forebears, are social animals. Where conditions are favourable, they form stable packs that maintain distinct territories that overlap little with neighbouring packs (Thomson 1992d). However, regional variations are seen, reflecting the flexible nature of dingo social structure (Green and Catling 1977; Newsome et al. 1983a; Corbett and Newsome 1987; Bird 1994). This flexibility is not surprising in view of the wide variety of habitats, prey species, climatic conditions and levels of human exploitation encountered across Australia. Studies by Robertshaw and Harden (1986), Corbett and Newsome (1987) and Thomson (1992d) support the notion that increasing specialisation on larger prey such as wallabies and kangaroos favours increasing sociality and the formation of larger groups. Corbett (1995a) concluded that the primary function of dingo packs is to defend hunting areas and other essential resources.

The social organisation of dingoes in the Fortescue River area of north-west Western Australia provides an example of dingo society in a relatively undisturbed ‘wilderness’ area, where euros and kangaroos were the main prey and natural water was widely distributed (Thomson 1992d). Here, dingoes were organised into stable packs occupying discrete territories that overlapped little with those of neighbouring packs. Packs comprised a dominant male and female and their offspring of various ages. Territory boundaries were stable over time and between-pack encounters were extremely rare. Packs varied in size (mean monthly pack sizes for five packs ranged from 3–12 individuals), with smaller packs tending to be found in the poorer areas and occupying larger ranges. Pack members cooperated to hunt prey and took part in communal activities such as feeding (Section 2.3.4), resting and raising pups. Pack members were not always together at one time; they usually operated in sub-groups that were flexible in size and composition. Lone dingoes were sometimes identified; these individuals displayed no pack affiliations, occupied large ranges that overlapped the mosaic of pack territories and avoided encounters with packs. They were probably individuals in varying stages of dispersal, seeking a mate and a vacant area in which to settle.

Corbett (1995a) reported a more fluid situation at Kapalga, in the northern tropical Northern Territory. Here, stable packs occupied territories, but they altered where and what they hunted according to season and prey availability. In the Simpson Desert, another wilderness area, the necessity of sharing sparsely distributed watering points meant that distinct spatial separation of packs was not possible. Howling and other forms of communication (Section 2.5.2) were more pronounced in these situations, allowing a temporal separation of packs (Corbett 1995a). When prey (mostly small mammals) were more abundant and widespread after good rains, dingoes tended to spread out to exploit these resources. Thus, packs were not as constantly stable or confined to such defined areas as in the more predictable northern environments.

'The influence of domestic dogs on the social structure of wild-living dogs, dingoes and hybrids in Australia is not documented.'

Research in the arid pastoral regions of central Australia revealed that most dingoes were seen alone, although they were loosely bonded in small amicable groups sharing a common living area (Corbett 1995a). Rabbits were a major dietary item and individuals tended to hunt alone (Section 2.3.4). The ranges of different groups tended to overlap considerably, sharing common resources such as the relatively sparse watering points. A similar pattern was observed in a relatively undisturbed pastoral region on the Nullarbor Plain in Western Australia (Thomson and Marsack 1992, and unpublished data 1982–1987). Here, dingoes preyed principally on rabbits. Water was sparse and shared by adjacent social groups and there was no evidence of strong territoriality. Groupings of dingoes were most commonly seen during the months leading up to mating, during the raising of pups, and when dingoes were feeding on large prey (kangaroos) (Section 2.3.4).

The large degree of overlap in the home ranges of wild dogs in north-eastern New South Wales (Harden 1985) suggests that the wild dogs studied were members of a single pack. Free-roaming domestic dogs in south-eastern Australia have also been reported hunting or foraging in groups (Meek 1999). Feral dogs in Baltimore, North America also formed groups of 2–17 animals although approximately 51% of dogs were seen alone (Beck 1973). Free-roaming dogs in central Victoria were usually seen in pairs (54% of sightings) or singly (34%), with packs of three to seven dogs being seen in 12% of sightings (Coman and Robinson 1989). The influence of domestic dogs on the social structure of wild-living dogs, dingoes and hybrids in Australia is not documented. However, it is likely that the factors that influence the social organisation of dingoes in different areas would also influence the social behaviour of feral dogs or hybrids.

2.5.2 Communication

Howling

Vocal communication is important for dingoes and other wild dogs because they are often spatially separated. Dingoes do not bark in the wild as domestic dogs and hybrids do (Corbett 1995a) but howling is common to all wild dogs.

There are three basic types of howl used, moans, bark-howls and snuffs, and these have at least 10 variations (Corbett 1995a). Howls travel over large distances and have the purposes of locating other wild dogs, attracting pack members and repelling intruders from the pack home range. The frequency of howling varies throughout each day and throughout the year, and is affected by breeding, dispersal, lactation, social stability and dispersion. Wild dogs often hunt alone and in times of food shortage, pack members may become more widely distributed within their home range. Howling is more pronounced at these times (Corbett 1995a).

Scent Marking

Dogs have a highly developed sense of smell that they employ in social communication. They use chemical signals originating in urine, faeces and scent glands (Ralls 1971). Scent marking in canids is oriented to specific objects, elicited by familiar conspicuous land-

In central Australia, dingo dens are commonly developed from enlarged rabbit burrows (Source: L. Corbett).

marks and novel objects or odours, and repeated frequently on the same object (Kleiman 1966). Scent marking probably originated as a means to familiarise and reassure animals when they entered strange and frightening situations. Bringing together of the sexes and pack members and maintaining territory are probably secondary functions that are important for survival (Kleiman 1966).

'Preliminary work has been conducted to find attractants that could be used to lure wild dogs to traps or poison baits.'

There is much evidence that dingoes and wild dogs defecate and urinate on objects at particular sites to communicate with members of their own and rival packs (Thomson 1992b; Corbett 1995a). The most frequently recorded objects that wild dogs mark are grass tussocks, small bushes, logs, fence-posts, rocks and the faeces of other animals. Most scent posts are located at shared resources such as water in arid areas, hunting grounds, trails and roads, particularly intersections. Males scent-mark, use raised-leg urination and rake the ground after marking more frequently than females (Corbett 1995a). In north-west and central Australia, raised-leg urination and ground-raking peaked in the mating season (Thomson 1992b; Corbett 1995a). One of the functions of scent-marking may be to synchronise reproduction between pairs, as has been suggested for wolves and coyotes (Rothman and Mech 1979; Wells and Bekoff 1981).

Another form of scent marking is scent rubbing whereby an animal rolls on its neck, shoulders or back. Scent sources that elicit scent rubbing are associated with food, chemicals, catmint, urine, faeces and carcases, and scent markings of conspecifics (Reiger 1979). The function of scent rubbing is unknown but one hypothesis is that it may increase the social attractiveness of a particular animal (Fox 1971). Dingoes and other wild dogs are known to scent rub this way (Corbett 1995a).

Scent-marking may be used by managers to assess the numbers of canids (Section 6.2.2). For example, the United States Fish and Wildlife Service have developed a scent-station index method to assess trends in carnivore populations (Roughton and Sweeny 1982). This method has not been used in Australia for assessing dog numbers but preliminary work has been conducted to find attractants that could be used to lure wild dogs to traps or poison baits (Jolly and Jolly 1992a,1992b; Mitchell and Kelly 1992). For example, Jolly and Jolly (1992b) found that about half of ten captive wild dogs responded to six chemical attractants in pen and field trials which suggests that less expensive and better controlled pen trials might find an effective attractant to lure wild dogs to traps and poisons. Those trials were conducted in November and better responses might be obtained from trials in the breeding season.

2.6 Reproduction

2.6.1 Breeding: dingoes

The pattern of breeding has implications for managing dingo predation on cattle (Section 3.6.5).

Dingoes produce only one litter of pups each year, and except for tropical habitats, litters are usually whelped in winter. This breeding pattern is determined by the female's annual oestrus cycle as males are continuously fertile in most regions (Catling 1979). The precise onset and extent of breeding varies with age, social status, geographic latitude, seasonal conditions and whether animals are pure dingoes or hybrid (Jones and Stevens 1988; Corbett 1995a).

In arid central Australia, most wild females commence breeding when they are two years old and usually mate in April–May, about one month earlier than most of their counterparts in southern temperate Australia. In stable packs, the most dominant (alpha) female, usually the oldest, tends to come into oestrus before subordinate females. Some of the subordinate females undergo pseudopregnancy (Corbett 1988b). During droughts, all young females less than one-year-old and some older females do not breed at all, and for those adults that do, the onset of breeding is delayed by about six weeks (Figure 4).

Pro-oestrus and oestrus periods for captive dingoes in central Australia and domestic dogs, as determined from vaginal smears, last about 10–12 days (Corbett 1995a). However, in the Fortescue River region, behavioural data suggest that pro-oestrus may last about 30–60 days (Thomson 1992b).

Males reach full sexual maturity at 1–3 years. Although continuously fertile, males in hot arid regions appear to be true seasonal breeders with maximum testis weights occurring about April, the peak of the mating season (Catling et al. 1992). In contrast, males in the cooler temperate highlands of south-east Australia can breed throughout the year and many successfully sire pups with domestic bitches outside of the dingo breeding season (Catling et al. 1992).

'Seasonality in breeding increases with latitude.'

Gestation lasts 61–69 days in captive dingoes. The average litter size for dingoes is five (range 1–10) throughout Australia and Thailand, and usually more males are born than females (Corbett 1995a).

Seasonality in breeding increases with latitude. In temperate regions of Australia, most dingo litters are born in winter (June–August). Litters born in summer and autumn (November–April) in south-east Australia, are almost certainly from hybrid females whereas in northern Australia, litters of pure dingoes have been recorded in most months with a peak in July (Corbett 1995a).

2.6.2 Breeding: feral dogs and hybrids

Female feral dogs and hybrids of similar size to dingoes may have two oestrus cycles each year, although it is unlikely that they successfully breed twice every year (Jones and Stevens 1988). Evidence from south-east Australian populations of wild dogs indicates

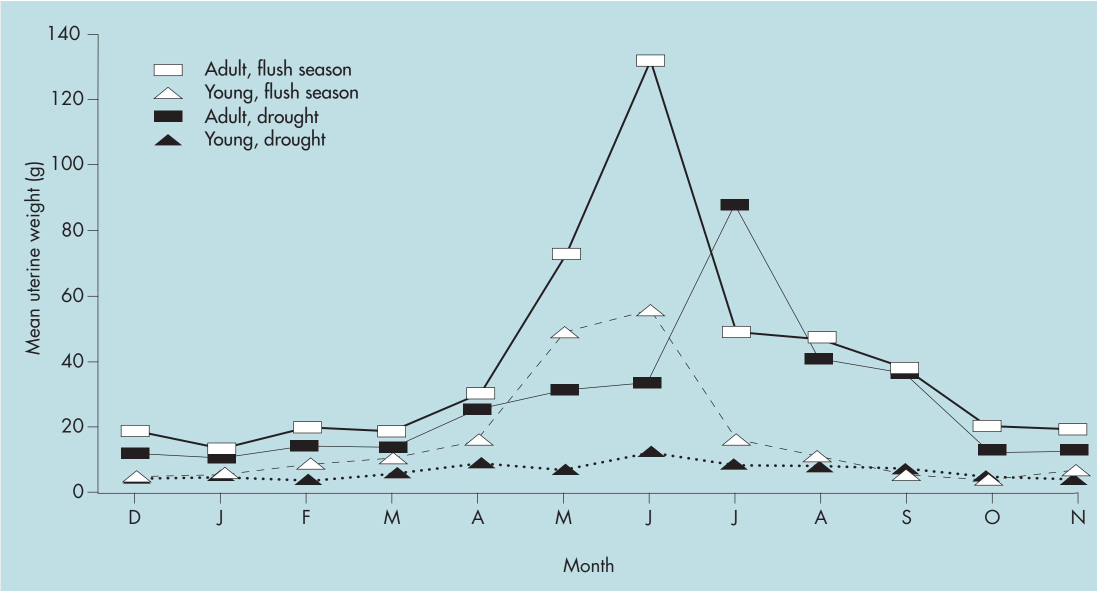


Figure 4: The breeding cycle of adult (more than one-year-old) and young (less than one-year-old) female dingoes in central Australia (adapted from Catling et al. 1992). In flush seasons, most adult females are heavily pregnant by May–July, but not all young females become pregnant, as indicated by their low uterine weights. In droughts, young females do not breed at all, and breeding is delayed by about six weeks for older females that do breed.

that the regular birth pulse of dingoes is disrupted where there is a large proportion of feral dogs and hybrids present (Jones and Stevens 1988). Male domestic dogs and hybrids do not show any seasonal changes in testicular activity and are fertile throughout the year (Jones and Stevens 1988). Gestation is 58–65 days for hybrids and domestic dogs in the same climate (Corbett 1995a). The average litter size for hybrids and domestic dogs is similar (about 5 pups) but varies with breed (Spira 1988).

2.6.3 Characteristics of dens

In central Australia most dens have been recorded in enlarged rabbit-holes, caves in rocky hills, under debris in dry creek beds, under large tussocks of spinifex, among protruding tree roots and under rock ledges along water courses (Corbett 1995a).

In the Fortescue River region, most dens were recorded in cave complexes in hilly terrain; others were in hollow logs, under spinifex or in enlarged goanna (*Varanus* spp.) holes (Thomson 1992b). Similarly, in tropical northern Australia, most dens were found in enlarged burrows of large goannas, with others under fallen trees and other debris (Corbett 1995a). Most dens in the Fortescue River region faced the south-east, possibly to minimise excessive heating from the sun (Thomson 1992b).

In contrast, in the cooler eastern highlands, most dens have been reported in hollow logs, old wombat burrows and occasionally in caves under rock ledges (Corbett 1974; Jones and Stevens 1988) and commonly faced north (B. Harden, unpublished data 1970–84).

2.7 Mortality and disease

In south-eastern Australia, pups become independent at 6–12 months (Harden 1981). Those that become independent and disperse at six months are less likely to survive than those that stay with the parents for 12 months (B. Harden, unpublished data 1970–84). The higher survival may be due to the increased hunting success that dogs in groups may have with larger prey (Thomson 1992c) or through the adults coaching the pups in hunting (Corbett and Newsome 1975). Coaching of pups has been observed in captive-bred hybrids in north-east New South Wales (T. Kempton, grazier, New

South Wales, pers. comm. 1979). In the stable packs of the Fortescue River region, most juvenile dingoes do not become independent and disperse in the first year, but stay in the social group, sometimes permanently.

2.7.1 Dispersal sinks

One of the main, consistent causes of dingo mortality is a cycle involving dingo population density, food supply and human control. When food becomes scarce for a large population of wild dogs in a 'safe' area (source), they disperse, singly or in groups, to resource-rich, pastoral and agricultural areas where there are fewer wild dogs. These are 'danger' areas, where human control measures are intense. Wild dogs are poisoned, trapped or shot here, creating vacant areas (sinks) and perpetuating the dispersal-mortality cycle.

For example, over nine years in the Fortescue River region, 25 lone dingoes and six groups (comprising 24 individuals from fractured packs) dispersed from non-pastoral 'safe' areas to sheep paddocks where control was intensive. All except one of these 49 dingoes (98%) were eventually killed — either trapped, poisoned or shot. This was twice the average mortality for dingoes dispersing to other areas (Thomson et al. 1992a).

2.7.2 Human-induced mortality

Humans have had a major impact on wild dog populations through habitat manipulation, the introduction of domestic dogs and control practices. For example, habitat changes associated with agriculture in southern Australia caused the demise of dingoes in these areas. Effective control programs in targeted areas of the Fortescue River region removed most dingoes (Thomson et al. 1992b). Human-induced mortality may also be high for wild dogs in areas of southern Australia where coordinated control programs operate annually. Although the effectiveness of wild dog control programs varies, severe mortality can be inflicted on wild dog populations (Fleming et al. 1996). The effect of trapping, poisoning and shooting on wild dog populations is discussed in detail in Chapter 6.

2.7.3 Parasites, diseases and associated causes of death

Wild dogs are susceptible to all the diseases that affect domestic dogs. Thirty-eight species of parasites and pathogens have so far been recorded in wild dogs. In Australia, at least another 50 infectious organisms in domestic dogs have been recorded (Seddon 1965a,1965b; 1966; 1967; 1968; Seddon and Albiston 1967; Kelly 1977; Appendix A), all of which could potentially become established in wild dog populations. The conditions under which establishment might happen and the characteristics of disease organisms that would allow establishment and persistence of these diseases require further evaluation. Appendix A is a detailed list of diseases affecting wild dogs.

'Wild dogs are susceptible to all the diseases that affect domestic dogs.'

In most cases, diseases have little effect on the survival of adult wild dogs. Exceptions include: canine distemper (Paramyxovirus), hookworms (*Unicinaria stenocephala* and *Ancylostoma caninum*) and heartworm (*Dirofilaria immitis*) in northern Australia and south-eastern Queensland (Coman 1972a; Corbett 1995a, Meek 1998; L. Allen, Department of Natural Resources, Queensland, pers. comm. 1989).

The effects of most diseases and parasites on wild dog mortality rates and morbidity rates have not been measured. The proportion of a population dying during a given time interval is the mortality rate. Morbidity rate is the proportion of a population affected by disease in a given time interval. The debilitating effects on wild dogs are unknown for 45% of dingo parasites and pathogens, but 29% (11 of 38) are known to be fatal, especially in pups (7 of 11 fatal infections). Lungworm (*Oslerus osleri*), whipworm (*Trichurus vulpis*), hepatitis (Adenovirus), coccidiosis (*Isospora rivolta* and *Eimeria canis*), lice (*Trichodectes canis* and unidentified species) and ticks (*Ixodes holocyclus, Rhipicephalus sanguineus* and *Amblyomma triguttatum*) can kill pups and thereby decrease recruitment to dingo populations. Heartworm virtually eliminated dingo populations at Kapalga (Kakadu National Park) in the 1980s and distemper decimated Barkly Tableland populations in the early 1960s and again in the 1970s (Corbett 1995a).

Sarcoptic mange (causal agent *Sarcoptes scabiei*) is a widespread parasitic disease in dingo populations throughout Australia but it is seldom debilitating. The highest prevalence (20%) was recorded in the Fortescue River region where 21% of mange-affected adult dingoes were in poor condition compared to 5% for mange-free dingoes; however, only one dingo was suspected to have died from mange (Thomson 1992b). Males were twice as likely to be affected by mange as females (Thomson 1992b) and it is likely that mange is associated with particular prey species (Corbett 1995a).

Hydatidosis (caused by the cestode *Echinococcus granulosus*) results in serious illness in infected humans and in the devaluation of infected livestock carcases at slaughter (Section 3.4). *E. granulosus* infection does not cause serious illness in dogs.

In central Australia, wild dogs mostly eat rabbits and consequently have relatively high infestations of rabbit stickfast fleas (*Echidnophaga myrmecobii*) and tapeworm (*Taenia pisiformis*). By comparison, the most common parasites of wild dogs in the nearby Barkly Tableland are lice and an unidentified tapeworm species which are both probably derived from eating long-haired rats, a major prey species in this region. Also, sarcoptic mange is usually associated with plagues of dusky rats in the wet–dry tropics. In south-eastern Australia, kangaroo flies (*Hippoboscid* spp.) were often found on free-roaming domestic dogs that frequently hunted macropods (Meek 1998). These insects are most likely to cause irritation rather than death.

2.7.4 Other causes of death

Where irruptions of rabbits are common, for example, in arid South Australia and the Nullarbor region of Western Australia, many wild dogs die from starvation when the irruption is over. Severe drought and concurrent declines in water availability and prey, particularly rabbits, are also significant causes of dingo mortality.

Other less common causes of mortality for dingoes and other wild dogs include: being run over by vehicles or horses, being chased and killed by people on horseback (Harden and Robertshaw 1987); buffalo and cattle goring and kicking; snake bite; and predation on pups by wedge-tailed eagles (*Aquila audax*). Unlike in north-east Thailand, where about 200 dingoes are butchered each week (Corbett 1985), human predation of dingoes and other wild dogs for food no longer occurs in Australia.

2.8 Population dynamics and changes in abundance

2.8.1 Overview of predator population dynamics

In contrast to the situation with dingoes, the regulation and dynamics of populations of other social canids such as wolves have been extensively studied (Mech 1986; Peterson and Page 1988). Food supply is thought to be the principal common natural factor affecting canid social organisation, group stability, dispersal strategies, mortality and reproductive success (all in turn influencing population dynamics). The supply of prey, predominantly herbivorous animals, is affected by environmental conditions (especially the extent and pattern of rainfall), as well as being influenced by the predator itself (Section 2.3). When the effects of people on the environment are added (altered landscape, altered fire regimes, introduced exotic animals, increased watering points, imposed control on predators and sometimes prey species), it follows that the dynamics of predator populations can be very complex.

2.8.2 Dynamics of wild dog populations

The most intensive study of the population dynamics of wild dingoes was carried out in the Fortescue River region of Western Australia (Thomson 1992a). Dingoes were radio-tracked over a nine-year period in an area with minimal human disturbance. At the start of the study, dingo numbers were relatively low because of control work (trapping and baiting) that had been undertaken in the area. As the study progressed, dingo numbers increased to high levels (Figure 5). Dingoes at that time had access to a moderate and apparently adequate supply of their principal prey, kangaroos. The area was fully occupied by territorial packs. The population rose as a result of reproductive success and consequent increases in the size of the packs. At the high population level, dingoes began to disperse, resulting in a subsequent fall in population size.

In the second period (1979–80, Figure 5), population density was still high, but fell markedly when dingoes were deliberately exposed to aerial baiting during research trials (Thomson 1986). At the time of baiting, kangaroo numbers were low and dingoes had begun to increase their use of other food, including cattle carrion and smaller prey species. The earlier signs of social perturbation, indicated by an increase in dispersals, were followed by other more dramatic changes prior to baiting. Large packs began to dissociate, dispersal continued, territory shifts were recorded, and signs of changes in activity patterns emerged. These features have also been recorded in populations of wolves facing food shortages (Messier 1985).

'Monitoring to detect and act on such circumstances is clearly a sensible option for managers.'

After baiting removed almost all wild dogs, re-colonisation from adjacent unbaited areas was rapid (Figure 5). The population rose, though not to the extent that occurred during the first period of the study. The new immigrants occupied large areas, and in some cases, their reproductive potential was unknown. When breeding increased, young dingoes were able to establish new territories

Dingoes may be attracted to urban settlements in remote areas (for example, Moomba Tip in northern South Australia pictured above) by the prospect of easy food. Such scenarios are likely to increase the rate of hybridisation with domestic breeds and may also create a public nuisance (Source: P. Bird, Animal and Plant Control Commission, South Australia).

Figure 5: Fluctuations in dingo density (•) in the Fortescue River region 1976–84. Census data exclude pups but all other dingoes known to have been present at any time during a particular quarter were counted. Dissociation of dingoes from packs and a paucity of ground survey work precluded an accurate tally in some quarters (○). Population size was probably underestimated in these periods. The histogram depicts the size of the area censused in each quarter. Arrows indicate when baiting took place (after Thomson et al. 1992b).

at the edge of their natal range. This meant that pack size did not necessarily increase as it did during the first period of the study. There were now vacant areas available in which wild dogs could settle, unlike the earlier period, when the area was fully occupied.

There are several important implications for wild dog management in these findings (Section 6.4.4). One of the most obvious is that populations of wild dogs within close proximity to livestock pose the greatest threat when their numbers are high and their food supply is limited. Movements into grazing areas are likely at these times. Monitoring to detect and act on such circumstances is clearly a sensible option for managers (Chapters 6 and 7). The research findings from the Fortescue River study also support the strategy of maintaining a buffer zone adjacent to stocked areas, where control work is carried out to remove resident wild dogs and create a 'dispersal sink' (Section 6.4.4). This reduces the risk of wild dogs moving from the adjacent area into the paddocks, and also provides an area for wild dogs dispersing from further out to settle before moving into stocked areas (Chapter 6).

A study by Fleming et al. (1996) in north-eastern New South Wales suggested that the dynamics of wild dog populations under regular high levels of control by aerial baiting were greatly influenced by the annual nature and timing of the baiting. A conceptual model of population dynamics under annual aerial baiting (Figure 6) shows that the sink caused by annual population reduction is filled by the time of the next annual baiting. There was evidence that the new dogs in the area were both young dogs born locally and immigrants. The time at which repopulation occurred was not determined. Repopulation and its timing obviously affect decisions about the timing of control programs (Section 6.4.4).

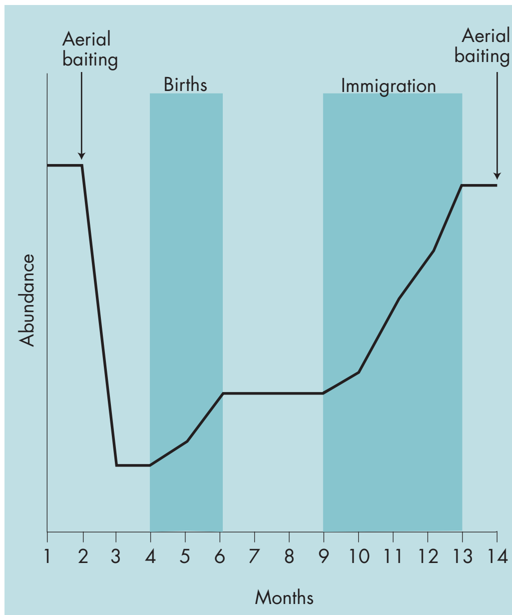


Figure 6: A conceptual model of the dynamics of a population of wild dogs in an area exposed to annual baiting programs (Month 1 is March) (after Fleming 1996a).

2.8.3 Social factors limiting population growth

A number of factors influence dingo numbers and affect their population density (Section 2.7). Breeding and immigration boost numbers and mortality, and emigration depletes numbers. Mortality factors may include disease, starvation and the direct effects of control actions. The type of food available, its abundance, and its dispersion all affect the social dynamics of dingo populations, and this in turn affects population dynamics (Section 2.3). Some of these social factors are outlined in this section.

In most stable packs, only one litter of pups is generally raised (Thomson et al. 1992b; Corbett 1995a), although several females in the pack may be capable of breeding and may even whelp. Social factors, including dominant female infanticide (Corbett 1988b), appear to limit the production or raising of additional litters. In a three-year study of a captive dingo pack, Corbett (1988b) found that less than half the potential increase in dingo numbers was realised, due to inhibition of breeding in subordinates, mating preferences by dominants, infanticide and the killing of subordinate females. In captive wolves, dominant males and females aggressively prevent subordinates from sexual soliciting and mating activities (Zimen 1976).

An important consequence of infanticide by dominant females is that subordinate females help to rear and even suckle the offspring of the dominant female. This reproductive strategy ensures the dominant female's offspring not only receive additional care from subordinate helpers, but also have no competition for resources from the offspring of other females. Infanticide in Australian dingoes may have evolved in response to widespread drought and fire when packs are forced to split into smaller units to survive on the patchy and scarce resources available. The more pups born, the greater the chance that some would survive adverse periods. Since most breeding dingoes would have been closely related, at least some of the dominant pair's genes would survive to the next generation if all pregnancies went to term and if some of the smaller social groups were able to survive. Once groups reformed, the dominant dingoes' genes would be better favoured by infanticide.

'In most stable packs, only one litter of pups is generally raised.'

Breeding success can be affected in a less direct way by food supply and the social context. In the Fortescue study (Thomson et al. 1992b; referred to in Section 2.3.4), dingoes appeared to have a lower chance of successfully raising litters when acting alone. The absence of helpers to provide additional food for mother and pups probably contributes to poor pup survival, as does the inability of solitary dingoes or pairs to successfully hunt kangaroos, the primary prey in the area. Larger groups are more successful at hunting kangaroos (Section 2.3.4), an advantage in providing food for the pack and its offspring. When sheep, an easy prey for solitary dingoes, became available to two bitches who were each caring for pups largely on their own, both litters were successfully raised (Thomson et al. 1992b).

2.8.4 Changes in abundance since European settlement

After dingoes were transported to Australia by Asian seafarers about 4000 years ago, their numbers would have been kept down by food supply, social factors and diseases systematically and periodically reducing populations. However, following European settlement and the development of the pastoral industry in inland Australia about 100 years ago (Bauer 1983), dingo numbers rose dramatically as food such as rabbits, stock and some macropods became more plentiful and dams and artesian bores increased water supply during droughts. In many of the more closely settled areas of Australia, however, changes to the environment and intensive control of dingoes by shooting, trapping and poisoning largely eradicated dingoes. Dingoes are now absent from large tracts of agricultural and grazing land in southern Australia. Dingo control over the extensive pastoral areas of inland Australia was probably not as effective, although the erection of barrier fencing probably tipped the balance in favour of graziers in some parts of Australia (Section 5.1.1).

'The dingo population probably peaked during the 1930–50s and since then has remained high but the proportion of hybrids has increased greatly.'

In some instances, haphazard control work probably was largely inefficient, in many cases only fracturing dingo packs into smaller units, each with a breeding female. In this way, the dingo's natural population suppression method, dominant female infanticide (Corbett 1988b), was discouraged, so that dingo numbers could increase abnormally during flush periods. Further, most of the victims of dingo control programs were probably young and very old dingoes. This meant that surviving populations tended to consist mainly of middle-aged dingoes, the age group most likely to mate and raise litters successfully.

The total dingo population in Australia probably peaked during the 1930–50s, and since then numbers have remained high but the proportion of hybrids in the overall population has increased greatly (Corbett 1995a) (Section 2.9). Dingo samples collected in the 1960–70s indicated that about half the wild dog populations in southern Australia were hybrids (Newsome and Corbett 1982), and the most recent surveys in the early 1980s (Jones 1990) confirmed the trend of increasing hybridisation. Even in the presumed safe bastion for pure dingoes on the mainland, Kakadu National Park in northern Australia, hybrids now occur (Corbett in press). If the current rate of hybridisation continues, pure dingoes may well be extinct by 2100 with only hybrids and feral dogs remaining on the Australian mainland.

Radio-tracking and mark–recapture studies have indicated dingo densities of 0.17 per square kilometre in Kosciusko National Park in south-eastern Australia (McIlroy et al. 1986a) and 0.14 per square kilometre at Kapalga in Kakadu National Park in northern Australia (Corbett 1995a). In the Guy Fawkes River region in north-eastern New South Wales crude estimates (using the index–manipulation–index technique) of wild dog density in unpoisoned areas were between 0.19 and 0.3 wild dogs per square kilometre (Fleming 1996b). An adjacent area in the Guy Fawkes River region that was annually baited with 1080 (sodium fluoroacetate) had pre-baiting densities of between 0.1 and 0.17 wild dogs per square kilometre. In the Fortescue River region the density of dingoes in pack territories varied between 0.03 and 0.25 per square kilometre (mean 0.08 per square kilometre). In South Australia, at the height of a rabbit plague, dingo numbers were crudely estimated at 0.3 per square kilometre based on the maximum number of dingoes observed visiting an isolated water and the area serviced by that water (Bird 1994).

2.9 Hybridisation

2.9.1 The extent of hybridisation

The expansion of farming and grazing activities in the nineteenth century led to the spread of domestic and feral dogs and their consequent hybridisation with dingoes. More than half of the wild dog population in southern and eastern Australia are hybrids (Section 2.8.4; Figure 2). Although wild dog populations in northern Australia and other remote areas remain essentially pure dingoes, hybrids are now being recorded there. Even on Fraser Island, five of a sample of 35 wild dogs recently culled there were hybrid animals (Woodall et al. 1996).

The genetic make-up of wild hybrid dogs has not been evaluated except at the broad level of presence or absence of domestic dog genes in the wild dog population (Newsome et al. 1980). Genetic evaluations have been difficult because hybrids often look like pure dingoes. New techniques are being developed to better assess the genetics of wild dog populations (Wilton et al. 1999).

2.9.2 The main processes of hybridisation

Hybridisation mostly occurs when domestic dogs go bush and dingoes come to town. However, since interactions between dingoes and feral dogs in the bush differ greatly from those in urban places (Figure 7), so too do the rates of hybridisation (Corbett 1995a).

> ***'Once hybrids become more prevalent, the resultant lessening of behavioural differences will expedite the hybridisation process.'***

It is well known that the dogs of cattlemen, recreational fishers, bushwalkers, holiday-makers and Aboriginal people are occasionally lost in the bush (Corbett 1995a). However, the behavioural differences between dingoes and domestic dogs seem great enough to make it difficult for dogs to infiltrate dingo society and breed, particularly in remote areas where there are more dingoes. Once hybrids become more prevalent, the resultant lessening of behavioural differences will expedite the hybridisation process. This could partly explain the greater proportion of hybrids in south-eastern Australia.

There is now a trend for people to acquire (often illegally) dingo pups as pets. The pups may be easily handled, but adults are usually not good pets, simply because they are wild animals that have not been selectively bred for the behavioural characteristics that make a good pet (RSPCA 1997). A pet dingo is likely to use its owner's home as a base from which to roam and do as it pleases, or else it is abandoned when it becomes an adult. The upshot of this pet trend is that dingo–domestic dog contact is increased; because pet dingoes have grown up without learning the social behaviours that curb crossbreeding with domestic dogs, they are more likely to hybridise with domestic dogs than wild bred dingoes. Many such hybrids are rejected by owners or stray to the bush where they may infiltrate wild dingo society and breed with pure dingoes. This process occurs more frequently in semi-rural areas near large urban centres. If dingo breed societies promote and sell hybrids as pure dingoes, the rate of hybridisation will increase (Section 5.3.3).

Some of the dogs that contribute to the gene pool of wild-living dogs are not truly feral but are strays or free-roaming pet domestic dogs (Meek 1998). There have been reports of dingo-like wild dogs mating with restrained female domestic dogs (A. Melling, grazier, New South Wales, pers. comm. 1984).

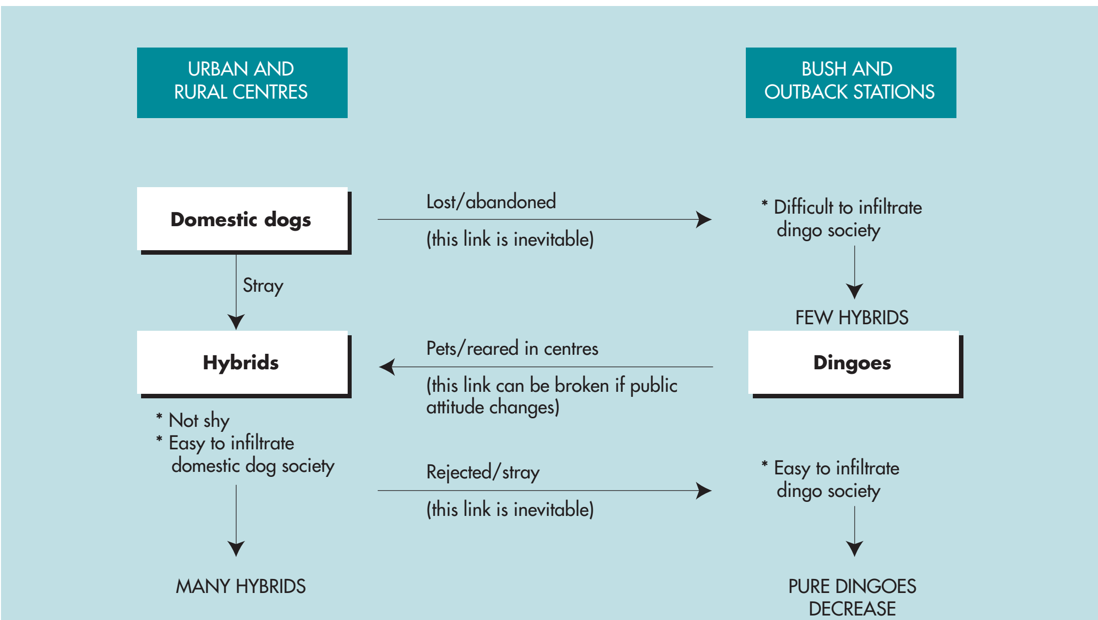


Figure 7: The process of hybridisation between dingoes and domestic dogs (after Corbett 1995a).

2.10 Co-occurrence with other predators

2.10.1 European red fox

The spatial relationship between wild dogs and the introduced European red fox (*Vulpes vulpes*) in Australia is poorly understood. Observations of an inverse relationship between wild dog and fox abundance (Jarman 1986) have been popularly interpreted to mean that wild dogs may limit the distribution and abundance of foxes. However, this speculation is based largely on the correlation of relative abundances and needs to be confirmed by a demonstration of causality.

'Although wild dogs may not influence the distribution of foxes, they do influence their access to resources.'

In areas of eastern Australia where wild dogs have not been excluded by human management, there is little evidence that wild dogs exclude foxes because the two species commonly co-exist (Newsome et al. 1983a; Triggs et al. 1984; Robertshaw and Harden 1985a and unpublished data 1977–84; Catling and Burt 1995; Fleming 1996a). Catling and Burt (1995) found no evidence in forested areas that foxes were excluded by, or avoided, wild dogs. They argue that populations of red foxes in south-eastern Australia are more likely to be limited by factors other than the presence of wild dogs. In many areas, the marked differences between the habitats and management regimes of agricultural (higher fox abundance) and non-agricultural land (higher wild dog abundance) confounds the comparison of the relative abundances of the two species, and provides a number of alternative hypotheses that could explain observed differences in the relative abundances of the two species.

In central Australia foxes appear to avoid wild dogs, especially at widely spaced and shared watering points. Wild dogs also exclude foxes from kangaroo and cattle carcasses during droughts (Corbett 1995a), so that, although wild dogs may not influence the distribution of foxes, they do influence their access to resources. In northern South Australia, foxes were also seen to avoid dingoes at waters and were frequently driven off by dingoes (P. Bird, Primary Industries and Resources, South Australia, pers. comm. 1999).

Similar evidence exists for Western Australia. In the Fortescue River region, the presence of foxes was noted (sightings, captures in traps, tracks and other signs) during a nine-year intensive radio-tracking study of dingoes (Thomson 1992a; unpublished data 1976–1984). In this area, foxes were relatively common on the productive coastal plains, where sheep were grazed and dingoes were subject to intensive control. In the adjacent rugged unstocked areas, dingoes were initially at low levels and foxes were present, albeit in low numbers. When dingo numbers increased, foxes were only ever recorded in the unstocked areas at the edge of the sheep paddocks. When dingo numbers fell, fox activity began to appear again deeper into the unstocked areas. Although circumstantial, it seems likely that foxes were affected by the abundance of dingoes. When dingo numbers were low in the unstocked areas, foxes appeared to invade from the adjacent coastal plains.

In contrast, in another study on the Nullarbor Plain in Western Australia (Thomson and P. Marsack, unpublished data 1982–1987), dingoes, foxes and feral cats commonly co-occurred in the same local areas. Although this seems to contradict the evidence from the Fortescue region, there are features of both environments that may explain the differences. In the Nullarbor area, rabbits were numerous and distributed relatively uniformly across the landscape. Foxes would have been able to hunt rabbits within dingo home ranges, while avoiding resident dingoes. In contrast, resources in the Fortescue area were patchy and rabbits were absent. Dingoes favoured the most productive areas (Section 2.2), so it would have been difficult for foxes to avoid dingoes, unless they remained in the poorer areas. In addition, the presence of rabbit warrens in the Nullarbor area gave foxes an opportunity for escape from dingoes should conflict arise. Dingoes kill foxes (Marsack and Campbell 1990) and avoiding dingo attack would have been more difficult for foxes in the Fortescue area.

2.10.2 Cats

Feral cats co-occur with wild dogs throughout most of Australia but almost nothing is known of their interrelationships. Fleming (1996b) found that wild dogs co-occurred with feral cats (and red foxes and spotted-tailed quolls (*Dasyurus maculatus*)) on a regional scale in north-eastern New South Wales but suggested that there might be some spatial segregation at a more localised level. Corbett (1995a) suggested that wild dogs exclude feral cats from kangaroo and cattle carcasses during droughts. Wild dogs occasionally eat feral cats (Robertshaw and Harden 1985a; Thomson 1992c, Corbett 1995a) although the impact of this on cat populations is unknown.

2.10.3 Quolls

Prior to European settlement, dingoes almost certainly co-occurred with the spotted-tailed quoll, eastern quoll (*D. viverrinus*), western quoll (*D. geoffroii*) and northern quoll (*D. hallucatus*). Today, the distribution of wild dogs and quolls has been much reduced by habitat changes associated with European settlement. However, dingoes and other wild dogs still co-exist in many areas with all quoll species except the eastern quoll, which is believed to be extinct on mainland Australia.

3. Economic and environmental impacts and values

Summary

Wild dogs have impacts on agriculture through predation of livestock. Measuring stock losses alone usually underestimates the true economic cost of wild dogs because these estimates do not include costs of dog control, the opportunity costs and other costs associated with wild dogs (for example, not grazing sheep on otherwise suitable land). However, most economic assessments have been limited to calculations of stock losses because these are the easiest and most comprehensible measures for landholders to use. Studies in Western Australia, Victoria, New South Wales and Queensland have shown that predation of sheep and cattle can threaten the economic viability of properties in some areas. Sheep are the most commonly attacked livestock, followed by cattle and goats. There is evidence of seasonal peaks in predation on livestock, possibly related to the seasonal breeding activity of wild dogs, as well as the timing of lambing and calving.

Although many wild dogs will attack or harass sheep, some individual wild dogs cause far more damage than others, sometimes maiming without killing outright. The presence of wild dogs can adversely affect the distribution and behaviour of sheep, even when dogs do not actively harass them. Wild dogs sometimes chase sheep without following through with an attack. This may lead to stress-associated behaviour such as mismothering of lambs and loss of production. Even when wild dogs kill sheep, they often leave carcasses uneaten. Individual wild dogs that kill sheep often eat natural prey such as kangaroos, indicating that killing of livestock is independent of the presence of natural prey.

Wild dogs have been in Australia long enough to become a functional part of the mammalian predator–prey relationships and fulfil an important role in the functioning of natural ecosystems. Dingoes are implicated in the extinction of Tasmanian devils and thylacines from mainland Australia. Dingoes are regarded as a native species and are subject to legislative protection in some States and Territories.

Wild dogs are implicated in the spread of hydatids which is a risk to human health and the cause of losses of production associated with hydatidosis in cattle and sheep. Wild dogs also provide a reservoir for heartworm infection and diseases such as parvovirus. Dog rabies is presently exotic to Australia, but of all Australian wildlife, wild dogs pose the greatest risk of maintaining and spreading dog rabies if it was introduced.

The dingo, often considered a native Australian mammal, has an intrinsic and aesthetic value and there is a public expectation that it will be conserved. Other wild dogs, as top order predators, may have an important, but as yet unclear, influence on the biodiversity of animal communities. They might also have an inverse density relationship with foxes and therefore be important in limiting the impact of foxes and cats on populations of small and medium-sized mammal prey.

In areas where dingoes are a major tourist attraction, they occasionally show aggressive behaviour towards people, particularly if they are often fed to encourage closer viewing.

3.1 Economic impact

The threat of predation of livestock by wild dogs has largely determined the distribution of sheep and cattle in Australia (Figure 2) (Newsome and Coman 1989). Rapid expansion of the sheep industry after the successful early 1800s ventures of the MacArthurs and Marsden into merino breeding brought the problem of predation by wild dogs to the attention of early legislators (Section 5.1.3). Sheep were under the constant supervision of shepherds (Gould 1863; Rolls 1984) who had responsibility for preventing sheep straying and preventing predation by wild dogs. The amount of fencing for the enclosure of livestock increased after the *Nicholson Land Act*

Even when livestock are not killed outright by wild dogs, economic losses may arise due to veterinary costs, decline in livestock condition and downgraded sale prices (Source: L. Corbett).

Victoria 1860 and the *Robertson Free Selection Act NSW 1861*, and the shortage of labour that accompanied the 1860s goldrushes. Consequently, the use of shepherds became less common although the threat of wild dog predation ensured that considerable investment of labour continued to be placed on wild dog control. Predation has continued until the present although there have been few attempts to quantify losses at more than the property scale.

A Western Australian example of losses caused by dingoes over an 18-day period is given in (Thomson 1984a) (Table 2). These loss figures are considered conservative as some events could have been missed and sheep were being mustered from the paddocks so not all were available to dingoes for the full period. Extrapolation of the data in Table 2 suggests an annual loss of 33% in area A and 16% in Area B. Had dingo activity continued, direct losses of this magnitude, along with those due to harassment, would have seriously threatened the viability of the enterprise (Thomson 1984a).

Predation of livestock by wild dogs continues to threaten the livelihood of some livestock producers in tableland environments of eastern New South Wales, the Australian Capital Territory and Victoria. In parts of the eastern tablelands of New South Wales, wild dogs are regarded as the major limitation to sheep production (Fennessy 1966; New England Rural Development Association (NERDA) undated c.1966; Hone et al. 1981; Schaefer 1981; Fleming and Robinson 1986; Fleming and Korn 1989). Holdings where wild dogs are a problem are mostly situated along the Northern and Southern Tablelands of New South Wales (Fleming and Korn 1989). The study by NERDA (c. 1966) also estimated the opportunity cost of sheep not being run in areas that were suitable but for the presence of wild dogs. The timing of the survey corresponded with a regional increase in pasture improvement with superphosphate. It was believed that pasture improvement combined with dingo control could increase sheep numbers by 93%.

Table 2: Sheep losses caused by dingoes over an 18-day period, detected during radio-tracking in two areas on Mardie Station, Western Australia where dingoes were being controlled (after Thomson 1984a).

	Area A	**Area B**
Radio-collared dingoes involved	3	6
Potential sheep available	800	4200
Harassments, no injuries	5	3
Minor injuries	1	3
Kills/mortal injuries	13	26
Other verified deaths	0	7
Total identifiable losses	**17***	**33**

*Total includes four sheep killed on a neighbouring property by one of the radio-tagged dingoes.

'There were seasonal peaks in predation, possibly related to the seasonal breeding of wild dogs and control activity, as well as the timing of lambing and calving.'

The surveys of dingo damage (Table 3) conducted by NERDA (c. 1966) and Schaefer (1981) were inherently biased because their samples were obtained from graziers attending meetings to discuss the issue of wild dog predation. Fleming and Korn (1989) report a monthly survey of authorised wild dog control officers (of Rural Lands Protection Boards) from eastern New South Wales over the four years from 1982 to 1985 (Table 3). During this period, 25 644 livestock were attacked by wild dogs. Sheep were the most commonly attacked animal, followed by cattle and goats. Regional differences were apparent in the livestock species attacked and these reflected the ratio of sheep to cattle grazed in each region. Not surprisingly therefore, the major losses occurred in areas where sheep were present. Fleming and Korn (1989) found seasonal peaks in predation, possibly related to the seasonal breeding of wild dogs and control activity, as well as the timing of lambing and calving.

In 1984 and 1985, another survey of 111 randomly selected livestock producers with land close to or within terrain inhabited by wild dogs was conducted in north-eastern New South Wales (Table 3; Fleming 1987). Thirty-six per cent of producers reported that wild dogs had attacked their livestock during the survey and 1194 sheep and 127 cattle were killed in those attacks. The mean losses during the survey were 7.17 sheep per property per year and 0.76 cattle per property per year. The mean value of losses suffered by those participants that had livestock preyed on by wild dogs was $1900 (Fleming 1987). The mean value was largely dependent on the values of livestock that prevailed during the survey. The cost to the sheep industry of predation by wild dogs in eastern New South Wales for 1988 was estimated at around $4 million (Saunders and Fleming 1988). Of the surveys undertaken in north-eastern New South Wales, only one survey (Fleming 1987) was an unbiased sample from landholders within or adjacent to terrain inhabited by wild dogs.

In 1985, Backholer (1986) mailed a questionnaire to 809 properties in 23 shires of Victoria that had a history of livestock predation by wild dogs. The 508 respondents reported mean losses per property of

Table 3: Predation of livestock by wild dogs in north-eastern New South Wales. Mean losses were calculated as the total number of sheep killed by wild dogs divided by the total number of sheep run by the survey participants and expressed as a percentage (from Fleming 1996b).

Year(s)	Sheep killed (Number/property/year)	Mean losses of sheep (%)	Source
1961–62	19.5[a]	1.33	NERDA (undated c. 1966)
1980–81	19.4	0.9	Schaefer (1981)
1982–85	N/A	0.7[b]	Fleming and Korn (1989)
1984–85	14.5	0.8	Fleming (1987 and unpublished data 1985)

[a]To equate the data with previous biased surveys (NERDA undated, c. 1966; Schaefer 1981), only the losses of Wild Dog Control Association members in Fleming (1987) are presented in this column.

[b]Losses reported to local Rural Lands Protection Boards multiplied by three to account for two-thirds under-reporting recorded in Fleming and Korn (1989).

between $700 and $7400 per annum, 0.1 to 24.9% of the total value of the enterprises. The total loss was $835 000. As well as this, opportunity costs (including time, moving stock, repairing fences) totalled $662 500 and government agencies spent $1 444 500. Therefore the total annual loss was around $3 million. During the preceding eight years, the annual average of the total losses that were reported in the surveyed area was 2400 sheep which would be equivalent to an average annual loss of $1650 per property (Backholer 1986).

The most recent survey of livestock losses inflicted by wild dogs was in the Northern Territory in 1995. The results of a questionnaire of approximately 67% of pastoralists led to a rough estimate that annual calf losses attributable to predation by wild dogs were between 1.6% and 7.1% (Eldridge and Bryan 1995). The estimated annual value of all cattle killed by wild dogs in the Northern Territory (assuming an average value of $540 per head and 100% calving — such calving rates are optimistic) was $13.5 million with control costs of $300 000. This represents average losses of $89 000 per property and costs of $2000 per property. Despite the extreme losses and comparatively small investment in wild dog control, 96% of respondents rated wild dog control as being worthwhile.

One of the difficulties in providing clear data on the impact of wild dogs on livestock production is that most wild dog control programs manage to achieve, at least to some extent, their aim of reducing predation on livestock. Thus, figures on losses or damage can be misleading, rarely reflecting the potential impact that could arise in the absence of wild dog control. The economic impact of wild dog predation of livestock cannot simply be measured in terms of livestock killed by wild dogs. Losses other than direct maimings and killings of livestock caused by wild dogs are especially difficult to quantify. The costs of control activities, losses of genetic material, capitalisation of the risk of wild dog predation into land values (Schaefer 1981) and opportunity costs (such as the allocation of labour and capital to predation mitigation and planning instead of other on-farm activities) need to be accounted for in economic assessments. Other opportunity costs are the imposition of sub-optimal enterprise mixes for a particular agro-environment and sub-optimal pasture management caused by the presence of

(a) Calves are most vulnerable to wild dog attack when they are newborn and left while the cow feeds; (b) 'nursery groups' of calves protected by older cows are common in areas where cattle are familiar with wild dog attacks (Source: L. Allen, Department of Natural Resources, Queensland).

wild dogs. Although the mix of sheep and cattle may be partially offset by capitalisation of the costs of wild dogs into the purchase price of land, enterprise mixes that are below the optimum are likely to negatively affect the cash flows and long-term profitability of grazing enterprises in wild dog inhabited areas.

'Figures on losses or damage can be misleading, rarely reflecting the potential impact that could arise in the absence of wild dog control.'

Despite potential shortcomings, surveys of the type outlined above substantiate the generally accepted view that the major losses caused by wild dogs occur amongst sheep flocks. An attempt to specifically document and quantify the types of losses caused to sheep flocks was made on Mardie Station in the Pilbara region of Western Australia (Thomson 1984a). In this study, 26 radio-collared dingoes in sheep paddocks were observed from the air. Interactions with sheep were followed up by investigations on the ground. Additional information was obtained when sheep were mustered and inspected at shearing time. The major findings were:

- Some dingoes caused far more damage than others did, although most attacked sheep, sometimes maiming without killing outright.
- The presence of a dingo could adversely affect the distribution and behaviour of the sheep, even if the dingo did not actively harass them.
- Dingoes sometimes chased sheep without following through with an attack. This could still lead to harm such as mismothering of lambs.
- When dingoes killed sheep they often left carcasses uneaten.
- Individual dingoes that frequently killed sheep often ate natural prey such as kangaroos (*Macropus* spp.).

Dingoes easily outpaced sheep, although it was clear that many of the witnessed chases were not motivated by hunger; chases were sometimes seen after wild dogs had been observed feeding. At times wild dogs simply broke off chases, or moved on to chase other sheep in the mob, then left with no actual physical contact with the sheep. Sheep were sometimes chased through fences (this has also been reported in north-eastern New South Wales), on occasions into waterless areas. At times, clear changes in the distribution of sheep within large (up to 150 square kilometres) paddocks were observed; sheep abandoned favoured grazing areas when dingoes were present. When ewes and lambs were chased, ewes ran off wildly, leaving lambs to keep up as best they could and potentially causing their death through mismothering. All these events could cause production losses, although they would not necessarily be reflected in a 'carcass count'.

The survival of most bitten sheep was poor. Far fewer bitten sheep were tallied at shearing than would have been expected based on observations in the paddocks. Nevertheless, rams seemed to survive severe scrotal injuries, with some being fully castrated by wild dogs attacking from behind (Figure 11).

In some areas, producers have elected to run cattle instead of sheep because of the effects of wild dog predation. For example, Backholer's (1986) survey showed that, to minimise wild dog predation, 12% of eastern Victorian respondents reduced their sheep numbers or did not run sheep. Although wild dogs can cause losses to cattle herds, as discussed next, the impacts are usually less severe and more easily overcome. Nevertheless, some grazing lands are more suited to running sheep than cattle, and the move to other enterprises such as cattle production can be viewed as an opportunity cost of wild dog predation.

Damage by wild dogs is likely whenever their ranges overlap those of sheep. Damage occurs largely independent of age and condition of sheep, age and density of the dogs, seasonal conditions and availability of alternative food for dogs. However, most of these factors influence wild dog predation on cattle (Rankine and Donaldson 1968; Corbett 1995a; Allen and Gonzalez 1998). In contrast to the situation with sheep, the impact of wild dogs on cattle production is more variable. Generally, attacks on young calves are the major cause of cattle losses to wild dogs (Corbett 1995a; Fleming and Korn 1989). However, the cost of wild dog predation to the beef industry in Australia has not been estimated. The profitability of northern Queensland cattle enterprises is substantially affected by branding percentage (Sullivan et al. 1992). Predation of calves by wild dogs is the main cause of neonatal losses in northern Australian cattle (Rankine and Donaldson 1968) and hence has major bearing on branding precentage. Branding percentages also vary considerably with seasonal conditions, pasture improvement and level of animal husbandry. Predation is greater when alternative food is scarce (Thomson 1992c; Corbett 1995a; Allen and Gonzalez 1998). Improved weaner management and nutrition have been shown to potentially increase branding percentages from 40% in 1968–69 to 1970–71 (Anderson and McLennan 1986) to 80% twenty years later (Fordyce and Entwistle 1992).

'Predation may be higher when control operations cause invading young wild dogs to come into contact with cattle herds.'

Estimates of predation losses of calves and weaners in normal conditions in rangeland grazing areas are in the range of 0–29.4% per year (Rankine and Donaldson 1968) and studies of reproductive failure in cattle herds in Queensland have suggested up to 30% loss of calves caused by predation by wild dogs (Allen and Gonzalez 1998). Such losses would negate the potential gains due to improved livestock and pasture management in northern Australia.

There is evidence that the age and social organisation of a wild dog population can affect the extent of predation on calves. Calves are most vulnerable when newborn, though the protective behaviour of the cow can be sufficient to deter wild dog attacks (Thomson 1992c, and unpublished observations). Experienced wild dogs, operating as a hunting unit, are more likely to be successful at killing calves. On the other hand, there is evidence from north Queensland (Allen and Gonzalez 1998), that risks of predation may be higher when control operations cause a preponderance of invading young wild dogs to come into contact with cattle herds. Seasonal effects (Corbett 1995a) and the scale of control may modify the damage response; a larger baited area would reduce the rate of repopulation and the number of transient dogs, as Thomson (1984b) found in Western Australia.

It is possible that increased predation could be caused by the greater mobility of immigrant dingoes, increasing the probability of an encounter with a newborn calf. This might be exacerbated by the lone status and relative inexperience of immigrant wild dogs, resulting in their poor success at hunting larger and faster native prey such as kangaroos.

Appropriate strategies to manage the impacts of wild dogs differ markedly depending on the type of livestock and the conditions prevailing in an area (Chapters 5, 6 and 7).

3.2 Environmental impact

Predation by wild dogs may have an impact on the survival of remnant populations of endangered fauna. For example, predation by the dingo has been implicated in the extinction of the Tasmanian native-hen (*Gallinula mortierii*) from mainland Australia (Baird 1991). Endangered populations of marsupials may require management of their predators to become re-established or to survive (Johnson et al. 1989). Predation by wild dogs is less likely to threaten populations of more abundant marsupials (Robertshaw and Harden 1989).

The other environmental impacts of wild dogs relate to their management, rather than to the presence of the animals themselves. First, control measures may have a direct impact on non-target species (Section 6.6.2). Second, reducing wild dog density may result in an increase in other predators with overlapping diets. (This process of substitution of predators is called 'mesopredator release' (Soulé et al. 1988)). There is a commonly held opinion (Denny 1992; Smith et al. 1992) that removing wild dogs from a system where foxes (*Vulpes vulpes*) also occur will result in an increase in fox numbers with consequent increased predation on critical body weight range (CWR) mammals (35–5500 grams) (Burbidge and McKenzie 1989). However, neither an increase in fox numbers resulting from a reduction in wild dog numbers nor a resulting increase in predation of CWR mammals have been demonstrated. Schlinder (1974) has also argued that, by the same mechanism, feral pigs could replace dingoes in some situations.

'Predation by wild dogs may have an impact on the survival of remnant populations of endangered fauna.'

Predation on environmentally damaging feral ungulates has been suggested as a positive impact of dingoes and other wild dogs. For example, Parkes et al. (1996) suggested that the limited distribution of feral goats in northern Australia was attributable to dingo predation. Twenty sterilised dingoes were released on Townshend Island, off Queensland, in an attempt to reduce the population of 2000–3000 feral goats. Within one-and-a-half years 99% of the goats had been removed and feral goats were eradicated from the island after three-and-a-half years (L. Allen, Queensland Department of Natural Resources, pers. comm. 1998). Given that the dingoes survived for two years on very few goats, this raises the interesting question of the impact of dingoes on alternative prey (Section 3.6.5) that must have been killed during the latter part of the exercise. Caution should be exercised in translating these results to mainland ecosystems. Pavlov (1991) provided circumstantial evidence that, while dingoes undoubtedly kill feral pigs, they do not significantly affect feral pig abundance.

3.3 Resource and conservation value

Although feral dogs and hybrids are seldom regarded as a wildlife resource, dingoes have potential value from five resource perspectives: (1) harvest for food or skins; (2) conservation of native species and natural communities (Section 4.4); (3) in Aboriginal mythology; (4) tourism; and (5) as a specialised dog breed.

1. Unlike in some Asian countries where dingoes are eaten (Corbett 1995a), there is no current harvest of dingoes for food in Australia. There is evidence that Aboriginal people ate dingoes and other wild dogs (Manwell and Baker 1984). Dingoes could be harvested for their pelts, but these are generally of low value. It is illegal under the Commonwealth *Wildlife Protection (Regulation of Exports and Imports) Act 1982* and subsequent amendments, and associated *Amendment Acts of 1986, 1991 and 1995*, to export native wildlife products, including pelts, without appropriate licenses. Trade in skins, except for the recovery of bounties, is not permitted in those States and Territories where the dingo is afforded some conservation status.

2. The dingo has been in Australia long enough to have colonised most suitable habitats and, in many instances, is still a functional part of predator–prey relationships. The implication from this is that the dingo fulfils an important role in the functioning of ecosystems. Legislation in some States acknowledges the ecological significance of dingoes and provides protection in some situations (Section 5.2). Whether dingoes have conservation value because they have a functional role in the conservation of natural ecosystems is unclear (Sections 3.4, 3.5 and 3.6). Regulation of macropod and emu (*Dromaius novaehollandiae*) populations by wild dogs has been inferred, but not proven, in a number of studies (Caughley et al. 1980; Shepherd 1981; Robertshaw and Harden 1986; Thomson 1992c; Fleming 1996b; Pople et al. 2000). Prey regulation by wild dogs has been inferred for rabbit populations after droughts have reduced rabbit numbers in arid areas (Corbett 1995a). Conversely, in an experiment in the wet–dry tropics, Corbett (1995c) demonstrated that dingoes do not regulate feral pig populations (Section 3.6.5).

   In contrast, there is evidence that dingo numbers in many areas of central and northern Australia have increased since

European colonisation. Predation by dingoes may threaten the survival of some CWR mammals. Where this occurs, dingoes may be considered a biological liability rather than a biological resource. Where feral dogs and hybrids have supplanted dingoes, these too may perform a similar role in the function of the ecosystem. Predators affect the distribution and abundance of their prey (Huffacker 1970) and so the substitution of one canid subspecies with a similar subspecies is likely to maintain the dynamics of the community in which they occur.

3. The dingo is an important animal in Aboriginal mythology. For some Aboriginal peoples (for example, the Pitjantjatjara) dingoes are associated with sacred sites and are considered the physical embodiment of a Dreamtime character or Tjukurpa. The local disappearance of native species significant to Aboriginal people has caused them distress in the past and similar distress may be caused if dingoes become extinct.

4. Dingoes provide an indirect resource value from tourism. They are present in many zoos and private wildlife parks. Fraser Island is an example where free-living dingoes are a tourist attraction providing income to island businesses. Tourism by recreational hunters is another source of value of dingoes (Allison and Coombes 1969). The 'howling-up' of a dingo may be regarded as a test of hunting skills and the presentation of scalps for bounties (Section 5.1.1) as a small remuneration to help cover the costs of the hunt (Allison and Coombes 1969).

5. The dingo is recognised as an official breed of dog by the Australian National Kennel Council and was adopted as Australia's national breed in November 1993. In New South Wales, this status has been recently recognised in legislation (*Companion Animals Act 1998*) which allows people to keep dingoes under the same restrictions as other breeds. Animals kept by breed societies are traded as pets or specimen animals. This is potentially damaging for the conservation of pure dingoes because many animals held by breed societies are likely to be hybrids and there are no valid checks in place to detect them (Corbett 1995a; Corbett in press; Section 2.9).

The presence of dingoes has an 'unpriced' value (Sinden and Worrell 1979) that is difficult to quantify and comprises the non-monetary value that many people place on dingoes. The dingo is an icon which many people value knowing is present in the wild, that is, its 'existence value'.

3.4 Diseases and parasites

Endemic diseases and parasites

Hydatidosis (causal agent *Echinococcus granulosus*) causes fatalities and morbidity in humans. The prevalence of hydatidosis in humans is often linked to sylvatic cycles in wild dogs and wildlife (Coman 1972a; Thompson et al. 1988). The prevalence in humans is relatively low but is more common in south-eastern Australia (Jenkins and Power 1996).

Hydatidosis associated with a sylvatic cycle within wild canids and macropods (Durie and Riek 1952; Coman 1972b) leads to the condemnation of offal from up to 90% of slaughtered cattle from endemic areas (D. Jenkins, Australian Hydatids Control and Epidemiology Program, unpublished data 1999). An abattoir survey of sheep from the Southern Tablelands of New South Wales from 1970–72 found hydatidosis in up to 40% of carcasses (Hunt 1978). Bovine hydatidosis (causal agent *Echinococcus granulosus*) prevalences of 2.2–55.7% have been reported in south-eastern Queensland (Baldock et al. 1985) and of 0.5–7% in north-eastern Victoria (D. Jenkins, Australian Hydatids Control and Epidemiology Program, Australian Capital Territory, pers. comm. 1998). The latter prevalences were in spite of an extensive hydatid control program aimed at domestic and farm dogs. Hydatidosis is an occupational risk for wild dog trappers and researchers.

Red foxes have also been identified as definitive hosts and macropods as intermediate hosts for hydatid transmission in south-eastern Australia (Obendorf et al. 1989; Reichel et al. 1994). Where feral dogs, dingoes and free-roaming domestic dogs co-occur with foxes (for example, in coastal south-eastern Australia, Meek 1998) the control of human hydatidosis becomes more difficult.

'The prevalence of hydatidosis in humans is often linked to sylvatic cycles in wild dogs and wildlife.'

Wild dogs also transmit the viruses that cause canine distemper (Paramyxovirus), canine hepatitis (Adenovirus) and parvovirus disease (causal agent Parvovirus). Although these diseases adversely affect domestic dogs, their transmission by wild dogs is unlikely to pose a significant threat because these diseases can be controlled.

The presence of heartworm (*Dirofilaria immitis*) in dog populations is linked to the presence of mosquitoes in endemic areas (Russell 1990). Heartworm infections are uncommon in the tablelands of south-eastern Australia, with most cases of infection in domestic dogs being in animals that have been moved by their owners to and from endemic areas (Carlisle and Atwell 1984). Heartworm infection has not been recorded in foxes from the Northern, Central and Southern Tablelands of New South Wales (P. Fleming and B. Kay, NSW Agriculture, and D. Jenkins, Australian Hydatids Control and Epidemiology Program, Australian Capital Territory, unpublished data 1999). It is therefore unlikely that wild dogs and dingoes from tablelands of south-eastern Australia will experience heartworm infection and that, more commonly, infection will be in coastal areas and northern Australia. In urban Melbourne, where heartworm infection has been recorded in foxes, a sylvatic cycle of canine heartworm has been postulated (Marks and Bloomfield 1998). This process may also apply in endemic areas where foxes and wild dogs co-occur.

Seddon and Albiston (1967) suggest that wild dogs may act as hosts for the parasite that causes sheep measles (*Taenia ovis*) and the consequent condemnation of sheep carcasses. However, Coman (1972a) failed to find evidence of *T. ovis* infection in a sample of 204 dingoes and other wild dogs in north-eastern Victoria and linked this absence to the infrequent occurence of sheep and cattle in the diet of dogs in his sample.

Parasites have also been instrumental in the identification of dingo origins. The occurrence of the biting lice (*Heterodoxus spiniger*) on dingoes and macropods in Australia and on Asian dingoes implies that dingoes were transported to and from Asia (Corbett 1995a) (Section 1.2).

Exotic diseases and parasites

Canids are regarded as the most important source of rabies (Rhabdoviridae) in humans (Garner 1992), with dogs causing an estimated 75 000 cases annually throughout the world (Fenner et al. 1987). As dog rabies is presently exotic to Australia (there has been one reported outbreak since European settlement in Tasmania in 1867; O'Brien 1992), the potential role of wild dogs can only be speculated. Newsome and Catling (1992) suggest that of all Australian wildlife, wild dogs and foxes pose the greatest risk of maintaining and spreading dog rabies after introduction, and Thomson and Marsack (1992) propose aerial baiting of buffer zones as the primary weapon against the spread of rabies among dingoes in rangelands. Forman (1993) indicated that the establishment of a sylvatic dog rabies cycle in Australia was remote but possible. The dog strain of rabies remains the main focus for quarantine barrier prevention of this disease in Australia.

If dog rabies were to become endemic in Australia, interaction between free-roaming dogs and feral dogs and dingoes would be the most likely avenue for dog rabies transmission to humans. Free-roaming dogs have been recorded making linear movements of up to eight kilometres into bushland where wild dogs and foxes co-occur (Meek 1998). These animals entered bushland with high macropod density to hunt and then returned to their owners. The mean duration of hunting forays was 23 hours, and it is probable that interactions between wild and free-roaming dogs occurred on these trips. Newsome and Catling (1992) consider that, at the high densities of wild dogs and dingoes found in northern Australia and south-eastern Australia, dog rabies would persist were it introduced. Interactions of unrestrained and unvaccinated domestic dogs with wild dogs would contribute to human infection if rabies were to become established in wild dogs. Rabies is not solely a problem of human health but also affects livestock production; for example, bat rabies from vampire bats (*Desmodus rotundus*) is a serious cause of mortality in cattle in Central and South America (Garner 1992). Should a sylvatic cycle of dog rabies become established in wild dogs in Australia, it might affect sheep and cattle production and make the treatment of animals injured by wild dogs more risky.

> ***'Wild dogs and foxes pose the greatest risk of maintaining and spreading dog rabies after introduction.'***

A number of other diseases are important pathogens of dogs in other parts of the world and their introduction to Australia would adversely affect domestic dogs, particularly in breeding kennels, in much the same way as canine distemper does. Wild dogs at high densities may also be affected and their populations limited by infection levels. Among these diseases are: canine brucellosis (infective agent *Brucella canis*), which causes abortion and infertility; Chagas' disease (*Trypanosoma cruzi*), which may cause myocardial and central nervous system degeneration; and tropical canine pancytopaenia (*Ehrlichia canis*), an often fatal parasite of the blood associated with the common brown dog tick (*Rhipicephalus sanguineas*) (Geering and Forman 1987). Canine brucellosis and Chagas' disease are both zoonoses when endemic but human infections are few. Geering and Forman (1987) suspect that tropical canine pancytopaenia may be present in northern Australian wild dogs although no positive diagnoses have been made.

Dogs are also susceptible to infection by three other exotic disease organisms: the viruses causing Aujeszky's disease (Herpesviridae, Alphaherpesvirinae) and transmissible gastroenteritis (Coronaviridae), and screw-worm fly (*Chrysomya bezziana*) (Saunders et al. 1999). Wild dogs might spread transmissible gastroenteritis, a disease affecting young pigs, but dogs are unlikely to be important in spreading the other two diseases if they were to enter Australia.

3.5 Interactions between wild dogs, marsupial carnivores and introduced predators

The thylacine (*Thylacinus cynocephalus*), a marsupial carnivore about the size of the dingo, was once distributed throughout Australia, but 'suddenly' disappeared from the mainland about 3000 years ago (Archer 1974; Dixon 1989; Rounsevell and Mooney 1995). The Tasmanian devil (*Sarcophilus harrisii*), a marsupial carnivore about half the size of a dingo, was also widespread throughout Australia about 4000 years ago, but its population declined and it became extinct on the mainland about 450 years ago (Jones 1995). Their demise can be attributed to competition with dingoes according to the 'superior adaptability' hypothesis (Corbett 1995a). This hypothesis hinges on the superior social organisation of dingoes during critical periods when food supplies were scarce, widely dispersed or clumped, which usually occurs during drought or after extensive wildfire. Only dingoes form large integrated packs and cooperate to catch large prey and to defend carcasses, water and other crucial resources. On the other hand, thylacines hunted alone or in pairs and devils were essentially solitary so that neither could successfully compete against the weight of dingo numbers during those critical periods.

This contention is supported by early records of thylacines as having a stiff gait; they probably could not run after their prey (mainly macropods) as fast as dingoes could. They apparently located prey by scent and tired it by dogged pursuit, usually alone, as there are no records or anecdotes of thylacines hunting cooperatively. This apparent lack of pack hunting is supported by bushmen's observations that the thylacine was normally mute except for a coughing bark (Rounsevell and

Mooney 1995). Social hunters, such as dingoes, have a large vocal repertoire for communicating over distances (Corbett 1995a). Similarly, observations of devils in Tasmania, where they are still common, confirm that they hunt alone, and that although they can catch a variety of live prey, they subsist mainly on carrion such as macropods and sheep (Pemberton and Renouf 1993). It seems that their aggregations around carcasses are not cohesive social units, so, as for thylacines, it is quite likely that devils could not successfully compete with dingoes when food was scarce during drought and after fires.

'Dingoes form large integrated packs and cooperate to catch large prey and to defend carcasses, water and other crucial resources.'

Wild dogs may now present foxes and feral cats with a similar kind of competition. In central Australia, the most common prey species of wild dogs, foxes and feral cats are rabbits and small rodents. During a drought between 1969 and 1972 these prey became scarce and wild dogs changed their diet to red kangaroos (*Macropus rufus*) and cattle carcasses (Corbett and Newsome 1987). Wild dogs were more successful at catching kangaroos by hunting cooperatively than alone (Section 2.3.1), and stable packs of wild dogs defended carcasses and waters more successfully than less cohesive groups (Corbett 1995a). During the first year of this drought, cats and foxes were also seen scavenging cattle and kangaroo carcasses, but sightings of them ceased and their tracks disappeared about midway through the drought. They most likely starved because many emaciated cats suddenly appeared around homesteads and many were easily killed by park rangers (Hooper et al. 1973). Wild dogs undoubtedly contributed significantly to the demise of cats and foxes by their increased monopoly of carcasses as the drought persisted. Foxes were observed avoiding wild dogs at shared waterholes and an increase of cat in the wild dogs' diet was recorded. In any event, there were no signs of cats or foxes until the drought broke and after the rabbit and rodent populations had resurged (Corbett 1995a).

3.6 Predator–prey relationships

Dingoes and other wild dogs have changed in abundance and status since European settlement led to modified ecosystems (Section 2.8.4), and so has the nature of their sociality and predation.

3.6.1 Dingo behaviour and predation on cattle

There are potential problems if peak calving coincides with the dingo mating season. For example, in the Barkly Tableland of the Northern Territory, most dingoes operate independently but during the dingo mating season (about four months peaking in March–April), dingoes form temporary breeding groups which often comprise one oestrous female and several males (Corbett 1995a). The dingo mating season coincides with the peak in calving and this coincidence contributes to the deaths of many calves (Corbett 1995a). Calves and dingoes are often together at water, which is where many attacks occur. In many cases, attacks on calves are probably more of a displacement activity than a hunger drive, perhaps because dingoes become frustrated from competing over oestrous (in heat) females and fighting with rival males. Within dingo groups, there are many aggressive interactions between males but actual fighting is uncommon because of complex behaviours associated with dingo dominance hierarchies. Aggressive behaviour can be appeased or diverted by submissive behaviour to avert serious wounding and death (Corbett 1988b). However, a calf cannot appease or divert the aggression as a submissive dingo would, so the dingo, irrespective of social rank, continues to attack, often joined by other dingoes, until the calf becomes wounded or dies. Calves killed this way are rarely eaten. Even if the calf survives well enough to be sent to market, the meat is often classified as second class because of scars from dog bites. Such loss to the cattle industry is probably substantial but it is difficult to quantify (Section 3.1). As wild dogs seldom eat calves, examining stomachs or faeces of wild dogs would be misleading.

3.6.2 Extinctions of native fauna in central Australia

In central Australia, before the 1930s, 14 species of bandicoots (Peramelidae), macropods and rat-kangaroos (Potoroidae) were common in the areas where cattle now graze, but only five species survive today, and of these, two are rare and endangered (Newsome and Corbett 1977; Morton 1990).

It is probable that a combination of factors operated to cause those extinctions and declines including:

- habitat fragmentation and modification from heavy grazing by rabbits and livestock
- increased competition from rabbits and livestock
- altered fire regimes
- predation by feral cats, foxes and dingoes.

With respect to predation, Corbett (1995a) indicates that cat and fox numbers were low at the time and that dingoes played a major role in the demise of those medium-sized mammals that mostly sheltered on the surface amongst grass and shrubs.

The expansion of grazing enterprises from the 1930s was due to the establishment of supplementary water from artesian bores (Bauer 1983), which allowed cattle to graze further from natural water sources and modify and fragment habitats. This expansion coincided with the most severe droughts (Foley 1957) on record and widespread severe grassfires (Friedel et al. 1990) (Figure 8).

During drought the native fauna declined. In contrast, dingo populations remained high due to cattle carrion and water provided for stock. Dingo predation on macropod and bandicoots would have become increasingly severe as dingo populations grew and as the protective shelters were removed by cattle and rabbits. It is probably no coincidence that the native mammals became extinct or rare.

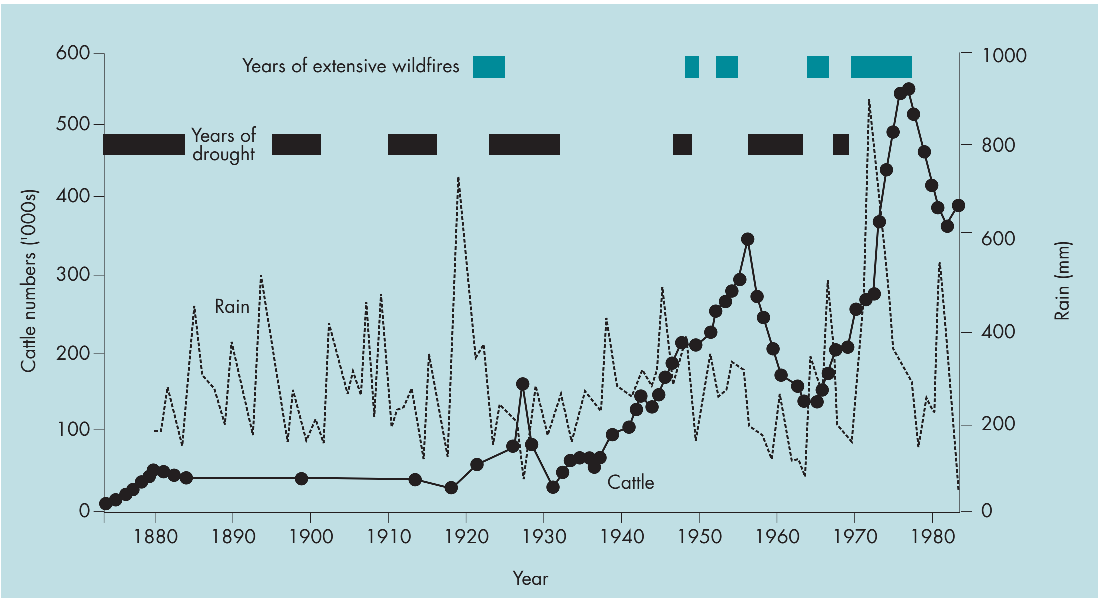


Figure 8: Cattle numbers and rainfall in central Australia from 1874 to 1985. The increase in cattle numbers from the 1930s corresponded with the availability of sub-artesian bore water. Droughts are unpredictable and common in arid areas, yet cattle numbers quadrupled between the worst droughts (1924–1930 and 1958–1965). Wildfires became more frequent in the 20th century. The combination of extensive fierce fires and cattle grazing exposed many medium-size mammals to predation by wild dogs. This predation was probably a cause of some native species' extinctions (after Corbett 1995a).

3.6.3 Factors affecting wild dog–prey interactions with native prey

In the tropical coastal wetlands of the Northern Territory, most dingoes live in packs of three to eight and defend more or less fixed territories. They mostly eat dusky rats (*Rattus colletti*), magpie geese (*Anseranas semipalmata*) and agile wallabies (*Macropus agilis*). When these prey are unavailable dingoes can switch to a range of at least 33 species of substitute prey although they usually concentrate on only one or two species at a time (Corbett 1989; 1995a).

Wallabies are available all year round whereas the supply of rats and geese varies with wet and dry seasons. Most geese are eaten as fledglings in the dry season. Rats irrupt into huge plagues on the floodplains about every three or four years, but they are only available to dingoes during the dry months. Floodplain fauna (rats and geese) are mostly eaten during the dry months and more forest fauna (wallabies (*Macropus* spp.) and possums (Phalangeroidea)) are eaten during the wet months (Figure 9).

Climatic conditions influence both when and where dingoes hunt particular prey species. This alternation of predation between habitats, illustrated in Figure 9, is a well-defined, predictable cycle in which dingoes do not appear to influence the abundance and diversity of any particular prey.

In the temperate coastal mountains of south-east Australia wild dog–prey interactions are determined more by wildfire than by rainfall. Most fires are low to moderate intensity so that the environment remains fairly stable and food supplies for wild dogs are usually high. Fires of high intensity, although infrequent, devastate entire forests and change the prey available to wild dogs, but the total food supply usually remains high. It is therefore not surprising that the predatory cycle is less defined than in the tropical wetlands. Lower densities of wild dogs living in smaller packs (averaging three members) and in smaller territories are also a consequence of this environmental stability (Newsome et al. 1983a).

This predatory cycle still alternates between consistently available prey and seasonal prey. At Nadgee Nature Reserve in south-eastern New South Wales, for example, the main prey are medium-sized mammals (wallabies, rabbits, possums) and waterbirds such as black swans (*Cygnus atratus*) and coots (*Fulica atra*). Both prey types are eaten seasonally and are supplemented by large macropods (eastern grey kangaroo)

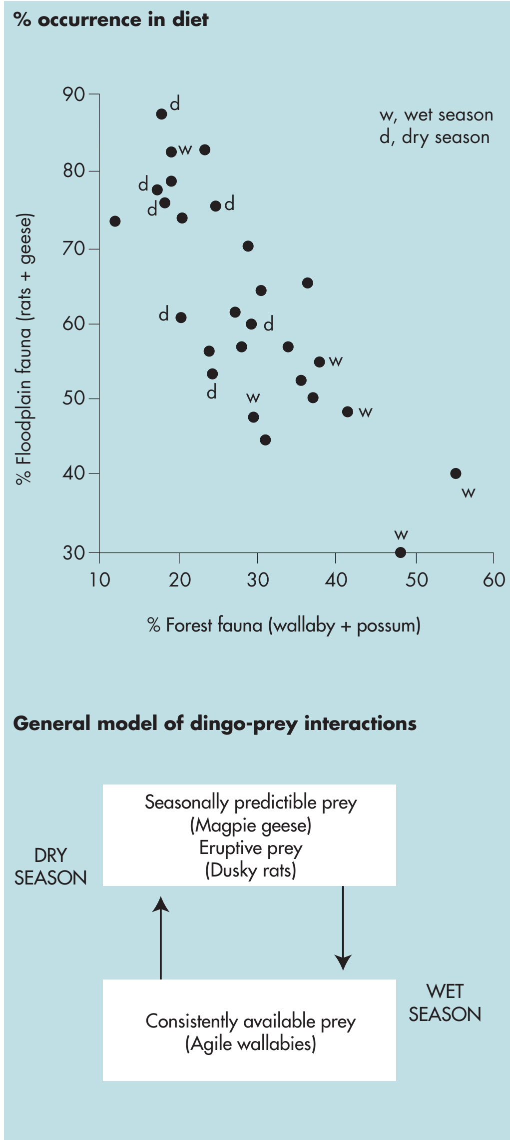


Figure 9: A model of predation by wild dogs in a pristine coastal ecosystem in tropical Australia. Predation by wild dogs alternates between habitats, switching from forest during the wet season to floodplain in the dry after the floodplains dry out. The main prey are dusky rats and magpie geese in the dry and agile wallabies in the wet (after Corbett 1995a).

(*Macropus giganteus*) and small mammals (Newsome et al. 1983a). In this ecosystem wild dog predation sometimes affects prey diversity, abundance and population structure, probably because severe wildfires change habitats and thus alter the composition of the prey base. This encourages wild dogs to either concentrate on a vulnerable, relatively uncommon species, or to prey on an abundant species, thereby relieving the pressure on another species and allowing its population to recover. At Nadgee, wild dogs usually concentrate on macropods immediately after severe fires and sometimes eliminate local populations of eastern grey kangaroos (Newsome et al. 1983a).

'The predatory cycle alternates between consistently available prey and seasonal prey.'

The effects of such intense predation is alleviated when waterbirds are in great abundance, as sometimes occurs when severe storms replenish the coastal lakes with water and food for the birds. When there are no substitute prey available after severe fires, wild dog numbers decline soon after macropods decline (Newsome et al. 1983a).

In the mountains, where waterbirds are less available, there is no clear cycle. In Kosciusko National Park, wild dogs mainly hunt wombats (*Vombatus ursinus)*, wallabies and rabbits, and these prey are supplemented by a variety of other species (Newsome et al. 1983a). Similarly, in the mountains near Armidale in north-east New South Wales, the main prey of wild dogs are macropods, especially swamp wallabies (*Wallabia bicolor*), red-necked wallabies (*Macropus rufogriseus*) and eastern grey kangaroos (Robertshaw and Harden 1985a; 1985b). Wild dogs concentrate on juveniles (pouch young and young at foot) and reduce macropod recruitment rates so considerably that the populations of these species may decline. In some areas, small isolated populations of eastern grey kangaroos and red-neck wallabies have been completely eliminated (Robertshaw and Harden 1986). This happened because enough substitute prey was available to support the wild dog population; otherwise the wild dogs would have moved away or starved.

Another outcome of the wild dogs' concentration on swamp wallabies was a disruption of the usual seasonal pattern of wallaby births (Robertshaw and Harden 1986). Many females ejected their pouch young when pursued by wild dogs, but as most of these offspring were soon replaced (96% of sexually mature females carried a blastocyst), there was a continuous output of young instead of the usual spring–summer peak. Besides this change in breeding pattern, the number of ovulations per female increased as predation pressure of wild dogs increased, and so did male swamp wallabies' testicle and epididymis weights.

3.6.4 Factors affecting wild dog–prey interactions on pastoral lands

Two major environmental disturbance factors in much of Australia have been the introduction of exotic animals, especially rabbits and livestock, and pastoral industry infrastructure, such as artesian bores and dams. In temperate zones, land clearing has also changed the structure of the landscape. This alteration in habitats and introduction of exotic animals has made some native prey species increase and others decrease. Wild dogs have mainly benefited from extra supplies of food and water, which have helped them to survive drought and increase their numbers, but these extra resources have also changed the natural pattern of predation.

'Dingo predation is greatest on small and medium-sized mammals during flush periods and greatest on large mammals in drought.'

The interplay between seasons (drought and flush years), native prey and introduced prey (pests and cattle) and predation by dingoes is well illustrated by a study at Erldunda in central Australia (Corbett and Newsome 1987). When rains broke the longest drought on record (1958–65), rodents irrupted over widespread areas and dingoes concentrated on them for about a year. Then rabbits predominated in the dingo's diet for the next three years. When another drought reduced the rabbit populations, predation on red kangaroos increased, even though they became uncommon. Then, as this drought lengthened, cattle began to die and carrion became more frequent in the diet. This sequential emphasis upon vertebrate prey of increasing body size as aridity increased can be summarised as a general model (Figure10) which indicates that dingo predation is greatest on small and medium-sized mammals during flush periods and greatest on large mammals in drought. This seasonal variability provides a basis to understand the impact of dingo predation on prey, critical periods when dingoes kill cattle, and whether or not predation can regulate or limit prey populations.

3.6.5 Does predation by wild dogs regulate prey populations?

Predation by wild dogs has often been assumed to be a cause of fluctuation or lack of fluctuation in some prey populations, as indicated by the following examples:

- Wild dog predation has been assumed to account for the contrast in density of red kangaroos and emus on the two sides of the Dog Fence between the borders of Queensland, New South Wales and South Australia. Outside the fence, where wild dogs abound, kangaroos and emus are rare; but the opposite applies inside the fence (Caughley et al. 1980; Pople et al. 2000). There is evidence that, in this situation, the predation rate by dingoes on red kangaroos and emus regulates their populations at low densities (Pople et al. 2000).
- Feral goat populations persist only in areas where dingoes are absent or are subjected to high levels of control (Parkes et al. 1996).
- At Petroi, in the mountains of north-eastern New South Wales, the occurrence of swamp wallabies in the diet of wild dogs was proportionally higher than expected from the number of observed wallabies. When wild dog numbers increased, so too did their consumption of wallabies which was soon followed by a marked decline in the wallaby population (Robertshaw and Harden 1986).
- At Nadgee Nature Reserve, post-fire predation by wild dogs on macropods held their numbers in check for 2–3 years, probably because the fire opened up habitats and made these prey more vulnerable (Newsome et al. 1983a).
- In arid central Australia, red kangaroos became more vulnerable to predation during drought, partly because they were clumped around waterholes and remaining feed. At one site on the plains, kangaroo populations declined during a drought when dingo predation became progressively greater, and kangaroos remained low after drought — at about 15% of their pre-drought numbers (Corbett and Newsome 1987).
- In the Harts Ranges, near Alice Springs, Northern Territory, red kangaroos declined from being common to rare after a 7.5-year drought, and populations did not recover in the subsequent 10 years even though pasture was generally better than average. There is evidence that dingoes, whose numbers had remained stable throughout the drought, mediated competition between rabbits, cattle and kangaroos to the detriment of kangaroos (Corbett and Newsome 1987).
- In the Fortescue River region of north-west Western Australia, euro (*Macropus robustus erubescens*) populations were fairly low in an area where dingo populations were allowed to remain high, because they preyed selectively on particular age classes of euros. When dingoes were greatly culled by a baiting program, euro populations immediately and dramatically increased (Thomson 1992c).
- In the Guy Fawkes River region of northern New South Wales there is circumstantial evidence that dingoes limited the abundance of macropods (Fleming 1996b; Fleming and Thompson unpublished data 1993). It is possible that annual removals of wild dogs and foxes by aerial baiting increased the abundance of macropods in baited areas.

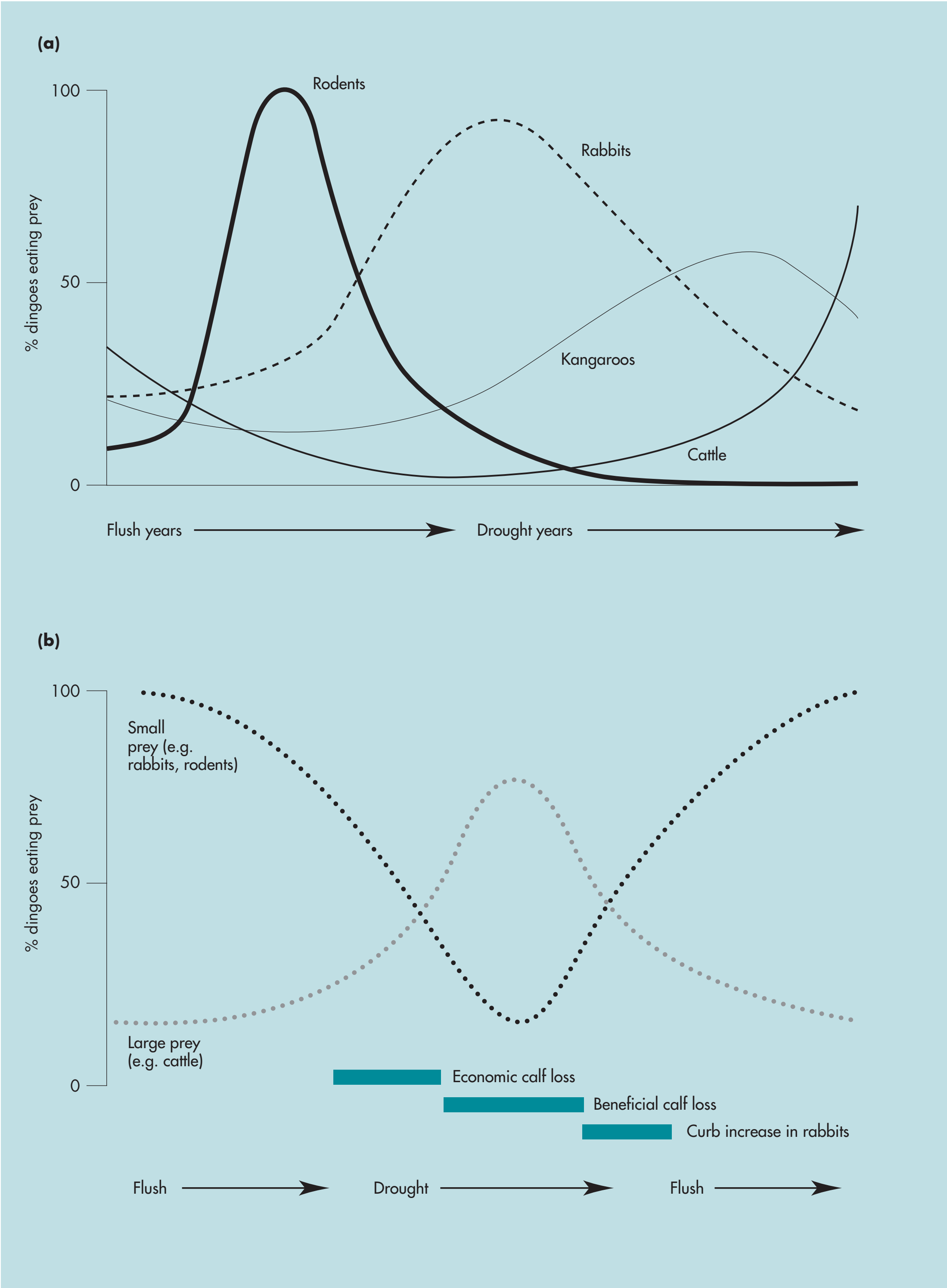


Figure 10: Models of predation by wild dogs in disturbed ecosystems in arid Australia showing: (a) sequential predation on prey of increasing size; and (b) dingo predation on small and large prey. Note, the time scale on the x-axis is longer in graph (b) (after Corbett 1995a).

These examples provide evidence that dingo predation can affect prey populations, especially macropods, but the long-term effect of this predation, and whether or not the effect is regulatory, cannot be assessed without experimental studies (Sinclair 1989). For some of the listed examples, alternative explanations could be feasible for the observed changes in prey abundance.

'Cattle carrion enabled dingoes to survive droughts and subsequently to concentrate on red kangaroos and perhaps regulate their population after a drought.'

In Queensland, analyses of bounties paid annually on wild dogs and feral pigs over 24 years indicated that pig mortalities increased more than threefold with every doubling of wild dog numbers, and this inverse relationship suggested that predation on pigs by wild dogs was a limiting and potentially regulating factor for populations of feral pigs (Woodall 1983). However, reanalysis of Woodall's data indicates that wild dog bounties were negatively related to rainfall over the previous year, suggesting that fewer wild dogs were killed in the 12 months following high rainfall (Choquenot et al. 1996). Correcting for the effects of rainfall removes the apparent relationship between pig mortality rate and wild dog density. Other problems with the analysis of scalp returns are identified in Section 6.2.1.

There has only been one experimental study to assess the impact of dingo predation on feral pig populations. This was at Kapalga in northern Australia and clearly demonstrated that predation alone did not regulate (see Glossary) feral pig populations. Instead, predation by dingoes was one factor acting in concert with interference competition from buffalo (*Bubalus bubalis*) to limit (See Glossary) feral pig numbers (Corbett 1995c). That is, feral pig numbers would have been higher if competition with buffalo and predation by dingoes were absent. Dingoes did not cause higher pig mortality as pig abundance increased.

Evidence from other regions of Australia (Newsome and Coman 1989, Newsome 1990, Pech et al. 1992) indicates that predation alone can significantly curb prey populations only when prey numbers are initially depressed by a widespread environmental event such as drought in arid rangelands or intense wildfire in temperate forests. The theory is that prey are trapped in a 'predator pit' (Walker and Noy-Meir 1982) where there are too few animals successfully breeding for births to exceed off-take by predation. At the same time, the extra food that such circumstances usually provide allows the predators to survive. For example, in arid central Australia, cattle carrion enabled dingoes to survive droughts and subsequently to concentrate on red kangaroos and perhaps regulate their population after a drought. However, in tropical regions of Australia, with the absence of prolonged droughts or other circumstances to simultaneously reduce populations of main prey, it is unlikely that dingoes could ever limit feral pig populations to low levels.

3.7 Interactions between humans and wild dogs

There are few records of dingoes attacking or killing Aboriginal people, either in camps or in the wild but such incidents are not likely to be reported. There are more reports of dingo attacks on non-Aboriginal people but most are anecdotal (Savant 1969). During the Royal Commission into the Disappearance of Azaria Chamberlain, evidence was presented on the deaths of five children caused by dingo attacks and several other dingo attacks on children and adults throughout Australia over the past 50 years or so (Morling 1987).

'Aggressive behaviour is apparently most common during the dingo's breeding season.'

In recent years, dingoes have become a major tourist attraction at sites in outback Australia and Fraser Island in particular. Consequently, many visitors and residents have deliberately or inadvertently fed dingoes to encourage contact for close viewing and photographs. This has led to many dingoes and other wild dogs losing their fear of people and occasionally displaying aggression towards people, especially at commonly used areas such as camping grounds and picnic areas. Aggressive behaviour is apparently most common during the dingo's breeding season. This provision of food for wild dogs by people and the resulting change in wild dog behaviour has been documented on Fraser Island by Marsterson (1994); Moussalli (1994); Price (1994) and Twyford (1994a,1994b). Current management of this problem is addressed in Section 5.3.2.

Wild dog territories that are centred on areas of high human activity, such as townships, town refuge dumps, camping grounds, picnic areas and resorts, appear to be smaller in size but have relatively higher numbers of wild dogs per pack compared to wild dogs that rely on natural prey in bush areas (Corbett 1998). The nature, frequency and intensity of interactions with people are likely to vary depending on the age and sex of wild dogs, pack size and composition, time of year, supplementary natural food supplies and human reactions to wild dogs. Types of wild dog–human interactions include wild dogs stealing and soliciting food, wild dogs stalking and harassing (nipping, 'playful' biting) humans and outright attacks.

Similar human–predator interactions (involving coyotes (*Canis latrans*) or bears (*Ursus* spp.)) have been recorded in North America (Howell 1982; Carbyn 1989). There appear to be many parallels in the case of the coyote (the ecological equivalent of the dingo in North America) where many attacks are directed towards young human females, with a baby being killed in one instance (Carbyn 1989).

Interactions between humans and wild dogs may occur for other reasons. These include:

- Wild dogs regarding humans as competitors or intruders into wild dog domains and thus defending oestrous females, pups and 'hunting' areas (garbage sites, camp sites, barbecue areas, beaches).
- Wild dogs (mainly adults) regarding humans (mainly children) as prey.
- Juvenile and subadult wild dogs 'playing' with humans.

In relation to the latter example, it is likely that in places such as Fraser Island and Uluṟu, many generations of dingoes have been reared in the close presence of humans (imprinting) so many young dingoes engage in what appears to be 'playful' behaviour. These are normally directed towards other dingoes. In reality, the dingoes are practising behaviours that will be vital for their survival in later life such as nipping and biting to assess the vulnerability of prey (to avoid serious injury to themselves) or to achieve dominance amongst litter mates. Humans, especially children, naturally do not understand this and are most likely to turn and flee (often shrieking) which generally will stimulate chasing and further aggression from dingoes.

4. Community attitudes affecting management

Summary

The management of dingoes and other wild dogs is affected by community attitudes and perceptions. Opinions vary as to the pest status of dingoes and other wild dogs. Some primary producers view them simply as an unwanted pest to be removed from the environment while other sections of society view them as wildlife or icons to be conserved as far as possible. Public opinion influences not only the type of management strategies that are developed but also the type of control methods that may be deployed. Wider public attitudes rightly demand that the techniques used for wild dog control must be as humane as possible and expose non-target animals to minimal hazard. Management strategies that do not address or acknowledge broad community attitudes are susceptible to disruption or interference.

4.1 Community perceptions and attitudes

Community attitudes towards dingoes and other wild dogs are diverse and greatly affect management decisions. Dingoes and other wild dogs were condemned from the earliest time of European settlement in Australia as vicious killers of livestock and a threat to the domestic animals raised by struggling settlers. The dingo is also regarded by some people as a desirable species for recreational hunting (Allison and Coombes 1969) and was hunted by early setters as a substitute for foxes (*Vulpes vulpes*) (Rolls 1984). The term 'dingo' came into usage as an insult when applied to a person. Later, the high profile of the dingo saw it being used as an advertising image (for example, Dingo Flour and Dingo Bitter beer).

With the increased urbanisation of Australia and a growing awareness of environmental issues, other attitudes towards dingoes have emerged. A recent demographically representative survey of 2000 Victorians of voting age showed that 79% of respondents classified wild dogs as pests regardless of the respondents' background (Johnston and Marks 1997). The survey did not ask respondents to classify 'dingoes' as pests or otherwise. Given that the majority of respondents regarded other native species (including possums (Phalangeroidea), kangaroos (*Macropus* spp.) and wombats (*Vombatus ursinus*)) as 'non-pests', the responses may have been different if dingoes had been separately identified.

'Nor is there a common view about dingoes and other wild dogs amongst livestock producers.'

The dingo is viewed by many as an animal which has an important place in Australian ecosystems, and one which should be preserved as far as possible (Section 5.3.3). Such attitudes have been enshrined in legislation in some States and Territories (Sections 3.3 and 5.2). Strength of opinion can be influenced by the perception of purity of strain; conservationists wish to preserve pure dingoes but see hybrids and feral dogs as a threat to the dingo (Section 2.9). Others believe that because a dingo-sized canid has been present in Australia long enough to have affected the biodiversity of the communities in which they occur, the removal of wild dogs from these environments might have unforeseen impacts on biodiversity, and that some wild dogs should therefore be retained irrespective of their genetic status.

Nor is there a common view about dingoes and other wild dogs amongst livestock producers. Sheep graziers would be unanimous in condemning the presence of a single wild dog near their flocks, whereas cattle producers tend to have a variety of opinions. Some cattlemen are ambivalent towards dogs. Others reflect previous or current bad experiences of calf predation by wild dogs and regularly control them; for example, 71% of Northern Territory pastoralists surveyed in 1995 indicated that dingoes were a major or serious pest on their properties (Eldridge and

Bryan 1995). Another group recognise the potential role of dingoes in controlling macropod abundance and are prepared to experience some losses of calves in the belief that overall enterprise productivity is better when there is less potential competition for forage between cattle and macropods (Section 3.6.5). Still others tolerate dingoes and other wild dogs until predation of calves becomes apparent and then institute a control program (K. Watters, grazier, New South Wales, pers. comm. 1984; D. Wurst, Parks and Wildlife Commission (Northern Territory), Northern Territory, unpublished data, 1995). Some are strongly opposed to baiting because of the perceived risk to their own dogs. There is also the perception among some landholders living near national parks and other conservation reserves that wild dogs belong to the government and therefore responsibility for wild dog control on adjacent grazing lands lies with State agencies (J. Burley, Department of Natural Resources and Environment, Victoria, pers. comm. 1999). As with other groups, trappers hold different views on the relative merits of different control methods and the role of wild dogs in animal communities (Ward 1986). The views of trappers must be considered because these people are often responsible for much of the control effort spent on wild dogs.

In 1981, evidence from a series of public meetings and submissions from landholders within the original barrier fence in Queensland (Holden 1991) showed that attitudes toward wild dogs were explained in part by the location of their holding in relation to the fence. Similar trends are evident in other States. Those individuals who have first-hand and ongoing experience with livestock predation by wild dogs generally express the strongest sentiments. These people often rate wild dogs as their biggest productivity inhibition. Those landholders that are far removed from any threat of predation tend to be less concerned about wild dogs and may be more subject to influences from non-agricultural sectors of the community. Fear of predation by wild dogs has meant that in some areas greater control effort has been spent on wild dogs than other pests that may be more damaging in a less obvious way.

Traditional Aboriginal groups generally perceive dingoes and other wild dogs as a component of the natural landscape with a rightful place therein. Dingoes often feature in Aboriginal mythology and are therefore seen as part of the cultural heritage of Australia. These interests must be kept in mind when devising management programs for dingoes. In general, conflicts with the views of Aboriginal people rarely occur because of the alienation of traditional Aboriginal people from most of the grazing areas where control work is undertaken. However, where Aboriginal people maintain an ongoing affinity to these areas their concerns must be considered and included in the planning process.

'In some areas greater control effort has been spent on wild dogs than other pests that may be more damaging in a less obvious way.'

Public perception of wild dogs as objects of fear will also influence attitudes towards local management. Without doubt, the most publicised case of dingoes as predators of humans involved the alleged taking of a baby, Azaria Chamberlain, by a dingo at Uluṟu in central Australia in 1980. Reaction to the allegation led to an immediate control program around the camping area where the Chamberlains were staying. Local control and education programs have been instigated in other national parks and nature reserves in response to attacks on people (for example, Fraser Island; Australian Associated Press 1998).

As a result of these various views in society, as well as the results of scientific research, the approach to wild dog control has altered considerably in the past 20–30 years (Chapter 5). Management strategies now focus on problem areas, that is, in livestock paddocks and on neighbouring land. For example, dogging or baiting forays are no longer made into the vast areas beyond pastoral leases in Western Australia. Indeed, such control work would be condemned as being economically and environmentally undesirable.

Nevertheless, scientific research and analysis does not always alter management practices. For example, the usefulness of bounties has been discredited in a number of reviews (Section 5.1.1) yet the recent proposed removal of bounties from Queensland legislation resulted in heated debate (C. McGaw, Department of Natural Resources, Queensland, pers. comm. 1999). A compromise allowing the payment of bounties by local governments resulted from pressure by some community groups.

Attitudes about controlling wild dogs are influenced by the control methods used. For example, pressure from animal welfare groups has resulted in changes to legislation and policy for the use of leghold traps in Victoria, the Australian Capital Territory and New South Wales. Some sections of the community do not accept the use of poisons, and would oppose any control campaigns based on baiting (Section 4.2.4). Indeed, some people regard the killing of an animal, even if it is considered to be a pest, as wrong.

4.2 Animal welfare issues

4.2.1 General

Animal welfare groups aim to ensure that all animals are treated humanely and that actions that cause stress and suffering should be minimised as far as is feasible. Groups such as the Royal Society for the Protection of Cruelty to Animals (RSPCA) and the Australian and New Zealand Federation of Animal Societies (ANZFAS) accept that control of wild dogs may be required in certain circumstances, but advocate restrictions on the type of control techniques that are used. For example, the RSPCA believes that the use of 1080 (sodium fluoroacetate) poison on native species is unacceptable, and that its use against introduced species should be strictly controlled by legislation. Non-lethal means such as exclusion fencing are encouraged.

Conversely, owners of livestock have legal and moral obligations under the various State Prevention of Cruelty to Animals Acts to provide the best husbandry possible for their livestock and there are model codes of practice to ensure this (Animal Health Committee, of the Standing Committee for Agriculture 1990). Predation by dogs is not humane and most graziers are concerned by the suffering and distress imposed on their animals. This is particularly so when surplus killing and injury occurs. The adverse effects of predation on the welfare of livestock is likely to influence landholders' attitudes to management of wild dogs, including the control and conservation of dingoes. Counter to this is the argument that sheep should not be grazed in areas where predation by wild dogs is likely and poses the question whether governments should subsidise wild dog control in such areas.

'Counter to this is the argument that sheep should not be grazed in areas where predation by wild dogs is likely.'

Clearly, welfare concerns must be considered in all control programs involving lethal techniques. These should be as target-specific as possible and take into account maximum welfare for the target species as well as welfare issues relating to the accidental capture or killing of other species.

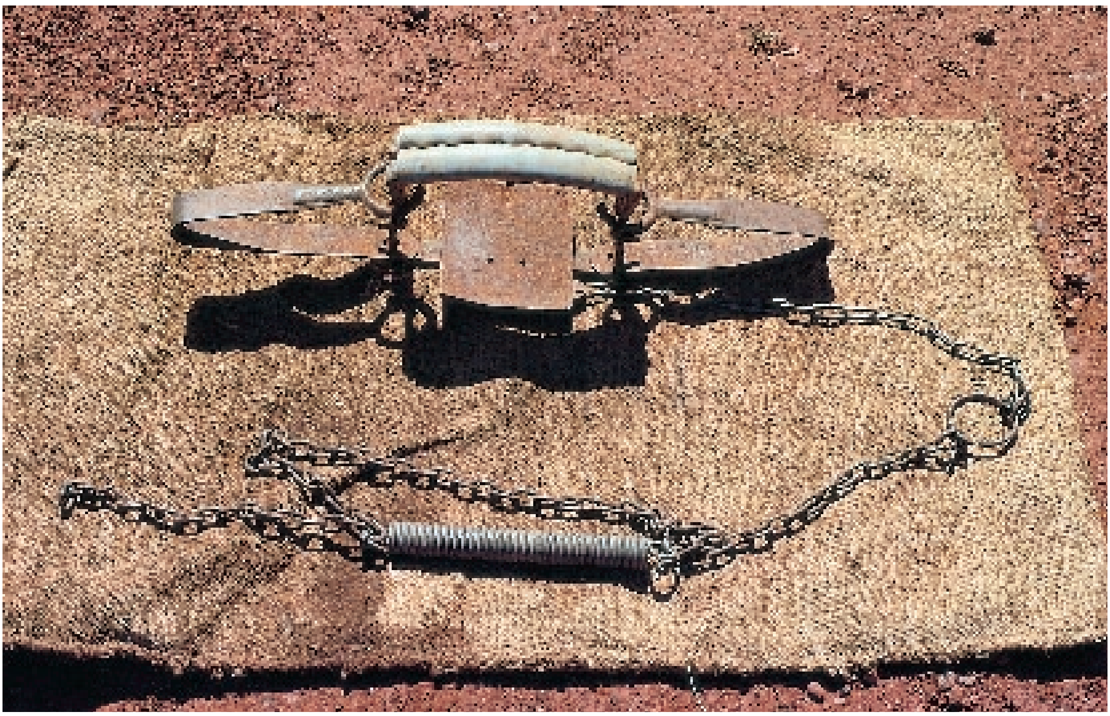
4.2.2 Shooting

Shooting by skilled marksmen is probably the most humane method of controlling wild dogs and for this reason is the favoured control technique of the RSPCA. The objective should be to kill the animal as quickly and cleanly as possible with a shot to the head. In some States and Territories, a Code of Practice or government agency policy specifies the minimum specifications (calibres, projectile weight, range) for the shooting of feral or pest animals (Section 6.4.2). Shooting can usually only be viewed as an opportunistic method of wild dog control, although it can sometimes be useful to target individual animals inside sheep zones. It is not a cost-effective option for reducing populations of wild dogs.

4.2.3 Trapping

Steel-jawed leg-hold traps have been traditionally used in Australia for wild dog control. These traps are generally viewed as inhumane, with the bare steel jaws causing tissue damage, serious cuts, broken bones, dislocated joints and sometimes amputation of feet of the captured animal (Fleming et al. 1998). The degree of injury and suffering of a trapped animal is also related to the length of time that the animal spends in the trap (that is, how often traps are checked) and whether analgesic drugs (C. Marks, Victorian Institute of Animal Sciences, Victoria, pers. comm. 1998) or poisons have been applied to the trap to reduce stress or hasten death (Fleming et al. 1998). As well, the sites where traps are set can greatly affect the likelihood of catching non-target animals (Newsome et al. 1983b). Different groups of non-target animals suffer different levels of injury (Fleming et al. 1998). For example, possums mostly had minor injuries in Soft Catch, traps whereas 73% of varanids experienced major trauma.

There is an increasing awareness of the inhumaneness of steel-jawed traps. Modifications to existing and new traps and capture devices that are more humane continue to be developed and are progressively being adopted. The Victorian treadle-snare and the Victor Soft Catch, padded trap and modified Lanes traps have been shown to result in fewer injuries to trapped animals (Meek et al. 1995; Fleming et al. 1998) and their use is preferred over steel-jawed traps by animal welfare groups. In Victoria, the treadle snare has replaced the steel-jawed trap for use in wild dog control, except in special circumstances. In New South Wales, steel-jawed traps are outlawed, though the use of padded traps and treadle snares is allowed. These must be used in accordance with a code of practice that specifies, amongst other things, that traps should be checked daily. In South Australia, steel-jawed traps are outlawed in the 60% of the State outside the Dog Fence. Trapping is still the preferred technique to target dingoes killing sheep inside the fence and where poisoning has proved unsuccessful.



Padding steel-jawed traps should be promoted to improve the humaneness of trapping (Source: P. Thomson).

'There is an increasing awareness of the inhumaneness of steel-jawed traps.'

In some areas, the practice of applying strychnine poison to the jaws of traps is advocated. The strychnine is bound into a cloth and the trapped animal bites on the soft material and ingests the poison. This results in a rapid death, and is seen by some to be preferable to the animal remaining in the trap until dying of exhaustion or exposure, or being discovered many hours later by the trapper. However, strychnine is classed as an inhumane poison (Section 6.4.4) and its use for other purposes is not sanctioned. Strychnine cloths are generally favoured in the more remote pastoral regions, where trappers cover large areas and cannot return to their traps within a reasonable time. Additionally, many doggers believe that traps set for rogue animals should not be visited too often as the presence of human scent near the trap may deter the target animal (B. Morris, dogger, Yass Rural Lands Protection Board (New South Wales), pers. comm. 1998). Daily checking of traps is simply not a practical option in all circumstances. In Western Australia and South Australia, steel-jawed traps can be used for wild dog control only if strychnine is applied to the traps. In New South Wales, strychnine cloths must be applied to traps that are not checked daily. A fast-acting, more-humane replacement poison for strychnine on trap jaws would be preferable and requires investigation. (Section 8.7). The use of 1080 poison on traps is not practical because it is too slow acting.

4.2.4 Poisoning

The RSPCA is generally opposed to the use of poisons (RSPCA 1997) but may accept target-specific baits containing humane toxins. It is widely recognised that poison baiting remains one of the few viable options available to control wild dogs, particularly in the more remote rangeland areas (Section 6.4.4).

Strychnine baits are viewed as inhumane because the affected animals remain conscious and appear to suffer pain and anxiety from the onset of clinical signs through to death from asphyxia and exhaustion. The clinical signs of strychnine poisoning in dogs are: deep reflexes and cramping of muscles, particularly in the legs; muscular spasms that increase in severity and extent through to death from respiratory failure; and vomiting and diarrhoea.

1080 is now the preferred poison for use in wild dog control throughout Australia. It is a far more selective poison than strychnine and poses minimal risk to non-target animals. Canids are particularly susceptible to 1080. Many other mammals are less sensitive to the poison, particularly many native species in Western Australia that have evolved an enhanced tolerance due to exposure to plants containing 1080 (King 1984). Birds and reptiles are in turn less susceptible to 1080 than mammals.

'Research is underway to develop an orally-active analgesic for incorporation into baits to counter debate about the humaneness of 1080.'

1080 causes the blocking of the Krebs cycle, the major cellular biochemical mechanism for releasing energy from food. In dogs, the primary action of 1080 is on the central nervous system. Symptoms appear after a latent period of up to several hours, the period varying according to the amount of poison ingested. Dogs become excited, may become nauseated, frequently howl, and exhibit running fits (McIlroy, 1981). The final phase of poisoning involves continuous muscular contraction and death through lack of oxygen supply to the respiratory centre. During convulsions, affected dogs are unconscious and appear to be unaware of their surroundings, suggesting that they are not suffering pain or distress (Gregory 1991). Cases of sub-lethal human poisoning support the view that 1080 is a relatively humane poison; victims convulsed but later reported no recollection of pain or physical distress (Gregory 1991). In Victoria, research is underway to develop an orally-active analgesic for incorporation into fox baits to counter debate about the humaneness of

1080 and to reduce regurgitation and multiple bait take by foxes (C. Marks, Victorian Institute of Animal Sciences, Victoria, pers. comm. 1997). Success in this work would also have application to wild dog baiting.

4.2.5 Control at breeding dens

In the past, doggers searched for dens each breeding season, in order to fumigate or capture the pups, bitch, and any other associated adults. This activity was aided by the use of sniffer dogs to seek out the dens. As for other control techniques, the associated welfare issues need to be considered. The practice of blocking off the den entrances if the pups cannot be retrieved is clearly unacceptable from a welfare aspect.

4.2.6 Exclusion fencing

The use of exclusion fencing is generally regarded as causing fewer animal welfare impacts than lethal control means. However, fences alter the movements of larger ground-based animals and care must be taken with design and placement of fences so as not to adversely affect their survival. Electric dingo fences can trap and kill macropods, emus (*Dromaius novaehollandiae*) and echidnas (*Tachyglossus aculeatus*).

4.2.7 Biological control

Wild dogs are susceptible to many diseases (Section 2.7). It is unlikely that the release of diseases already present in the wild would be effective for biological control. Given the fact that lethal diseases generally cause suffering and emaciation, and also affect domestic dogs, this type of control is unlikely to be supported by welfare groups or the general public.

Other forms of biological control may be possible in the future. The RSPCA supports the concept of hormonal control to limit reproduction (RSPCA 1997). The RSPCA and ANZFAS strongly support the development of fertility control measures, such as immunocontraception (Tyndale-Biscoe 1994), as humane techniques for controlling pest animals. Immunocontraception research is still in its early stages and the technique has not yet been used for the control of any pest species. Domestic dogs and desirable populations of dingoes would be susceptible to any form of biological control targeting problem wild dogs. Transmissible forms of fertility control such as immunocontraception are therefore unlikely to gain favour with the general community.

4.3 Public health issues

4.3.1 Diseases and parasites

There have been a number of publicity campaigns aimed at reducing the prevalence of hydatidosis (causal agent *Echinococcus granulosus*) in humans (D. Jenkins, Australian Hydatids Control and Epidemiology Program, pers. comm. 1998). Although occurrence is rare, the disease can be fatal. In areas where hydatid infection of domestic dogs and livestock is endemic, awareness of the disease is highest. However, few people are aware of the sylvatic hydatids cycles between wild dogs and wildlife or between wild dogs and livestock (Section 3.4). Local awareness is likely to increase participation in programs to control wild dogs and increase the pressure on government instrumentalities to control wild dogs at the interface of public and grazing lands.

If rabies (Rhabdoviridae) ever became established in Australia, there would be a much greater public impetus to control all free-roaming dogs. Trade-offs between the desire to conserve dingoes and concerns about human health would require much discussion, as the range of stakeholders involved would increase substantially.

4.3.2 Interactions with humans

Aboriginal people sometimes used dingoes for hunting, as food, decoration (fur), mobile blankets or currency (scalps) (Meggitt 1965; Hamilton 1972) but preferred European domestic dogs when they became available. These dogs remained in the camps and thus obviated the need to seek new dingo pups each year or to retain adult animals by breaking one of their legs. Domestic breeds also barked and thus were better sentinels (Hamilton 1972; White 1972).

Free-roaming dogs are still common in remote Aboriginal settlements and the presence of these dogs has human health implications for the communities (Section 3.4). Human health programs that involve controlling wild dogs in and around Aboriginal communities need to address the potential conflicts that arise from traditional Aboriginal views of dingoes and other wild dogs (Sections 3.3 and 3.7).

4.4 Conservation issues

Community attitudes to dingoes have changed considerably since the early days of European settlement when they were seen only as a threat to the fledgling pastoral industries. Research in the last 30 years has greatly increased the understanding of dingoes and led to more rational and effective management techniques that significantly reduce the risk that dingoes pose to the pastoral industries. Concurrently, there has been an increase in public awareness of the importance of conserving biodiversity. Dingoes are now commonly perceived as native fauna and are formally recognised as such in some States (for example, New South Wales). Consequently, there is now a public expectation that dingoes will be conserved as part of Australian biodiversity.

'There is now a public expectation that dingoes will be conserved as part of Australian biodiversity.'

During the past 30 years, there has been considerable conflict between conservationists and managers of wild dogs. Three issues have been central to this conflict. The first is that the public perception of dingoes as a native species creates an expectation that they will be conserved. Thus, some sections of the public are opposed to all wild dog control, particularly when it is conducted in conservation reserves.

Resolution of this conflict has been achieved in some States and Territories by attributing a different status to wild dogs dependent on their location. For example, in New South Wales, the National Parks and Wildlife Service effectively recognises dingoes as native fauna, and while they are 'unprotected' in conservation reserves, they are not a declared noxious species until they move off the reserve (Chapter 5). Control within conservation reserves is only permitted when dingoes emanating from there are implicated in stock losses and measures conducted outside the reserve have failed to solve the problem.

'Resolution of this conflict has been achieved in some States and Territories by attributing a different status to wild dogs dependent on their location.'

The second issue arising from this is the dilemma of how to differentiate dingoes from other wild dogs. This is compounded by the exhibition of dingo coloration in many hybrids. While DNA fingerprinting might determine the frequency of dingo and domestic breed genes, this technique does not address public perceptions. The genetics of a wild dog is largely irrelevant to many people. These people are more concerned with the appearance of a particular wild dog and compare it with their concept of a dingo. For conservation directions to be set, public and expert inputs must be collected. A decision is needed on what proportion of a wild dog population is required to be pure dingo before conservation efforts are instituted. The feasibility of conservation strategies on the mainland also needs investigation. After these decisions are made, conservation policy can be formulated.

The third issue is the risk to non-target species during wild dog control programs and particularly during aerial baiting programs with 1080. Many concerns about non-target risks have been allayed by the seminal works on the toxicity of 1080 to Australian fauna by John McIlroy and Dennis King and their collaborators (McIlroy 1981). In some States, reductions in loadings of 1080 in baits, better bait placement and a reduction in the number of baits used have resulted in a theoretically negligible risk to non-target species (Fleming 1996a). However, because of public misconceptions or lack of education about 1080, there remains some concern about non-target risk during wild dog baiting (Section 8.11). This issue needs to be addressed by a public education program and by field-based studies to assess non-target risk and confirm that wild dog baiting is target-specific and effective.

The commonly held but unproven belief of a universal, inverse relationship between wild dog and fox abundance (Section 2.10.1) has been popularly interpreted to mean that conserving dingo populations may limit the distribution and abundance of foxes and thus reduce their impact on small and medium-sized native animals. If this proves true, conserving dingoes and other wild dogs could enhance the conservation of native species threatened by foxes.

5. Past and current management

Summary

In the past, legislation for the management of wild dogs has included punitive Acts and Acts dealing with the conservation of wildlife. Dingoes have been included with other dogs in early colonial legislation designed to remove troublesome dogs and to reduce the threat of predation of livestock. Management of wild dogs relied heavily on labour-intensive techniques of trapping, shooting and ground baiting, with bounty payments being offered as an incentive to kill dogs. With cheap labour and materials, and a profitable grazing industry, the erection of exclusion fencing was also feasible in some parts of Australia, and became an essential element of wild dog control in those areas. Much of the control work was reactive, dealing with problems as they arose. Nevertheless, some strategic, preventative control was carried out, and in extreme but misguided cases, efforts were made to control wild dogs hundreds of kilometres from the nearest sheep grazing enterprises.

The dingo is extinct in much of the sheep and cereal production zones of eastern and southern Australia because of habitat modification and the success of early poisoning campaigns. The areas largely without wild dogs are mostly separated from areas where they are present by dog-proof fences that were erected around the turn of the century.

In most States and Territories, obligations or provisions are made for the destruction of wild dogs in sheep and cattle grazing zones. The Dog Fence, which runs for about 5600 kilometres from Fowlers Bay in South Australia to south of Dalby in south-eastern Queensland, is maintained or subsidised by government agencies. Poisoning programs form the basis of most lethal control efforts, although trapping and shooting are important in some contexts. Groups and boards have provided finances that allow for better management.

The scientific information on the biology and movements of dingoes and other wild dogs did not begin to accrue until the late 1960s. Since then, research has served to correct or refute much of the folklore and mythology surrounding dingoes and enabled management programs to be more soundly based. In addition, research has allowed for the objective evaluation of control techniques and strategies. For example, the demonstration of the effectiveness of aerial baiting with 1080 in pastoral regions of Western Australia led to this technique being adopted far more widely than previously. A further influence on wild dog management has been a growing public interest in conservation and animal welfare; control programs had to be not only effective but to show due regard to welfare and risks to non-target species.

Current management strategies focus on the objective of minimising the impact of predation on livestock, not on killing wild dogs. Aerial baiting with 1080 baits forms a major part of most management programs and is primarily targeted at limited zones and buffers adjacent to livestock grazing areas. Larger coordinated campaigns have generally been adopted, being more efficient and effective than localised, ad hoc efforts. Ground-based baiting and trapping are still carried out, although to a lesser extent than earlier times. Far fewer professional doggers are now employed, although they still play an important role in targeting specific animals and in monitoring buffer areas. Bounty payments have not been successful in reducing predation by wild dogs and are subject to abuse. The use of government-subsidised bounties should cease.

The greatest threat to the survival of dingoes is hybridisation with domestic dogs. In the more settled coastal areas of Australia, and increasingly in outback Australia, the barriers between domestic dogs (feral and owned) and dingoes are rapidly being removed. Hence hybridisation is becoming more common and the pure dingo gene pool is being swamped. Already in the south-eastern highlands, more than half of wild dogs are hybrids. The extinction of pure dingoes on the mainland is probably inevitable

unless there are changes to community attitudes and government policies on wild dogs. In particular the keeping of 'dingoes', which are often hybrids that later 'go bush', can increase the rate of hybridisation of wild dingo populations.

Conservation of dingoes was indirect until the 1970s and 1980s when dingoes were listed on conservation schedules in some States and Territories. Policy and legislation to encourage the conservation of pure dingoes is required in some States and a concerted nation-wide effort is needed to ensure that dingo conservation is not thwarted by conflicting legislation. Simultaneously, the control of wild dogs, including dingoes, must be permitted where there is a recent history of livestock predation.

The main hope of conservation is to educate people about the plight of dingoes and to manage pure dingoes on large islands such as Fraser Island and Melville Island.

5.1 Past legal status and management

5.1.1 Control measures and legislation

During the 1800s, the combination of clearing for farming, exclusion fencing, poisoning and trapping resulted in the dingo becoming extinct over much of its previous range in southern Queensland, New South Wales, Victoria and South Australia. By 1889, all mainland States and Territories had enacted legislation to facilitate and administer the control of wild dogs. Control was organised by government agencies or regional semi-government organisations, run by boards of local landholders, and funded by government and by rates levied on landholders. There were four elements to wild dog control.

The bounty system

Bounties were paid on presentation of a wild dog scalp to the appropriate authority. The first record of a bounty system is from 1836 in the Melbourne district (Breckwoldt 1988). A bounty system was soon introduced in all mainland States and Territories and persisted until recently. The aim was to create an incentive for the control of wild dogs. This encouraged the perception that every wild dog was a sheep killer regardless of its access to sheep, the hunting and trapping of wild dogs by individuals rather than groups, and fraudulent claims (Tomlinson 1958a).

'Despite the millions of dollars paid in bounties, there is little evidence that the bounty system is or was an effective tool for managing wild dogs.'

The control value of bounties has long been debated. In 1930, the Royal Commission into the Dingo and Stock Route Administration in Queensland concluded that bounties should not be paid as they were subject to fraud (Holden 1991). Tomlinson (1958a) outlined arguments for and against the system, concluding that the evidence was overwhelmingly against bounties. A resolution recommending that all bounties in Australia be stopped was passed by the Vertebrate Pests Committee in 1975 (Smith, 1990). Bounties were accordingly reduced to $2 (around $10 in current values) in South Australia in 1975 and were phased out in 1990. Another inquiry, held in Queensland in 1975, recommended that the bounty system be abolished there (Smith 1990). Saunders et al. (1985) proposed significant changes to wild dog management in New South Wales including the abolition of bounties. Because of that review, bounties are no longer paid for wild dog scalps in the Eastern Division of New South Wales. A wide-ranging review of bounty payments by Smith (1990) concluded that all bounty systems were subject to fraud, were ineffective in creating incentive, not cost-effective and were not related to wild dog abundance. More recently, Hassall and Associates (1998) concluded that, worldwide, most bounty schemes have failed to deliver effective vertebrate pest control. In response to the recommendations of Smith (1990), new legislation in Queensland will remove the provision for bounties although local governments can still pay them. (C. McGaw, Department of Natural Resources, Queensland, pers. comm, 1999).

Despite the millions of dollars paid in bounties, there is little evidence that the bounty system is or was an effective tool for managing wild dogs. In north-eastern New South Wales, Harden and Robertshaw (1987) found that between 1958 and 1983, two-thirds of bounties were paid to graziers, the group at risk from wild dog predation. The incentive of the bounty was questionable because of there was no relationship between the value of a bounty and the number of bounties claimed.

Professional doggers

The employment of professional doggers by government agencies, wild dog control organisations, and sometimes by groups of landholders, was an important part of the implementation of wild dog control. Doggers were responsible for both strategic and reactive control of wild dogs by trapping, shooting and poisoning. They were sometimes offered substantial additional bounties by landholders to kill particularly troublesome dogs.

'As fencing materials became more sophisticated and more readily available, the use of exclusion fences became feasible.'

In some areas (for example, south-east New South Wales, Victoria, the Australian Capital Territory and some parts of Western Australia) doggers are still an integral part of ongoing wild dog control. In much of rangeland Australia, however, increasing labour costs and the introduction of mandatory wages for Aboriginal workers in the 1960s, plus the declining profitability of the pastoral industry, resulted in most stations ceasing to employ specialist doggers. For these reasons, and because of the greater adoption of large-scale aerial baiting, the number of government-funded doggers has also fallen dramatically.

Shepherding and exclusion fencing

Before the extensive fencing of pastoral runs to manage the movements of sheep, the first method used to reduce predation by wild dogs was shepherding of flocks by paid shepherds. Shepherds were often sent into isolated areas where they had to protect their stock from human and wild dog predation. Clearing and fencing of pastoral lands and extensive strychnine baiting programs pushed wild dog populations towards the fringes of the 'improved' country as graziers radiated from the central settlements. Shepherding to prevent predation by wild dogs is now only practised as a last resort (C. Young, grazier, New South Wales, pers. comm. 1984) because of the expense and time constraints.

As fencing materials became more sophisticated and more readily available, the use of exclusion fences as barriers to wild dog movements into sheep country became feasible. Exclusion fencing for wild dogs began at least 100 years ago with the erection of 13-wire, 1.8 metre high fences laced with vertical wires at about 15 cm intervals (Harden, unpublished data 1991), and became widespread after the introduction of wire netting. Often a continuous fence resulting from adjoining landholders fencing around their own properties, protected groups of properties. As examples: in Western Australia fences were erected around holdings to keep emus (*Dromaius novaehollandiae*) out and were maintained dog-proof (Holden 1991); and at least 1000 kilometres of non-continuous barrier fencing was erected by landholders on the New England tablelands in New South Wales in the 1920s and 1930s (NERDA undated c. 1966). Similarly, in South Australia, about 3800 kilometres of private dog fences were erected by 1908. Between 1896 and 1908, an additional 5000 kilometres of fencing was erected to maintain the State Vermin Fenced Districts of South Australia (Holden 1991).

Governments and control organisations wholly funded or subsidised the erection of other barrier fencing. The best known such fence (known as the Dog Fence or barrier fence) extends 5614 kilometres from near Dalby in south-eastern Queensland to Fowlers Bay on the Great Australian Bight in South Australia (Figure 2). Prior to shortening of the Queensland section of this fence in 1989, it was 8614 kilometres long (Breckwoldt 1988).

The Queensland–New South Wales fence (359 kilometres) was originally built as a rabbit-exclusion fence. This failed and it was converted to a dog-proof fence in 1914. However, the agreement between the States requires that the fence be maintained rabbit-proof. The fence between South Australia and New South Wales was converted from a rabbit-proof fence to a dog-proof fence in 1917. The New South Wales *Wild Dog Destruction Act 1921* placed the responsibility for the exclusion fence under the Western Lands Commission and an amendment to the Act in 1957 established the Wild Dog Destruction Board (WDDB) which retains responsibility for the fence and the payment of bounties for scalps. The South Australian dog fence replaced a series of separately fenced vermin district fences in 1947 following introduction of the *Dog Fence Act 1946*. Responsibility for the fence is with the Dog Fence Board, membership of which is mostly landholders.

Poisoning

From the early 1800s, when strychnine was found to be useful for poisoning wild dogs, control programs were instigated at the property level or cooperatively. Cooperation between landholders was necessary because strychnine was expensive and could only be imported in quantities too large for individual landholders. Stockmen carried strychnine that they inserted into carcasses they found, and in some areas bait stations were established and maintained. In 1946, a manufactured brisket fat and strychnine bait wrapped in paper (the 'Minty' bait) was developed in Queensland and was subsequently used in Queensland, New South Wales, Western Australia and the Northern Territory.

Aerial baiting began with experimental drops of the Minty bait in Western Australia and Queensland in 1946 (Tomlinson 1954), and continued for a number of years there, in the Northern Territory and in South Australia. It was also used on the coast and tablelands of New South Wales from 1957.

Since the mid-1960s, 1080 (sodium fluoroacetate) has largely replaced strychnine in baits. However, strychnine can still be used in baits in South Australia, Queensland and parts of Western Australia. Because 1080 is closely regulated, baiting programs are under much tighter control than previously. Both fresh meat and manufactured baits are used.

'Aerial baiting was generally regarded as successful and many dog fences were allowed to fall into disrepair.'

1080 meat baits were first aerially distributed in the Northern Tablelands of New South Wales in 1964 and had replaced strychnine baits in aerial baiting programs in most areas by the late 1960s. Aerial baiting was generally regarded as successful and many dog fences were allowed to fall into disrepair. The reduction in the area of Queensland protected by the barrier fence could be attributed to the perceived success of 1080 baiting, especially aerial baiting (Holden 1991). Fixed-wing aircraft were used until 1986, when helicopters became mandatory for aerial baiting in the east of New South Wales because baits could be placed with more accuracy (Thompson et al. 1990). Aerial baiting with 1080 has evolved considerably to increase its efficacy against wild dogs while reducing potential non-target effects. It is now generally accepted as a cost-effective, safe method for the extensive strategic management of wild dogs (Thomson 1986; Thompson and Fleming 1991), and is used in Queensland, New South Wales, Western Australia and the Northern Territory.

Aerial baiting is the major control method in Western Australia where, in 1996–97, 823 900 baits were dropped during 505 flying hours; the average number of baits used annually has varied little over the past decade. Similarly, in north-eastern New South Wales, aerial baiting using helicopters is the primary form of wild dog control.

Fixed-wing aircraft are used for baiting in Queensland, western New South Wales and Western Australia but not in the other States and Territories.

5.1.2 Past management strategies

When labour was cheaper, and before scientific information about dingo movements and behaviour began to emerge, many control operations took place that would now be viewed as inefficient and inappropriate. In Western Australia, for example, there was a strong belief in dingo migration routes from far distant ranges and deserts to the grazing leases (Tomlinson 1958b). The attitude that any dingo killed would be 'one less to attack a sheep' prevailed. This led to major expeditions being mounted to seek out dingo 'breeding areas' (Tomlinson and Blair 1952), and to considerable effort being expended in attempts to control dingoes in these remote areas, hundreds of kilometres from the closest livestock.

Despite much wasted effort in earlier times, there was still the recognition that a coordinated, community approach to wild dog control was the most effective strategy. This generally took place in the form of 'baiting drives', including aerial baiting (Tomlinson 1954). Tomlinson (1958b) wrote:

'Wild dog baiting drives, organised on a district-wide basis and combining all available manpower and aids such as aerial baiting, are without doubt the most effective destruction method.... Careful planning and organisation to ensure the work is properly coordinated, is carried out at the best possible time, and gives the most effective coverage, is essential. Possibly, the most important requirement is to secure the participation of the landholders in these drives and the continuation of control work afterwards.'

Over the years, this approach has been refined, promoted and increasingly adopted, as outlined in Section 5.1.3.

5.1.3 Historical /past organisation of control

Since European settlement, two organisational levels of wild dog control have existed:

- By 1889, all mainland States had enacted legislation to facilitate the control of wild dogs (Breckwoldt 1988). Semi-government administrative structures, usually governed by boards of local landholders, were created and empowered to levy rates on landholders to fund the bounty system and other control measures. These funds were commonly supplemented by government subsidies. For example, until the mid-1980s, most of the control of wild dogs in Victoria was by Government-employed doggers. Groups to facilitate the control of wild dogs were common in eastern Australia where the resources of the local groups were supplemented by government contributions and rates collected by the boards of management. Until recent times, wild dog control groups often held important social significance. Dog drives and poisoning programs served as meetings where neighbours could get together to socialise and discuss other issues affecting their holdings.
- Many properties, leases and runs employed doggers and boundary riders who had responsibility for trapping 'vermin' and maintaining fences in dog-proof condition. Privately employed doggers were more common in the extensive pastoral leases in northern central Queensland, South Australia and Western Australia.

5.2 Current legal status (around Australia)

5.2.1 Legislation

The legal status of dingoes and other wild dogs varies between States and Territories (Table 4). This status affects the control measures that are applied and the level of cooperation between individuals and groups.

Western Australia

Dingoes and hybrids are 'declared animals' under the *Agriculture and Related Resources Protection Act 1976* and are placed into Categories A4, A5 and A6. These categorisations are determined by the Agriculture Protection Board (APB) and are administered by Agriculture Western Australia (AGWEST). Populations must be controlled and animals cannot be introduced or kept in captivity except in approved institutions or under a permit which carries specific conditions. Although category A5 requires that populations should be controlled throughout the State, it is recognised that dingoes pose no threat in vast areas beyond the limits of pastoral or agricultural land. APB policy restricts control activities to stocked land and its immediate environs. Domestic dogs (run wild, feral, or being at large) are classified in Category A5, meaning that they must be controlled. In municipal areas, domestic dogs are covered by the *Dog Act 1976*.

Dingoes are covered by the *Western Australian Wildlife Conservation Act 1950*, administered by the Department of Conservation and Land Management (CALMWA). Under this Act, they have been listed as 'unprotected fauna', although they are not subject to control in fauna reserves and National Parks without appropriate consultation between CALMWA, landholders and AGWEST. Despite the declared pest status of dingoes outside conservation estates, they are not controlled over most of their range.

Part of the funding for wild dog control in pastoral areas of Western Australia is derived from rates levied on pastoral leases matched by government funds.

Northern Territory

Dingoes are undeclared in all areas of the Northern Territory (Table 4). They are unprotected in all areas of the Northern Territory outside parks, reserves, sanctuaries, wilderness zones and the Arnhem Land Aboriginal Reserve (*Parks and Wildlife Conservation Act 1993*). Although there is no obligation on landholders to control them, the Parks and Wildlife Commission organises aerial and ground control programs if requested by graziers. The dingo has been protected within national parks and nature reserves since 1984 when dingoes were removed from the declared vermin list. The *Aboriginal Land Rights (Northern Territory) Act 1976* requires that traditional owners be consulted before any wild dog management programs are undertaken on their lands. Dingoes are unprotected in Arnhem Land Aboriginal Reserve.

South Australia

Dingoes and hybrids are 'proclaimed' pests under the *Animal and Plant Control Board (Agricultural Protection and Other Purposes) Act 1986* in the sheep zone south of the Dog Fence (Figure 2). Dingoes must be controlled and can only be kept there in authorised zoos and wildlife parks. Monies for the control of dingoes (Dingo Control Fund) is levied from all landholders with more than ten square kilometres and is matched by the government.

North of the dog fence the dingo is regarded as a legitimate wildlife species and although unprotected, is afforded a level of protection by the South Australian Dingo Policy (Animal and Plant Control Commission 1993). This policy was formulated in 1977 with input from the Vertebrate Pests Control Authority (now Animal and Plant Control Commission), pastoralists, the Dog Fence Board, the Pastoral Board and the Australian Conservation Foundation. Beyond a 35 kilometre-wide baited buffer zone, conservation of dingoes is enhanced by restrictions to ground baiting, prohibition of aerial baiting and phasing out of bounties.

The Dog Fence Board, under the *Dog Fence Act 1946*, administers maintenance of the 2178 kilometre dog fence. Funding is shared equally between the Government and landholders receiving protection of the fence.

Queensland

Dingoes and other wild dogs are declared pests under the *Rural Lands Protection Act 1985*. The responsibility for wild dog control in Queensland lies with landholders and is administered by the Land Protection Branch of the Department of Natural Resources (QDNR) and local governments. Dingoes and dingo hybrids can only be kept with ministerial approval and this is restricted to zoos and wildlife parks. The Queensland barrier fence (about 2500 kilometres long) (Figure 2) and funding for its maintenance has averaged around 60% from State funds and 40% from 'precepts' (levees) charged within the 'benefited area' over the long term. Local governments also maintain a number of smaller 'check' fences. A team of people employed by QDNR is responsible for the continued maintenance of the fence.

New South Wales

The *Act to Consolidate the Acts for the Protection of Pastures and Live Stock from the Depredations of Noxious Animals 1898* in New South Wales declared certain animals including 'native dogs' noxious and obliged land owners to control them. The Pastures Protection Act 1939 reiterated this position as did the *Rural Lands Protection Act 1989* and the *Rural Lands Protection (Amendment) Acts 1994* and *1997*. The wild dog policy of the National Parks and Wildlife Service (*National Parks and Wildlife Act 1974*) effectively protects dingoes within national parks and nature reserves, and the dingo is recognised as a native species under the *Threatened Species Conservation Act 1995*. The *Rural Lands Protection Act 1998* allows wild dogs to be declared as pest animals and requires that the government be responsible for their management on government lands. Dingoes can be kept as pets under the restrictions of the *Companion Animals Act 1998*.

In the Western Division of New South Wales, the WDDB administers the control of wild dogs and is responsible for the maintenance of the 584 kilometres of the Dog Fence (Figure 2). The Board was established under the *Wild Dog Destruction Act 1921* and is funded by rates on Western Division landholdings and State Government subsidies.

Australian Capital Territory

The *Nature Conservation Act 1980* in the Australian Capital Territory defines protected species in the Territory which includes dingoes. Control of wild dogs, including dingoes, on private lands is allowed subject to a permit authorising the killing of a protected species being issued by Environment ACT.

Victoria

In Victoria, dingoes are offered some protection within the lands administered under the *National Parks Act 1975* through the Wild Dog Policy of the National Parks and Conservation Reserves Guidelines and Procedures Manual. Elsewhere they were 'declared vermin' as were all wild dogs under the *Vermin and Noxious Weeds Act 1958* and, since its repeal, under the *Catchment and Land Protection Act 1994*. Landholders have a legal obligation to control declared animals on land they own or occupy.

Tasmania

There have never been dingoes in Tasmania and the import of dingoes is banned along with a schedule of other exotic animals (*National Parks and Wildlife Act 1970*). Punitive action against feral and commensal dogs preying upon livestock is covered under the *Dog Control Act 1987*.

5.3 Current management strategies

5.3.1 Threats to livestock

It is now widely accepted that the threat to livestock from wild dogs comes from within the stocked areas and immediately adjacent 'refuge' areas. This has been supported by considerable scientific research (Section 2.4). With the increasing need to achieve the optimum cost-effectiveness of control work, the message to managers about confining work to high-risk areas becomes even more attractive. This coincides with a greater public interest in the preservation of dingoes (Chapter 3), and a greater public scrutiny of lethal control methods (Chapter 4).

One of the major changes in management strategies has been the abandonment of the bounty system in some States and Territories (Section 5.1.1). Many of the arguments surrounding bounties are well recognised, although it is worthwhile emphasising several that have undoubtedly hampered effective wild dog control in the past, and may well still do so in some areas. Apart from the encouragement of fraudulent practices, the payment of bonuses encourages a 'scalp count' mentality. This can result in the targeting of areas where dogs are easy to catch, rather than areas where dogs are posing the greatest risks to livestock. As well, bounties clearly encourage the use of techniques that yield easily-found carcasses (trapping, shooting, and the use of inappropriate poisons). There is strong evidence in Western Australia that the use of highly efficient 1080 baiting is not undertaken by some operators because carcasses are seldom found (Chapter 6). Success of control operations should be measured by a reduction or elimination of livestock losses, not by a scalp count.

'Success of control operations should be measured by a reduction or elimination of livestock losses, not by a scalp count.'

The one exception to the general failure of bounties in preventing livestock losses is the case of affected landholders paying large bounties for the destruction of identifiable dogs responsible for extensive predation on sheep (that is a 'rogue animal' bounty or 'smart' bounty, Hassall and Associates 1998). Because 'rogue' animals have often thwarted considerable attempts to kill them, they may take a long time to catch, and although the sums offered may appear large ($100–$1000, E. Lackey, Rural Lands Protection Board (New South Wales), Inverell, pers. comm. 1984), the effort required to catch the offending dog(s) and the cost of their impact may also be large. This happens on a case-by-case basis and is different from the standard bounty system.

All of these factors have driven control authorities to adopt cost-effective, target-specific and humane control techniques and strategies. The major features of current wild dog management in Australia are summarised below:

- A strategic approach to management, with an emphasis on identifying and concentrating control in areas where stock are at risk.
- A streamlined control effort to reflect the degree of risk (the objective in sheep grazing areas being to keep paddocks free of wild dogs, with less stringent requirements in the case of cattle enterprises).
- Conducting control work in buffer areas immediately adjacent to stocked paddocks, to provide a sink for dispersing wild dogs to settle before they reach the paddocks.
- The application of control on a larger scale and integrating the efforts of different groups.
- An increased use of aerial and ground baiting with 1080 as cost-effective, strategic control methods.
- Less reliance on professional doggers and the bounty system than previously (although bounties are still paid in Queensland, the Western Division of New South Wales, and parts of Western Australia).
- Acts and policies to protect dingoes within national parks and similar fauna reserves in some States and Territories providing a legislative framework by which dingoes can be conserved.

5.3.2 Attacks on people

Wild dogs which come into close contact with people may become aggressive (Section 3.7). Authorities have attempted to manage such problems through culling and/or legislation to control the feeding of wild dogs and through a public education program. Warnings about the dangers (to humans) of feeding wild dogs and seeking close contact are sometimes provided in signs and brochures. People, especially children, who live in areas where wild dogs (including dingoes) are present, need to be taught safe and appropriate behaviour towards dogs.

In addition to culling, methods to minimise wild dog–human interactions in tourist areas may include aversive conditioning techniques that educate dingoes to avoid specific areas (Tauchmann 1998). For example, food scraps spiked with lithium chloride, which if eaten will cause dingoes to vomit, can be placed around camp grounds. Similarly, devices which emit high pitched sounds and impinge on the dingo's sensitive hearing might be a deterrent; as are electric shocks administered by modified cattle prodders (dingo prodders) or electrified fences (Bird 1994). Other deterrents include weapons that fire kinetic energy rounds (sting balls), bean bags, or sponge cartridges (containing an irritant) (English and Taske 1998). The effectiveness of all these approaches for deterring dingoes is largely unevaluated (Section 8.7).

5.3.3 Conservation of dingoes

(i) Public and government education

Education programs are required to help people recognise the dingo as a native Australian species, understand its ecological role and its plight, and push for policies to retain it as part of Australia's national heritage.

> ***'Governments can use improved knowledge of dingo ecology to instigate better control methods.'***

To prevent hybridisation, people who wish to keep pure dingoes or hybrids as pets should require permits and these animals should be neutered. Hybridisation would also be reduced if domestic dogs kept in outback mining towns, outback cattle stations and Aboriginal settlements in wilderness areas such as Jabiru in Kakadu National Park, were neutered unless they are specifically kept for breeding. However, introducing such changes would require extensive consultation with dog owners in these places.

State and Territory governments can play their part here by recognising the overall role dingoes and other wild dogs play in wilderness and pastoral areas, and by legislating accordingly. The Northern Territory removed dingoes from the pest list in 1976 but does not protect them, except in parks, reserves and in Arnhem Land. In South Australia in 1977, dingoes north of the Dog Fence (60% of the State) were declassified as pests, but not protected. Survival of the dingo is ensured by restricting the availability of organised baiting campaigns to certain areas and to times when dingoes are present in excessively high numbers and causing hardship for cattle producers. No bounties are paid on dingo scalps and trapping and the aerial laying of baits is prohibited outside the Dog Fence. Dingoes remain proclaimed pests in the 40% of the State inside the dingo fence. New South Wales protects dingoes only in national parks and the conservation estate, as does the Australian Capital Territory. Dingoes remain 'declared pests' subject to various levels of control throughout Queensland, Victoria and parts of Western Australia. Any new laws on the keeping of dingoes by the general public should take into account the fact that such general ownership will increase the rate of hybridisation (Corbett in press).

Governments can also use improved knowledge of dingo ecology to instigate better control methods. For example, the Northern Territory Government was the first to stop annual broadscale aerial baiting and the Western Australian Government drew on new knowledge about dingo movements to set up buffer zones (nominally two dingo territories wide) between pastoral and wilderness areas.

(ii) Dingo preservation societies

The Australian National Kennel Council (ANKC) is a co-ordinating body for State and Territory canine controlling organisations. The ANKC recognises the dingo as an official dog breed and has adopted it as Australia's national breed with the proviso that exhibition, breeding or ownership of dingoes is not allowed in States where these activities are prohibited. In some States, preservation societies (such as the Australian Native Dog Conservation Society Ltd at Bargo, the Australian Dingo Conservation Association Incorporated at Erindale in New South Wales and the Dingo Farm at Chewton in Victoria) legally obtain dingoes to preserve and enjoy them. The philosophy and attitude of such societies is admirable and their aims can be achieved if they take a united and scientifically valid approach. This is being done by the Bargo and Erindale groups that are collaborating with researchers at the University of New South Wales (Barry Oakman, Australian Dingo Conservation Association Incorporated, New South Wales, pers. comm. 1999). Otherwise dingoes may become inbred or the artificial environment and selective breeding may discourage the natural selection of wild characteristics. The best scientific knowledge must be used to ascertain the dingo's general and specific characteristics and this knowledge should be derived from samples collected over most of the dingo's huge geographic range in Australia and Asia.

With agreement from ANKC affiliated State and Territory canine councils or associations and the dingo preservation societies, a national register of dingoes and breeders could be constituted. The following recommendations would ensure that only pure dingoes were registered:

- Registered dingo breeders ensure that their stock comprises only pure dingoes. At present, this can only be done using skull measurements from dead animals supported by coat colours and breeding patterns. In future, dingoes may be assessed for purity by DNA fingerprinting techniques (Wilton et al. 1999) or possibly by skull measurements from x-rays of live dingoes.
- Only verified pure dingoes be included on the national register; that is, animals whose parents are both from a pure dingo breeding line confirmed by the skull measurements or DNA analysis of the founding parents of that line. During the initial years when stocks of proven pure dingoes are low, care must be taken to minimise inbreeding and other genetic problems. It should be a registration requirement that the purity of every third generation of each breeding line is confirmed by reference to skull measurements.
- The overseeing canine controlling bodies, dingo preservation societies and registered breeders be encouraged to educate the general public about the plight of dingoes and the measures being taken to preserve them. This education should include the responsibilities and problems of keeping dingoes in captivity and the reasons why most people would not qualify to keep a dingo. In addition, close collaboration with the Royal Society for the Prevention of Cruelty to Animals (RSPCA) and other dog 'shelters' should be established to ensure that suspected dingoes and hybrids are culled rather than 'recycled' to members of the public.
- Most importantly, considerable effort be made to win over members and supporters of the pastoral industries, particularly those in the sheep industry. Accordingly, the interested bodies should assist governments to pass legislation that not only ensures the preservation of pure dingoes, but safeguards the credibility of preservation societies and combats the chicanery that unscrupulous 'dingo breeders' might employ.

(iii) Island refugia

It is unlikely that most Australian mainland habitats will stay or become free of hybrids, so that large offshore islands and other refugia offer the best hope of preserving pure dingoes in their natural habitat (Corbett 1995a). There are many islands around the Australian coastline, representing many climates and habitats, excepting hot deserts. Some, such as Fraser Island, Melville Island and Groote Eylandt, are large enough for dingoes to live and breed in natural conditions.

Hybrids would need to be eliminated. Dingo populations would need to be managed so that they did not over-exploit their natural food supply and crash. Also, local regulations banning the hand-feeding of dingoes must be enacted and strictly adhered to; otherwise many dingoes will not only become dependent on food handouts but also become accustomed to the close presence of humans. This increases the risk of dingoes annoying or biting people. Management plans, such as the one developed for Fraser Island (Queensland Parks and Wildlife Service 1999), are essential for the management of dingo populations on island refugia.

Islands do not necessarily need to be offshore. They could be islands of well-protected and maintained sanctuaries on the mainland, which would have the advantage of additional habitats, such as deserts, not available on offshore islands. Such sanctuaries already exist on the mainland for conservation of endangered mammals and birds (Wamsley 1998).

Table 4: Australian legislation and policies for dingoes and other wild dogs. D= Declared animal which land owners and occupiers are obliged to control; U= Undeclared animal which land owners and occupiers have no obligation to control or protect; P= Protected animal which it is an offence to kill; N= Not declared noxious within lands managed by some State agencies; some protection afforded to dingoes either through policy or in practice.

	QLD	NSW	WA	NT	SA	VIC	ACT	TAS	Commonwealth
Status of dingoes	D whole State	D pastoral areas N NPWS land	D pastoral areas N National Parks	U[1]	D inside barrier fence N other areas	D pastoral areas N National Parks	P	Not present Import prohibited	Export not permitted P National Parks
Status of wild dogs	D	D	D	U[1]	D	D	Dangerous dogs may be destroyed	Subject to control	Controlled where impact demonstrated
Agencies responsible for management	Department of Natural Resources; local government	NSW Agriculture; Rural Lands Protection Boards	Agriculture Western Australia	Parks and Wildlife Commission	Animal and Plant Control Commission	Department of Natural Resources and Environment	ACT Parks and Conservation Service	Department of Primary Industries, Water and Environment	Environment Australia
Landowner or occupier responsibility	Landholders required to control in all areas	Obliged to control in pastoral areas	Obliged to reduce/control numbers where causing damage	No obligation to control or protect	Obliged to control in sheep pastoral areas	Obliged to control in pastoral areas	It is an offence to kill these animals	Import prohibited	Dingoes protected on Commonwealth land
Relevant legislation	*Rural Lands Protection Act (1985); Nature Conservation Act 1996*	*Wild dog Destruction Act 1921; National Parks and Wildlife Act 1974; Threatened Species Conservation Act 1995; Rural Lands Protection (Amendment) Act 1998; Companion Animals Act 1998*	*Agriculture and Related Resources Protection Act 1976; Wildlife Conservation Act 1950*	*Territory Parks and Wildlife Conservation Act 1993*	*Animal and Plant Control (Agricultural Protection and Other Purposes) Act 1986*	*Catchment and Land Protection Act 1994; National Parks Act 1975*	*Nature Conservation Act 1980; Dog Control Act 1975*	*National Parks and Wildlife Act 1970; Dog Control Act 1987*	*Wildlife Protection (Regulation of Exports and Imports) (Amendment) Act 1995*

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Table 4 continued

	QLD	NSW	WA	NT	SA	VIC	ACT	TAS	Commonwealth
Bonuses paid[2]	Yes	Western Division only	Yes (Pilbara and Gascoyne/ Murchison)	No	No	No	No	No	No
Government finance[3]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Coordinated control[4]	Yes	Yes	Yes	No	No	Yes	No	No	Yes

[1]Dingoes are undeclared in all areas of the Northern Territory and are unprotected outside parks, reserves, sanctuaries, wilderness zones and the Arnhem Land Aboriginal Reserve.

[2]Bonuses paid on presentation of proof of destruction of a wild dog; usually a scalp. Bonuses are not paid under Conservation or Wildlife Acts.

[3]Government assistance to control wild dogs provided through barrier fence maintenance, the employment of doggers and subsidisation of baiting costs. Government finance is not available under Conservation or Wildlife Acts.

[4]Coordinated control groups are encouraged or required.

6. Techniques to measure and manage impact and abundance

Summary

To formulate management plans, some measure of trends in dog population densities is required, although an assessment of total numbers is not necessary. Trends in numbers indicate potential predation threats to livestock and allow advance action to be taken. Threats vary according to the type of livestock at risk. What may be a 'safe' rise in the abundance of wild dogs on a cattle station might seriously threaten the viability of a sheep station.

To assess the effectiveness of programs to manage wild dogs, it is essential to monitor the impacts of wild dogs on livestock production. Although knowledge of trends in wild dog numbers may assist in determining whether a new management approach is effective, the most important measure of success is a reduction in livestock losses due to wild dogs.

The principal techniques to control wild dogs are exclusion fencing, shooting, trapping and poisoning. Exclusion fences range from the famous barrier 'dog fences' of Australia, which aim to keep wild dogs from moving into huge sections of various States, to shorter fences maintained to protect individual properties. Traditionally, fences have been constructed from wire netting, but electric fences are now used in some areas. Poisoning with 1080 is the most cost-effective lethal means of reducing populations of wild dogs over large areas of remote or inaccessible country. Various types of bait are used, with methods of placement ranging from burying individual baits to dropping baits from aircraft. Trapping is still used for wild dog control and will probably always be needed to target particular dogs that cannot be removed by other means.

At present, there are no suitable agents for the biological control of wild dogs. Although in many ways a theoretically attractive control option, biological control would have potential drawbacks, including the risk to domestic dogs, and the threat to the conservation goal of maintaining populations of dingoes in reserve areas.

6.1 Introduction

Programs to manage wild dogs need to be strategically based, focusing the effort in areas where the highest risks to livestock occur. Not only is this economically sound, it also takes account of the conservation status of dingoes in areas where they pose little hazard to livestock. Vertebrate pest control programs are coming under increasing scrutiny by the public and the need for implementing each program must be soundly justified. There is also a need to justify the control methods used, not only in economic terms, but also on the grounds of animal welfare (Section 4.2) and hazards to non-target species.

'Managers should avoid the pitfall of continuing with action that is based on tradition rather than an objective assessment of the best options for addressing their current wild dog problem.'

This chapter outlines the various techniques that managers can use to effectively plan, implement and evaluate the effectiveness of management programs. The range of control techniques that are available are described, and suggestions are given on the circumstances that warrant their use. Strategies will vary from region to region across Australia, but the fundamental aim of most management programs, to protect livestock from wild dog attacks, will remain the same. Managers need to be aware of all options. They should avoid the pitfall of continuing with a course of action that is based on tradition rather than an objective assessment and evaluation of the best options for addressing their current wild dog problem.

6.2 Estimating abundance

6.2.1 Background

Wild dogs are elusive, mostly active at dawn, dusk and during the night, have seasonally variable patterns of activity and usually occur at relatively low densities (Chapter 2). These factors all contribute to the difficulty of obtaining accurate measures of wild dog abundance. However, measures of absolute density are usually not necessary and most managers only need a measure of changes in abundance that may result from management programs or environmental conditions (for example, changes in the availability of food). Such changes may indicate, for instance, that an increasing threat is emerging, warranting a reallocation of resources or indicate the success or otherwise of a control program.

Scalp returns are not a good measure of the abundance of wild dogs because they are strongly influenced by the level and type of control effort. For example, scalps are rarely recovered during baiting programs (Section 6.4.4). Scalp returns may also reflect the expertise of a particular operator, rather than reflecting the number of wild dogs in an area. Scalp returns would only be a guide to numbers if the same control methods were used throughout, and the effort remained constant. These criteria are seldom met, and in any event, capture success can decline over time as surviving animals become increasingly wary.

In many instances, estimates of the number of wild dogs in an area, based on simple counts of footprints, or sightings of wild dogs, provide sufficient information on which to base management decisions. In sheep paddocks, for example, the presence of any wild dogs warrants some control effort because sightings of wild dogs are highly correlated with predation (Fleming and Korn 1989) and because once predation commences it will continue until the predator or the sheep are removed (Thomson 1984a). In cattle grazing areas, assessments of potential risk may be related to the size of groups or packs of wild dogs seen in the area. In this case, the regular sighting of large packs throughout the area could indicate an increased risk of predation on calves, particularly if coinciding with a decline in the availability of the wild dogs' usual prey.

On a broader scale, managers may require a measure of overall trends in wild dog densities, particularly in the 'refuge' areas and buffer areas adjacent to livestock paddocks. In these situations, the option of carrying out preventative control is more efficient than undertaking reactive control after damage has already started. The most practical means of measuring changes in population density is to derive *indices* of abundance. The level of precision of the indices is most important. If the inherent variability of the indices is too large, then real changes may remain undetected or changes may be indicated when none really occurred.

'In many instances, estimates based on simple counts of footprints, or sightings of wild dogs, provide sufficient information on which to base management decisions.'

In most circumstances, indices of abundance are adequate to assess the effectiveness of a control program. Indices of abundance are also useful for making comparisons between sites of the effectiveness of a particular strategy for reducing abundance. If conservation of dingoes is the aim, the long-term numbers of dingoes must be assessed. Regular mark–recapture assessments of areas with pure dingoes, coupled with DNA sampling would be required to assess the success of such a conservation program.

Detailed discussions on techniques and analyses for measuring population abundance are given in Otis et al. (1978), Caughley (1980), and Caughley and Sinclair (1994). Some of the most useful techniques for deriving counts or indices of wild dog numbers for management purposes are described in the following sections.

6.2.2 Sign counts

Sign counts are often the most suitable methods for assessing relative abundance. Faecal deposits detected by trained 'sniffer' dogs can be used to index abundance (B. Morris, dogger, Yass Rural Lands Protection Board (New South Wales), pers. comm. 1998), as can footprints. Sign counts can be 'passive' (that is, the animals are detected in their normal movements without detection altering their behaviour, for example, faecal deposits per unit time), or 'active' (that is, the animals are encouraged by lures to leave their sign at stations, for example, scent stations and bait stations, see below). Sign counts can be made along roads (Allen et al. 1996; Catling et al. 1997; Edwards et al. 2000), animal tracks and creek beds (Fleming et al. 1996) or at randomly-placed or stratified stations (Mahon et al. 1998). The main problem with 'passive' indices is that it is often difficult to generate sample sizes large enough to adequately quantify low-density populations of wild dogs. On the other hand, 'active' indices may interfere with normal behaviour patterns and this can influence counts. In both cases, the relationship between actual abundance and the index is assumed rather than known. Further work to determine the relationship between indices and abundance is required. A study is currently being undertaken in the Eastern Highlands of Victoria which will shed light on the relationship for that environment (F. Gigliotti, Department of Natural Resources and Environment, Victoria, pers. comm. 1999).

Many studies of carnivores in North America have relied on scent stations to obtain indices of abundance. These 'stations' consist of an area of cleared ground on which tracks can be readily seen, with a scent lure used to attract animals to the site. The principle underlying this method is that the visitation rates are proportional to animal density. However, visitation of scent stations has been shown to be independent of density for some species (Smith et al. 1994). Bait stations are essentially scent stations modified by placing a bait in the centre. For canids, it is recommended that the baits be covered with

Cleared transects allow track counts to be used as an index of wild dog acitivity (Source: Queensland Rural Lands Protection Board).

soil to avoid removal by birds (Allen et al. 1989; Thompson and Fleming 1994).

'Further work to determine the relationship between indices and abundance is required.'

Frequency of visitation to both scent stations and bait stations would be affected by factors including spacing of individual stations, presentation of baits and attractants, habitat differences between sites, frequency of operations, length of index period and quality of tracking surfaces. These factors should be standardised to facilitate within and between site comparisons. Bait stations can also be used to assess cumulative bait uptake. This can then be used as an abundance estimator. Thompson and Fleming (1994) were able to demonstrate that cumulative bait uptake data produced reliable indices of fox (*Vulpes vulpes*) abundance, with low variability.

6.2.3 More detailed counts or estimates for research

In most circumstances, indices of abundance are adequate to assess the effectiveness of a control program as changes in abundance are reflected by changes in the indices. However, for more detailed estimates of numbers for specific research studies, other methods are also used. These include mark–recapture studies, where animals are live-trapped, marked (tagged and collared with plain or radio-collars), then released. Estimates are made of the overall population density when marked animals are either recaptured or re-sighted during specific trapping or monitoring phases. Estimates are affected by the altered behaviour of marked animals. Increased wariness after initial capture, for example, can produce overestimates of the overall population (Caughley 1980).

A novel assessment of population assessment that may have potential for monitoring wild dogs has been developed for grizzly bears (*Ursus arctos*) in Canada (Mowat and Strobeck 2000). DNA profiles are established from the hairs of bears that visit a bait site and mark–recapture analysis is used to determine population size. Likewise in California, DNA residual in faeces has been used to identify individual mountain lions (*Puma concolor*) (Ernest et al. in press). DNA recovered from mountain lion saliva left in wounds on bighorn sheep (*Ovis canadensis*) can then be matched to individual lions identified from faecal DNA (H. Ernest, University of California, Davis, pers. comm. 2000). Because mountain lions are mostly loners, control can then be targeted at the individuals responsible for killing bighorn sheep. In future, problem individual wild dogs might be better targeted through DNA analysis of faeces, saliva and tissues from captured wild dogs. That is, salivary DNA from wounds on sheep identifies the individual wild dog; faecal DNA identifies where the wild dog lives and tissue DNA confirms that the wild dog killed by controllers was indeed responsible for killing the sheep.

Cyanide baiting is a technique that can be used by researchers to generate 'catch-per-unit-effort' (CPUE) indices. Algar and Kinnear (1992) demonstrated the usefulness of cyanide baiting to generate CPUE indices of fox abundance. The technique has not yet been fully assessed for use with wild dogs. Using the known number of removals obtained by such a program, cyanide baiting also has the potential for estimation of absolute abundance. This is achieved with index–removal–index calculations (Caughley 1980) using the known number removed in conjunction with before and after manipulation indices.

Probably the most detailed information on the abundance of a wild dog populations was obtained during intensive research studies in the Pilbara region of Western Australia (Thomson et al. 1992b). There, dingoes were radio-collared and observed from aircraft. Because the dingoes were living in packs, information was obtained on the entire pack even when only one pack member was collared. Uncollared packs or individuals were identified by comparing aerial observations against data on dingo tracks counted during routine ground surveys. In this way, a reliable tally of total population size was possible over a number of years. Such data are difficult and expensive to obtain.

6.3 Estimating agricultural and environmental impacts

6.3.1 Agricultural impacts

Producers need to assess the type and extent of livestock losses from different causes as a first step in deciding how to deal with them. Measuring the impact of wild dogs on livestock production has always been difficult. Part of the problem is that, in rangeland areas in particular, there is little intensive husbandry of livestock. Musters are infrequent, stock are regularly seen only at waters, and the remains of animals killed by dogs are generally undetected. Often the first indication of dog attacks is finding injured animals at waters or during musters. In addition, livestock losses from other natural causes, including reproductive failure, can rarely be quantified, making it difficult to deduce losses due to dogs based purely on muster tallies. Further, information is usually obtained from areas where some form of wild dog control is being carried out, making it difficult to deduce what the impact may have been in the absence of any control work (Section 3.1).

In earlier scientific studies, there was a tendency to make deductions from dietary analysis about the likely impact that wild dogs had on livestock (Whitehouse 1977). However, such interpretations are generally not reliable, because wild dogs do not always eat the animals they kill. Neither is the relative abundance of predators and prey known so that a small occurrence of livestock in the faeces may represent a substantial livestock loss if there are many wild dogs present. In addition, wild dogs cause losses such as wounding and mismothering which are not reflected in stomach or scat samples (Section 3.1; Thomson 1984a; 1992c).

Various surveys have been undertaken in an attempt to quantify predation losses, generally over broad regions (Section 3.1; Fleming and Korn 1989). These have the limitations of any survey (for example, variable response rate, inaccurate estimations), although they can give a largely objective indication of where problems occur and trends over time. It is recommended that these data be collected as part of property inspection reports by staff from the relevant land management authority. Maps of such data provide managers with a powerful tool with which to assess resource allocation to reduce predation impacts. In New South Wales, it is a statutory requirement that records of stock losses be provided by a landholder when seeking 1080 (sodium fluoroacetate) baits for emergency baiting. Such reports can be included in regional maps.

> ***'Where there are areas with similar environments and production systems where wild dogs are controlled and uncontrolled the effectiveness of control can be assessed.'***

To obtain scientific estimates of reductions in predation losses under a particular control strategy, comparisons must be made between at least two similar areas over a number of years. One area must have no control and the other uses the control strategy (Hone 1994). This accounts for seasonal variation in wild dog activity and avoids control strategies being erroneously deemed successful or unsuccessful when the cause of changes in predation is seasonal. Obviously, it is unlikely that sheep producers would allow wild dogs to go uncontrolled and so there will always be an element of doubt in assessing the success of a program. In the extensive cattle areas of northern Queensland, there are areas with similar climates, environments and production systems where wild dogs are controlled and uncontrolled. In these cases, the effectiveness of control can be assessed (Allen and Gonzalez 1998).

Recognising predation

On an individual property scale, landholders need to be aware of how to determine losses due to predation. A number of factors to look for are summarised in Box 1. This information is derived from direct observations of radio-collared dingoes in sheep paddocks in Western Australia (Thomson 1984a), though much of it is also applicable to predation on cattle and other livestock.

Skinning of carcasses reveals the extent of wild dog attack and, particularly for woolly sheep, may be necessary to confirm whether a wild dog fed on the carcass post-mortem or was the cause of death (Source: (a) P. Thomson, (b) L. Corbett).

Box 1: Recognising wild dog predation of sheep

Carcasses found (sheep aged more than six months)

Signs — Depending on the type of ground and the amount of time elapsed since the attack, tracks may be found indicating a struggle. Both the wild dog and its prey often leave deep prints with toes spread out. Freshly broken vegetation, often holding tufts of wool, is sometimes found at the site of the attack. Pieces of wool with patches of torn skin attached, as well as blood trails, are good indicators of predation by wild dogs. Often, however, scavengers obscure the tracks and other signs. The presence of dog tracks at a carcass does not necessarily mean predation was the cause of death, particularly if the tracks are more recent than the carcass.

Position of carcass — In the hotter, arid regions, sheep dying from natural causes usually die in shady places, sometimes near water. A carcass found out in the open, away from available shade can indicate predation. In the same way, the age and condition of the sheep can give a clue to predation — if young and apparently healthy sheep are found dead, this often indicates predator attacks.

Carcass examination — Although wild dogs usually attack from the rear as they pursue their prey, they generally kill by bites to the throat, damaging the trachea and the major blood vessels of the neck. Blood and puncture marks on the throat are therefore good evidence of wild dog predation. Blood is often found at the mouth and nose, although care should be taken to distinguish this from other body fluids that drain from a decomposing carcass (Figure 11a).

Attacks from behind result in injury to the sheep's hind legs. Inexperienced wild dogs, or those attacking without any apparent motivation to feed, frequently inflict considerable damage to the hind end of the sheep. This often leads to its death after the event. In these cases, blood is often found caked on the hind legs. The pattern made by blood flowing down the legs while the sheep was still upright can be clearly distinguished from blood or fluids which may flow as a result of feeding, decomposition, or animals feeding on a carcass (Figure 11b). Saliva, even when dry, can sometimes be seen on the wool of attacked sheep.

Skinning the throat and hind legs is often sufficient to reveal hidden damage. Tooth punctures in the hide, subcutaneous bleeding, bruising and tissue damage will indicate wild dog attack (Figure 11c). External signs of tissue damage due to feeding or scavenging activities can be readily confirmed in a fresh carcass by such simple dissection. Tissue damage caused after death will show no bruising or bleeding as this only occurs if the animal is bitten while still alive.

Decomposition and/or scavenger damage can mask the cause of death in older carcasses. Often, however, blood-stained wool still remains (especially on the lower legs which often dry out intact). Again, care must be taken to ensure that decomposition fluids are not mistaken for blood. Depending on the carcass age, dissection is often warranted, as bruised tissue can still be distinguished from undamaged tissue in a decomposing carcass. Provided that the skin is still intact, simply pulling out the wool can often reveal damage. Puncture wounds in the throat will be uncovered in this manner (Figure 11d).

Carcasses found (sheep aged less than six months)

There are no predators in Australia apart from wild dogs that are large enough to inflict the sort of damage to adult sheep described above. In the case of sheep younger than about six months of age, however, the situation is often more complex. Many young lambs die from causes other than predation, and predators are often suspected as a result of scavenging on already dead or moribund lambs. To verify predation, dissection must show haemorrhage and bruising as described for adult sheep (other methods can be used to determine whether the lamb was healthy and likely to have survived in the absence of predation; Saunders et al. 1995).

A further complicating factor in relation to lambs is that predators other than wild dogs can be involved. It can be difficult to distinguish between fox and wild dog predation on lambs. The size of bites and puncture marks probably provide the most reliable guide, dogs having much larger and more widely spaced canine teeth. Although foxes often tend to feed from the heads of lambs, there are variations in the behaviour of both individual foxes and wild dogs that sometimes make definite predator identification difficult.

Injured sheep found

Injured sheep are sometimes found in areas where wild dogs are active. Sheep that have been bitten often drift towards the rear of a mob, and can frequently be seen hobbling behind. They sometimes remain close to water, although if the injuries are severe they may be unable to move at all.

Sheep showing signs of injury should be examined for bite marks and blood, particularly on the hind parts. As noted above, wild dogs often bite the hindquarters, causing easily identified injuries. Rams use their horns to deter wild dogs from frontal attacks and tend to suffer more rear attacks than other sheep. A torn scrotum or sometimes even complete castration may be found (Figure 11e).

Damage to the head or neck area of sheep usually results in a quick death, so almost invariably animals found with these injuries are already dead. Any doubts about the cause of substantial injuries can be easily solved by post-mortem examination.

Occasionally sheep bearing scars or fresh bite marks from wild dog attacks are discovered, particularly at shearing (Figure 11f). Care should be taken to distinguish bite marks from shearing or wire scars. Few sheep recover from severe wild dog-inflicted injuries; blood loss, shock, infection and inhibited movement are probably the most important factors in later death (Figure 11g).

Injured lambs are rarely found in rangeland areas, as they seldom survive a wild dog attack. In areas of prime lamb production in eastern Australia, a number of lambs may be injured or killed by wild dogs while the accompanying ewes are left unscathed.

Figure 11: Dingo predation on sheep showing: (a) ewe killed by dingoes, note blood on ground but little external damage apparent; (b) sheep attacked at rear end, note pattern of blood stain which took place when sheep was standing; (c) skin revealing tooth punctures, bleeding and tissue damage, clearly distinguishable from undamaged portions of the carcass; (d) tooth punctures and bruising revealed in a decomposing carcass by pulling out neck wool; (e) ram with damaged scrotum following dingo attack; (f) scrotum of ram showing scars from a previous dingo attack; (g) sheep severely injured by dingo attack that would not have survived (Source: P. Thomson).

(a) Traditional form of dog fence which is prone to breaching and expensive to construct and maintain (Source: P. Fleming); (b) Electric fence replacing old netting fence behind (Source: P. Bird, Animal and Plant Control Commission, South Australia); (c) Solar panel providing charge for electric fence (Source: P. Bird, Animal and Plant Control Commission, South Australia); (d) An alternative to a full electric fence is the placement of electrified outriggers (Source: Queensland Rural Lands Protection Board).

Indirect losses

Estimating losses caused by general harassment and mismothering is difficult. Mismothering is the most significant cause of neonatal lamb loss in merino sheep but it is difficult to distinguish from that caused by wild dog harassment. Producers sometimes become aware of the presence of wild dogs in sheep paddocks by observing unusual behaviour of sheep, such as sheep avoiding usually favoured grazing areas, or exhibiting panicky behaviour. Wild dogs sometimes chase sheep through fences into waterless areas, causing further indirect losses. Such instances can sometimes be positively identified by tracking back to where the chase took place.

> ***'Long-term branding figures with coincident data on wild dog control can reveal a predation effect not apparent from carcass counts.'***

Evidence of wild dog predation of cattle may be carcasses (rarely), lower-than-expected numbers of calves at branding, or numbers of injured or scarred calves or weaners at muster. The latter may be indicative of indirect production losses that are not evident from livestock audits. For example, in the coastal hinterland of eastern Australia, calves injured by wild dogs seldom recover from bites that invariably become infected and fly blown (P. Fleming pers. obs., 1989–91). If calves recover, they usually remain unsaleable even after a considerable convalescence. Long-term branding figures with coincident data on wild dog control can sometimes reveal a pattern suggesting a predation effect not apparent from carcass counts (Allen and Gonzalez, 1998).

6.3.2 Environmental impacts

The exact nature of past and present impacts of wild dogs on native fauna is unclear (Sections 3.2 and 3.6). In areas where there is a conservation goal to maintain dingoes, it must be accepted that there will be predation on native species. Depending on the size of the area, and the degree of disturbance that the environment has been subjected to, dingoes and prey would be expected to remain in an ecological balance. Only in situations where a remnant population of a particularly vulnerable prey species was at risk of extinction might a deliberate reduction of dingo numbers be considered (Section 3.6). Predation impact would be estimated by observing and monitoring populations of the prey species. In these situations, the secondary effects of any predator control campaign must be considered. There is some evidence, for example, that the removal of dingoes has resulted in an increase in the number of foxes in some areas (Sections 2.10.1 and 3.6). If this occurs, these smaller predators may pose a greater threat than dingoes to some native mammals.

6.4 Control techniques

A variety of control techniques are available to manage the impact of wild dogs on livestock production. These include the famous 'dog fences' of eastern Australia which aim to physically exclude dogs from the livestock grazing areas, the laying of poison baits, as well as specific techniques such as trapping and shooting to remove individual animals.

In many cases, a combination of methods may be used. Choice of control technique depends on a number of variables, such as the type and value of livestock being protected, the presence of, and the potential risks to, non-target animals posed by each control technique, the size of the area being protected, the accessibility of the terrain and the humaneness of the technique. The management strategies developed for a particular region (Chapters 3 and 5) will take these factors into account, along with an assessment of the cost-effectiveness of the various options.

6.4.1 Exclusion fencing

Exclusion fencing remains a popular method to prevent the incursions of wild dogs into sheep-grazing lands. Fencing ranges from the famous 'barrier' or 'dog fences' (Section 5.1), which aim to keep wild dogs from moving into huge sections of various States, to

Figure 12: A wire-netting wild dog-proof fence in north-eastern New South Wales. The fence has a single electrified outrigger wire and logs placed at the bottom to prevent damage by macropods (Source: P. Fleming).

Figure 13: New wire-netting fences like this one are rarely constructed because of the cost. The fence is 1.8 metres high with the bottom half constructed with rabbit-proof netting and the top with lighter, marsupial-proof netting. A 25 centimetre flap of rabbit-proof netting is either buried or laid flat on the ground to prevent wild dogs, rabbits and macropods from digging under the fence (Source: P. Fleming).

shorter fences maintained to protect individual or groups of properties. Traditionally, exclusion fences have been constructed from wire netting, but electric fences are now used in some areas. Netting barrier fences are usually about 1.8 metres high, constructed either entirely from marsupial netting or with the bottom half rabbit-proof netting (Figure 12). To prevent wild dogs getting under the fence, approximately 30 centimetres of netting is turned out (and sometimes buried) at the bottom on the wild dog side of the fence. These fences are expensive to construct ($8500 per kilometre; Bird et al. 1997). Marsupial netting is no longer manufactured and new fence designs using 1.8 metre high prefabricated deer fencing have been developed (Figure 13) at a cost of $5000 per kilometre for materials only (B. Harden, unpublished data 1999).

'The electrified outrigger proved to be a relatively inexpensive method of increasing the security of older fences.'

The security of 35 kilometres of netting barrier fencing under landholder management in north-eastern New South Wales was examined monthly for two years (B. Harden, unpublished data 1991–93). Fence maintenance was inadequate on four of the six properties (there was a hole a wild dog could use on average every 60 metres) and on some properties maintenance tended to be left until stock were killed. On average, a new hole was made in each kilometre of fence every 18 days. Approximately one-third of holes were made below ground level and another third just above ground level. Almost all (93%) were caused by animals, predominantly macropods, echidnas (*Tachyglossus aculeatus)*, wild dogs and foxes. Wild dogs regularly moved through the fence on four properties, although not all incursions resulted in stock losses. Sheep were killed on three properties, including one with a well-maintained fence. The wild dog responsible for losses on the latter property crossed the fence on an adjoining property then moved between properties inside the fence, illustrating the need for cooperation between neighbours in fence maintenance.

Snare trap being dug in beside a fence along which wild dog movement is likely (Source: Queensland Rural Lands Protection Board).

Recently, effective all-electric barrier fences have been developed in South Australia as a cheaper alternative to traditional netting fences (Bird et al. 1997). A number of designs were tested and the researchers found that simple, upright seven or eight-wire, 975 millimetre-high electrified fences excluded most dingoes. The most effective design was a seven-wire upright fence, with 900 millimetre-wide wire netting placed to a height of 400 millimetres, with the remaining 500 millimetres turned out on the ground to form a skirt on the dingo side of the fence. Two of the four wires above the netting were electrified. This fence cost $3700 per kilometre and excluded dingoes for the 69 months of the trial. A cheaper alternative ($2700 per kilometre) that prevented dingo incursions for 46 months was a 10-wire electric fence with the bottom 4 wires sloping to the dingo side of the fence at an angle of 45° to the vertical. Bird et al. (1997) concluded that the maintenance cost of this fence was likely to be less than that for the fence with the netting, particularly in areas where corrosion rates are high.

The increased security provided by adding an electrified outrigger near ground level on the wild dog side of existing old netting barrier fencing has also been evaluated (B. Harden, unpublished data 1992–94). An electrified wire was added to alternate one kilometre lengths of six kilometres of barrier fence in north-eastern New South Wales, and the fence was inspected and repaired monthly for two years. The electrified wire was run on Insultimber™ posts 300 millimetres from the fence and 210 millimetres above the ground. There was an earth return wire 50 millimetres above the ground and the barrier fence netting was also connected to the energiser earth. This wire spacing was wide enough to prevent trapping (and killing) echidnas under the electrified wire while preventing dingoes from reaching the bottom of the barrier fence without contacting the live wire. The rate of hole formation was lower in almost all months in the sections of electrified fence (average one hole per ten days per kilometre) than the non-electrified sections (one hole per six days per kilometre). Macropods, echidnas and foxes caused the majority of holes. In the two years of study, no dingoes or foxes breached the electrified sections from the outside, whereas four holes were made by dingoes, and five by foxes, in the non-electrified sections.

The total cost of the electrified outrigger was $900 per kilometre. This proved to be a relatively inexpensive method of increasing the security of older fences. Although the electric fencing components required little maintenance, the annual cost of maintaining the barrier fence itself was high. Most of this was the labour cost of inspecting the fence, so the annual cost was largely a function of the number of inspections. The annual cost of weekly inspections was $230 per kilometre of fence while the annual cost of monthly inspections was only $80 per kilometre. The 'best' inspection interval is a trade-off between security and cost.

One of the most important but often neglected aspects of electric fencing is proper earthing. Australian soils are usually very dry and are poor conductors, so electric fences will not work effectively unless they are properly earthed. For the control of wild dogs, it is recommended that one or more earth return wires be incorporated in the design to overcome poor soil conductivity; dogs contacting both the live and earth return wires simultaneously then receive the full shock (Gallagher 1991).

Well-designed netting and electric barrier fences are expensive to erect and to maintain but offer relatively continual protection from wild dog predation if well maintained. Adequate maintenance is the crucial issue; without this, the fence may do little more than create a false sense of security.

6.4.2 Shooting

Wild dogs are seldom seen during the day and are especially wary where they are subject to persecution by humans. Shooting is therefore generally regarded as an opportunistic method of wild dog control (Harden and Robertshaw 1987). Exceptions to this are situations where hunters 'howl up' and then shoot wild dogs or where a particular dog establishes a regular pattern of visiting a particular paddock or site and can be specifically targeted. Organised wild dog 'drives', where wild dogs are flushed into a line of shooters, were often unsuccessful and are now rarely undertaken. However, exceptions may occur. For example, a respondent to a survey by Fleming in 1985 (P. Fleming, unpublished data 1985) told of 40 men, in response to sheep losses over a period of months and unsuccessful trapping and poisoning campaigns, undertaking a dog drive in which only one wild dog was shot. No further sheep were killed for several months, indicating that the control was successful and the benefits made the effort worthwhile. Generally, shooting is not an appropriate technique to reduce populations of wild dogs over extensive areas.

'Generally, shooting is not an appropriate technique to reduce populations of wild dogs over extensive areas.'

A .22 calibre rifle is suitable for the humane destruction of wild dogs caught in traps. For free-ranging wild dogs, a high-powered centre-fire rifle should be used (minimum .222 calibre). The head or chest should be targeted, so that death is rapid. Less powerful weapons such as the rimfire .22 calibre should not be used for free-ranging wild dogs because of the greater risk of non-lethal wounding.

Drying the surface of meat baits prior to injecting with 1080. In some areas, complete (rather than just surface) drying of baits may reduce non-target risks (Source: L. Allen, Department of Natural Resources, Queensland).

In the Fortescue River region of Western Australia, the 'Judas' technique was used to remove specific dingoes. Radio-collared dingoes were regularly followed up by tracking and observation from an aircraft (Thomson 1992a). These dingoes were generally lone individuals that often formed associations with other lone, uncollared dingoes in the area. When uncollared dingoes were seen with the Judas individuals, the animals were followed to a resting site, and a marksman on the ground was guided into the site by an observer in the aircraft. The method was expensive but extremely effective, with over 30 uncollared dingoes being selectively shot. When the collared dingoes were eventually shot as well, the sheep paddocks had been completely cleared of dingoes. Although effective control was achieved, it is unlikely that this technique would ever be economically justifiable for an individual grazier. In arid South Australia, aircraft are occasionally used for spotting dingoes that have breached the dingo fence. Ground shooters were guided to and shot about 30 dingoes in two days on one property following a major breach by dingoes in 1991 (P. Bird, Primary Industries and Resources, South Australia, pers. comm. 1998).

6.4.3 Trapping

Trapping is still widely used against wild dogs in Australia, although in most areas, the emphasis has changed towards more specific targeting of individual problem wild dogs, rather than general population control. In Western Australia for example, trapping is mostly carried out by doggers employed by groups of stations. Individual doggers may cover large areas (areas of one million hectares are not uncommon) and rely on ground baiting and trapping to target wild dogs that have not been killed during large-scale aerial baiting operations (Section 5.1.1). Trapping tends to be used where baiting is less effective, for example, within sheep paddocks, where dogs are less likely to take baits because of the abundant and easily obtained food (P. Thomson, unpublished data 1976–1984).

Trapping has the disadvantage that it is labour-intensive and requires training and experience to be effective. Incorrect setting of traps can be inhumane and also result in target animals becoming trap-shy. Careful selection of trap sites is necessary to reduce the chance of trapping non-target animals (Newsome et al. 1983b). The proportion of non-target animals caught in traps varies according to the suite of animals present in an area and their relative abundance, the experience of the trapper and the type of trap used (Fleming et al. 1998).

'Trapping is usually regarded as an inefficient method of population control and is more effective against targeted individuals.'

In much of Australia, the steel-jawed leg-hold traps used in the past are being replaced by more humane, padded-jawed traps or snares (Fleming et al. 1998; Section 4.2.3). Traps are buried and usually set with some form of decoy (odours or carcasses) to attract the wild dog onto the trigger-plate.

McIlroy et al. (1986a) reported that trapping was more successful than the use of ground baits. Traps captured 56% of known wild dogs whereas baits removed 44%. However, because the control effort was not reported and the methods indicate that it was unlikely to be equivalent for trapping and poisoning, comparisons are impossible. It could be argued that neither technique was successful because a large proportion of the known wild dog population remained after both treatments. The true degree of success of a particular method can only be determined from a measure of the reduction of damage to livestock.

Trapping is usually regarded as an inefficient method of population control and is more effective against targeted individuals. However, a study in the Australian Capital Territory by Don Fletcher and Ian Faulkner (Environment ACT, unpublished data 1998) recorded trapping effectiveness in terms of catch per unit of trapping effort. They found that prior to 1993, trapping effort was largely responsive to sheep losses by neighbouring landowners. In 1995, in response to increased sheep predation, trapping effort was increased ten-fold from 1994. The number of dogs caught per 1000 trap nights declined linearly from 1994 to 1997 and in 1998, approximately 1.5 dogs were caught per 1000 trap nights compared to nearly 4 per 1000 trap nights in 1993.

In terms of cost-effectiveness, trapping is an expensive control option, the majority of the costs being for time and labour. The return for effort of trapping is generally low, often in the order of five wild dogs caught per 1000 trap nights (Fleming et al. 1998). However, this does not necessarily indicate a poor 'success' rate. If the five wild dogs trapped were the last particularly damaging individuals encroaching on a sheep grazing area, the effort could be deemed worthwhile because of the resultant long-term protection from predation. Because trapping is sometimes the only practical option for removing troublesome individual wild dogs, the costs must be weighed against the value of the damage caused.

6.4.4 Poisoning

Poisoning is the most cost-effective lethal technique available to control wild dogs and it is often the only practical means for achieving population control in remote and inaccessible areas.

1080 (sodium fluoroacetate)

1080 has generally replaced strychnine as the poison used in baits for wild dogs in Australia (Section 4.2.4 and Chapter 5). 1080 is also widely used in Australia for the control of other vertebrate pests, particularly rabbits and foxes. It is absorbed through the gastrointestinal and respiratory tracts and affects the central nervous system, causing convulsions. Its use is strictly controlled by government regulations, which restrict the use of the concentrated active ingredient to trained staff of government or semi-government agencies (for example, Rural Lands Protection Boards in New South Wales). Landholders are only permitted to use pre-pared products containing 1080 and then generally only after appropriate training.

Relative to native species, dogs and foxes are particularly sensitive to 1080, so this makes it an appropriate toxin for these species in terms of target specificity. The LD_{50} (the dose of toxin required to kill 50% of test animals) for dingoes is approximately 0.1 milligrams per kilogram of body weight (McIlroy 1981). An estimate of 0.3 milligrams per kilogram for an LD_{100} (McIlroy 1981) means that a 20 kilogram dingo would have to ingest six milligrams of 1080 to ensure a lethal dose. In reality, the LD_{100} for wild dogs is probably somewhat less than this, based on records of large farm dogs that have been accidentally poisoned and killed by eating single fox baits containing 4.5 milligrams or sometimes three milligrams of 1080 (P. Thomson, unpublished data 1999).

'Relative to native species, dogs and foxes are particularly sensitive to 1080.'

1080 is broken down by micro-organisms in the bait, soil and water (Wong et al. 1991). This detoxification is likely to vary considerably between different types of bait, methods of preparation, and temperature and other environmental conditions (Wong et al. 1991). These losses of toxin can be seen as an advantage over the longer term, reducing the extended hazard to domestic dogs and other non-target species that may arise from baits remaining toxic indefinitely. The losses are not, however, justification for raising the 1080 content of baits above the recommended six milligrams per bait. Fleming and Parker (1991) found that baits laid on the surface in north-eastern New South Wales during winter retained enough 1080 to deliver a theoretical LD_{99} for 42 days after injection. Baits collected after 90 days still retained low levels of 1080 although on each sampling occasion, 10% of baits still contained more than 2.0 milligrams of 1080, the theoretical LD_{99} for wild dogs in eastern Australia (Fleming and Parker 1991). Meat baits buried during hot humid weather may be completely decomposed and incorporated into soil within four days (P. Fleming, unpublished data 1993). In drier areas, 1080 may persist in baits for long periods. Twigg et al. (1999) found most surface-laid meat baits (67%) retained 2.5 milligrams or more of 1080 eight months after placement.

'The losses are not justification for raising the 1080 content above the recommended six milligrams per bait.'

Concern is sometimes expressed that not all the 1080 in a bait may be available to the target animal. However, evidence from studies on foxes reveals that this is unlikely to be a practical issue (Saunders et al. 1995). In addition, the target animals often eat more than one bait (Thomson 1986), thereby theoretically ingesting considerably more than the minimum amount of 1080 required to kill them.

A more serious concern about sub-lethal amounts of poison in a bait stems from the fact that 1080 is water-soluble and may be leached from fresh meat baits by rain falling soon after placement (McIlroy et al. 1988; Fleming and Parker 1991). Possible losses of 1080 caused by rainfall immediately after placement must be taken into account. Thus, the suggested national standard 1080 content for a 'dog bait' in Australia of six milligrams (Thompson 1993) is soundly based.

Strychnine

Strychnine can still be used to poison the jaws of traps in Western Australia, South Australia, Queensland and New South Wales. In all States and Territories except Queensland and some areas of South Australia and Western Australia, strychnine has been phased out in baits for animal welfare and non-target susceptibility reasons. It is absorbed through the gastrointestinal tract and acts on the central nervous system, causing violent tetanic spasms (Seawright 1989). Strychnine is an odourless powder with a bitter taste and rapid action. Despite its rapid action, strychnine is less humane in its action than 1080 because it causes deep reflexes, cramps and spasms in the muscles leading to respiratory failure and death (Hone and Mulligan 1982). Strychnine is not a selective poison at the dosages required to kill wild

The use of helicopters allows more precise aerial baiting in rugged terrain (Source: P. Fleming).

dogs (LD_{50} = 0.5–1.0 milligrams per kilogram (Hone and Mulligan 1982) and carnivorous birds and mammals are susceptible to strychnine meat baits. There is also the risk of secondary poisoning (Hone and Mulligan 1982).

Cyanide

Sodium cyanide is a white powder that is highly soluble in water; on contact with moisture, hydrogen cyanide is released. On inhaling hydrogen cyanide or absorbing it through the gastrointestinal tract, a poisoned animal has difficulty in breathing, becomes unconscious, suffers convulsions and dies. This process can be very rapid but death may take up to four hours (Hone and Mulligan 1982) and sub-lethal doses may result in bait shyness. In the USA, cyanide is commonly deployed for the control of canids in a M-44® cyanide ejector and these devices have been tested for the control of foxes in Australia (Busana et al. 1998). When distributed in wax capsules for foxes, cyanide baiting caused many non-target poisonings in north-eastern New South Wales (Thompson 1994), but non-target deaths were rarely recorded in Western Australia during extensive trials (P. Thomson, unpublished data 1992–1997). The main benefit of cyanide over alternative poisons, especially 1080, is its faster action. This is likely to result in a reduced incidence of multiple bait take and hence caching or vomiting of surplus baits by wild dogs, which lessens the risk to farm dogs of accidental poisoning. Cyanide baiting for wild dogs is not currently legal in any State or Territory (Busana et al. 1998).

Bait materials

Three types of bait are used in wild dog control. The first two, moist meat and dried meat, are the most commonly used and are made on-site from meat cut from culled kangaroos (*Macropus* spp.), cattle or horses. Baits are cut to size then injected with six milligrams of 1080, except in the Australian Capital Territory and Victoria, where 4.5 milligrams of 1080 is used, and parts of Queensland where up to ten milligrams of 1080 is surface-applied to baits. In Western Australia pastoralists are also able to make small quantities of baits by inserting an oat grain impregnated with six milligrams of 1080 into the meat; the 1080 leaches from the oat into the meat. Moist meat baits are used immediately but dried meat baits are sun-dried before use to about 40% of their original weight.

The toxicity of moist meat baits declines much more rapidly than dried meat baits (McIlroy et al. 1988; Fleming and Parker 1991; Kirkpatrick 1999). The dry baits are quite hard and therefore difficult for non-target species (birds and small carnivorous marsupials) to eat (Calver et al. 1989).

'The toxicity of moist meat baits declines much more rapidly than dried meat baits.'

The third type of bait is the manufactured Doggone® bait. These baits contain six milligrams of 1080 and are made from a soft meat-like substitute based on meat meal. They also contain fat, preservatives, binding agents and flavour enhancers.

Moist meat baits are used in the Northern Territory (300–400 grams), Queensland (125 grams in western areas and 250 grams in coastal areas), New South Wales (230 grams), the Australian Capital Territory (230 grams), South Australia (150 grams) and Victoria (approximately 125–230 grams). Dried baits are used in South Australia and Western Australia (110 grams wet weight). Doggone® baits (60 grams) are sometimes used in Victoria and the Australian Capital Territory.

Occasionally, meat baits are dyed with tasteless green vegetable dye to reduce the chance of detection and removal by birds (McIlroy et al. 1986b).

Ground baiting

Ground baiting is still an important control method used throughout the country and may be strategic or reactive (Section 7.3.4). Ground baiting allows for baits to be strategically placed to maximise the chances of wild dogs encountering them, at the same time reducing the risks of them being taken by non-target animals. The more strategic placement means that fewer baits are used than in aerial baiting operations.

Studies (Best et al. 1974; McIlroy et al. 1986a; Bird 1994; Fleming 1996a) of the effectiveness of ground baiting have revealed widely varying results. Variable results can be attributed to: the availability of natural food (Best et al. 1974; Thomson 1986); the removal of multiple baits by a single wild dog (Bird 1994; Fleming, 1996a); removal of baits by non-target animals (particularly ants, foxes and birds; Newsome et al. 1972; Allen et al. 1989); the number of baits available (or remaining) for the target animals to find (Fleming 1996a); and the attractiveness of the baits (Allen et al. 1989). There is evidence that burying baits reduces the take by most non-target animals (particularly birds) without reducing the uptake by wild dogs (Allen et al. 1989). Fleming (1996a) used buried baits and reported a very low removal by native non-target animals. For this reason, bait mounds are used in the forests of south-eastern New South Wales, the Australian Capital Territory and north-eastern Victoria. Bait mounds are bait stations comprising one or more baits buried in a mound of earth and often surrounded by an area of raked soil. The raked soil allows the identification from footprints and other signs of animals visiting the station. If a baiting program is conducted with an initial free-feeding period when unpoisoned baits are placed in the mound, visits by non-target animals can be identified and only mounds visited solely by target species refilled with poisoned baits.

'Burying baits reduces the take by most non-target animals without reducing the uptake by wild dogs.'

The use of bait stations is becoming more common. Replacement-baiting in bait stations was suggested by Thompson and Fleming (1994) as a method where baits are replaced as they are removed by foxes over a period of ten days or so to reduce the bait-susceptible population to near zero. Fleming (1996a) showed replacement-baiting is a successful method for reducing wild dog and fox numbers in eastern New South Wales. It is cheaper than aerial baiting and requires less skill and experience than trapping. Ground baiting remains a primary control tool in many accessible areas because the placement of baits can be better controlled.

Some doggers are reluctant to use 1080 baits because the carcasses of baited animals are seldom found. This means that it is more difficult to tally a definite 'kill' and some see this as a lost opportunity to retrieve scalps for bounty payments. These operators prefer to use traps instead. This is a major practical drawback of bounty or bonus payments, and one that managers need to take into account. In many instances, baiting is a more cost-effective technique, with trapping only being desirable to target specific individual dogs.

Aerial baiting

Aerial baiting using 1080 baits is a cost-effective method for the strategic management of wild dogs over large areas (Thomson 1986; Thompson and Fleming 1991). It is also an effective means of delivering baits in remote and inaccessible areas where ground-based operations are impossible or impractical. Aerial baiting began in Western Australia and Queensland in 1946 (Tomlinson 1954). Subsequently, considerable improvements to the materials and operations have been made.

'Helicopters allow more accurate delivery of baits in rugged mountain areas.'

Fixed-wing aircraft are the most suitable for dropping baits in flat terrain whereas the manoeuvrability of helicopters allows more accurate delivery of baits in rugged mountain areas (Thompson et al. 1990). Baits are dropped through a chute in the aircraft on the command of a navigator with local knowledge of wild dog activity. Increasingly in New South Wales and Western Australia, the aircrafts' flight-paths are automatically logged into an on-board global positioning system (GPS), providing accurate records of baiting operations. A future development in Western Australia will be the incorporation of sensors into the bait chute so that the location of each bait dropped will also be automatically logged.

Timing and frequency of baiting

The question of when and how often baiting should be carried out is frequently raised but there is no simple answer. Variables include resources (usually dollars), value and vulnerability of the livestock being protected, availability of alternative prey for the wild dogs being targetted, and season (weather, availability and distribution of water, stage of the breeding cycle).

'Aerial baiting is usually repeated on an annual cycle.'

Traditionally, baiting campaigns in Western Australia (Thomson 1986) and Queensland were carried out in autumn (late April–May) and spring (September–October). Autumn coincided with the breeding activity of dingoes when mating takes place and bitches are in early pregnancy. Spring coincided with the time when pups begin to move about, removing the restrictions on movements associated with denning (Thomson 1992d), and increasing the likelihood of animals encountering baits. Food demands are also likely to be high for groups of dingoes at this time, and in northern areas surface water becomes more restricted, making it easier to target the limited number of waterholes with baits. This approach is still followed, although baiting is often now only done in spring in Western Australia. Baiting earlier in the year is sometimes abandoned due to cost and the possibility of rain reducing the life of the baits (due to leaching of 1080). In some areas, baiting even later in the year has been considered, when the availability of water is even more restricted.

In eastern Australia, aerial baiting is usually conducted in late autumn and winter. This is because:

- Baits distributed in autumn and winter last longer than those distributed in spring and summer (Saunders and Fleming 1988; Fleming and Parker 1991), as baits may decompose in a few days in the conditions of high temperatures and humidity, or may be quickly removed by ants (Fleming 1996b).

- Bait take by non-target species that are less active in cooler weather, such as goannas (*Varanus* spp.), is reduced.
- The population of wild dogs is potentially at its lowest prior to whelping in spring and so a given proportional reduction in abundance in autumn and winter equates to a smaller remnant population than in spring and summer.
- In eastern New South Wales most of the aerial baiting occurs in areas of extensive cattle enterprises adjacent to sheep country and mustering is usually completed by winter reducing the chances of working dogs being baited while spring mustering.
- Lambing in north-eastern New South Wales is most common in spring and baiting conducted in winter prior to lambing is sensible.
- Movements of wild dogs are traditionally believed to be greatest in autumn and winter when young dogs are dispersing and mating is occurring.

Aerial baiting is usually repeated on an annual cycle. Fleming et al. (1996) found that indices of wild dog abundance taken prior to annual aerial baiting in north-eastern New South Wales were similar between years indicating that the wild dog population had recovered during the year following the previous baiting. In some areas, there may be occasions when baiting in buffer areas or baited zones (Section 6.2.1) could be missed in some years without jeopardising livestock (Thomson 1986). However, this could be a risky undertaking unless detailed information was available on how many wild dogs were in an area, how many were breeding, and food supply. Otherwise, the safest precautionary action is to bait the known problem areas on an annual basis.

Baiting strategies

One of the concerns raised about the application of haphazard control efforts is that the disruption caused by killing a few members of a pack could lead to increased pup production (Section 2.8). This could lead to rapid repopulation and possibly even an increase in dispersal from such an area. Therefore, strategies should be developed for baiting and other control efforts.

'A buffer zone is more efficient than controlling populations less intensively over much larger areas.'

The use of poison baiting is either strategic or reactive (Section 7.3.4) and this affects how it is conducted. Reactive baiting is in response to predation incident(s) and is usually conducted at the property level and continues until the offending animal(s) are killed and predation stops. It is essential that this facility remains available to graziers particularly so that they can respond to the occasional failure of strategic programs.

It is clear from studies in various parts of Australia that the movements of wild dogs are usually limited. It is rare for individuals to make long-distance forays beyond their normal range, refuting the commonly-held notion that wild dogs regularly travel large distances overnight to attack livestock. In addition, there is little evidence that dingoes or other wild dogs undertake any seasonal migration. Under severe conditions, dispersing wild dogs may congregate around a limited resource (for example, a waterhole), possibly giving rise to the notion that some form of 'migration' had taken place. Wild dogs do not engage in the annual juvenile dispersal more common among less social canids such as red foxes (Saunders et al. 1995), however, individual wild dogs do occasionally disperse (Thomson et al. 1992a; P. Fleming and D. Jenkins unpublished data 1999). It follows that wild dogs that reside within paddocks or adjacent areas pose the greatest danger to livestock. Control activities should therefore be focused in these areas.

The introduction of aerial baiting enabled wild dog control to be undertaken over large areas adjacent to areas where livestock were grazed. Thomson (1984b) investigated the value of baiting within these adjacent areas (buffer zones) to protect livestock from predation by dingoes in Western Australia and found that it was reduced or eliminated for two or more years after buffer zones were established.

The strategy of creating a buffer zone (Thomson 1984b), approximately one or two wild dog home ranges wide, adjacent to stocked paddocks is based on the rationale that by removing most resident wild dogs a 'dispersal sink' results. This effectively encourages dispersing wild dogs to settle rather than keep moving to reach the paddocks and is more efficient than to attempt to control populations less intensively over much larger areas. With a well-established buffer zone, constant control work is unnecessary. However, monitoring and periodic maintenance control work is needed to avoid any substantial build-up of numbers in the buffer zone. The buffer zone concept forms the basis of most aerial control programs in Western Australia (Thomson 1986) and northern New South Wales (Fleming et al. 1996). The environments and the size of holdings in north-eastern New South Wales are vastly different from Western Australia and buffer zones of two home range widths are not practicable. Baiting is focussed at the interface between sheep country and wild dog country (Fleming 1996b).

In South Australia, a buffer zone of up to 35 kilometres has been recently established outside the Dog Fence (Animal and Plant Control Commission 1993). The aim of the buffer is to reduce the incursions of wild dogs through the Dog Fence and decrease the vigilance required to maintain the Dog Fence in dog-proof condition.

6.4.5 Control at breeding dens

The practice of locating breeding dens (Section 4.2.5) has diminished as a routine seasonal activity and tends to be undertaken opportunistically. In areas where bounties are paid, there is sometimes a tendency for doggers to delay targeting pregnant bitches until pups are born and 'collectable', increasing the tally of scalps and therefore payments received. This is a further example of how bounty payments can influence control work in an undesirable way.

6.4.6 Sheep-guarding dogs

In North America and some areas of Central Europe and the Mediterranean, special dogs have been bred to guard sheep from predators including coyotes (*Canis latrans*) and wolves (*Canis lupus* ssp.) (Copinger and Copinger 1978). These large dogs live in the paddocks with sheep as part of the flock and chase off or kill other canids that approach their flock.

In Australia, two breeds, Anatolian karabash and maremma, have been used to protect sheep and goat flocks from predation by wild dogs and foxes. Sheep-guarding dogs have not been experimentally tested in Australian conditions but studies in the United States of America (USA) have given uncertain results. Although sheep producers with sheep-guarding dogs suffered fewer predation losses to coyotes than those without (Andelt 1992), results are inconsistent (Green et al. 1994). In Victoria, maremmas have been used to reduce stock losses from 10% to 3% in eight years since their first use (Balderstone 1992) and have been used successfully for approximately ten years in preventing predation by free-roaming dogs at Livingstone Farm, Moree in northern-central New South Wales (G. Esdaile, University of Sydney, pers. comm. 1986; Balderstone 1992).

6.4.7 Aversive conditioning and toxic collars

Aversive conditioning is the process of training a predator to avoid an activity or place by associating the activity or place with unpleasant experiences. Aversive conditioning of predators with lithium chloride has been the subject of much research (Burns 1983; Gustavson et al. 1983; Tauchmann 1998), although the results have been mixed. Cornell and Cornely (1979), for example, successfully used lithium chloride to deter coyotes from scavenging and begging at camp grounds in a National Park in America but other studies produced inconsistent results. Currently, the use of aversive conditioning is being trialed at Fraser Island to deter dingoes from camping areas.

Toxic collars have been suggested and tried for the control of coyote predation of sheep in the USA (Connolly 1980). The collars contain pouches of toxic liquid such as a solution of 1080. The technique relies on the coyote biting the sheep at the neck, puncturing the collar, and ingesting the toxin. Scrivner and Wade (1986) in a review of field trials, concluded that the collars were found to be an effective method when used in conjunction with other control techniques. The technique was most effective when a group of collared 'sacrificial' animals were isolated from other livestock. Problems experienced included the fact that coyotes sometimes attacked elsewhere than at the throat, collars were damaged or lost (caught on thorns, wire), or collars were pulled out of ideal position on the animal.

The toxic collar technique is labour intensive, and relies on intensive husbandry of livestock and isolation of animals in small areas. It is therefore unlikely to be useful against wild dogs in rangeland areas of Australia, but it might be feasible for use in the more intensive grazing areas. However, the same problems as those identified in the USA are likely to occur in Australia. Like coyotes, wild dogs do not always attack the throat of sheep; for example, in a sample of 133 sheep killed by dingoes in Western Australia, 56% had received mortal wounds to the throat (Thomson 1984a). Welfare concerns may well be raised about the notion of sacrificing sheep to wild dogs, particularly if other methods are available to prevent attacks in the first place. In addition, the use of 1080 in this way may breach current State or Territory regulations or policy on 1080 use. At present, there are no other obvious candidate toxins available. Interest in toxic collars has been shown in Queensland (L. Allen, Queensland Department of Natural Resources, pers. comm. 2000).

6.4.8 Livestock management strategies to reduce or prevent predation

The most obvious management strategy to avoid the predation of sheep by wild dogs is enterprise substitution, where sheep are completely or partly replaced by cattle. This strategy has been employed by some producers in the sheep zone of northern Queensland outside the current Dog Fence (L. Allen, Queensland Department of Natural Resources, pers. comm. 1997). This was in part caused by changes in profitability of sheep and cattle production and seasonal conditions. Similar changes have occurred in eastern New South Wales. When the margin from sheep production becomes too low, relatively low levels of predation may limit profitability and the high cost of enterprise substitution may become beneficial.

> ***'The most obvious management strategy to avoid predation is enterprise substitution.'***

Enterprise substitution is not always possible because the land may be better suited for sheep production and the cost of replacing sheep with cattle can be high. There is a time-lag between setting up the cattle enterprise and the receipt of income, particularly in breeding enterprises and the lack of cash-flow may be limiting in the first phases. Change of enterprise also raises the level of risk because of the delayed returns expose the producer to greater likelihood of unfavourable seasonal conditions. Lean cattle are severely discounted or unsaleable whereas lean sheep still produce wool. The knowledge base required to become a successful cattle producer is not the same as that required for successful wool or sheep meat production. There are important emotional consequences suffered by producers who regard themselves as sheep graziers and therefore find the change to cattle production difficult. These factors must be considered before substituting cattle for sheep.

In eastern Australia, in dog-inhabited areas where both sheep and cattle are grazed, predation of calves is rare (Fleming and Korn 1989). Graziers put cattle in paddocks close to timbered wild dog refugia and sheep in paddocks further away so that the cattle can provide an internal buffer to predation. Similarly in South Australia, sheep graziers often run cattle in paddocks adjacent to the Dog Fence where risks of predation are greatest. Although this strategy has not been formally tested, logic and circumstantial evidence suggest that it reduces predation of sheep. Other graziers run wethers in paddocks closer to wild dog refugia and graze their breeding sheep further away. While this strategy may not reduce the incidence of predation, the economic consequences of predation are lessened because profitability of breeding ewe enterprises is most strongly linked to lambing and weaning rates and because genetic material is less likely to be lost.

'Most calves killed by dingoes during these periods do not result in economic losses because calves cannot survive long droughts.'

On the Barkly Tableland of the Northern Territory, the dingo mating season coincides with the peak in calving and calves. At this time dingoes move around a lot and are often seen together with calves at watering points (Corbett 1995a). This contributes to the deaths of many calves. Therefore, an appropriate management option would be to manipulate cattle herds so that fewer calves are born in the dingo mating season. Strategic mating of cattle has also been shown to be more economically productive in much of tropical Australia (Sullivan et al. 1992). This management strategy is practised in the Alice Springs region and calf losses are rarely recorded, probably because the peak of the calf drop (September and October) does not coincide with the dingo mating season. Although droughts in the Alice Springs region are unpredictable in frequency and severity, the effects of wild dog predation are predictable and pastoralists can benefit from this factor in the following three ways (Corbett 1995a):

- In the Alice Springs region, high numbers of dingoes are maintained because human control methods effectively increase the numbers of breeding dingoes and because abundant natural food ensures the survival of most pups. During runs of flush years, dingoes eat mostly rabbits and rodents, but in the middle and latter years of drought, dingoes survive well on cattle (Figure 10a), usually carcasses. Most calves killed by dingoes during these periods do not result in economic losses because calves cannot survive long droughts. In fact, such calf losses are probably an advantage to pastoralists because the mother's chance of surviving the drought is increased if she has no calf to feed. Thus, in situations like this, dingoes benefit pastoralists by helping breeders survive droughts and the management strategy is easy: relax dingo control in droughts.

- Management decisions during the initial periods of droughts are complex. After a few dry months, the populations of small native mammals and rabbits decline before cattle begin to die. Dingoes therefore have no choice but to tackle large kangaroos or kill calves, so dingo control is necessary. If the drought breaks after a few months, such calf losses are indeed economic losses (Figure 10b). Since the losses are beneficial if the drought continues, when should a pastoralist heighten or relax dingo control? One pastoralist in central Australia is reported to have shot calves, not wild dogs, after the first seven months of a drought, and also to have swapped truckloads of his calves for hay from farmers in southern Australia. It was also reported that this property recovered from the drought much earlier than neighbouring properties, which suggests that predation by dingoes and destocking both work well. A strategic approach for drought management in northern and central Australia is provided in RANGEPACK (Stafford-Smith and Foran 1990).

- The presence of dingoes may also benefit pastoralists immediately after drought. Rabbits and small native mammals quickly resurge when rain comes, and wild dogs concentrate on them (Figure 10b). If dingoes numbers are high due to relaxed control effort during the drought, the heavy predation will hold down rabbit numbers so that they take longer (perhaps two years) to reach their former levels. This gives a pastoralist more time to establish other forms of rabbit control (Williams et al. 1995) before they become a serious problem again. In effect, wild dogs and pastoralists work in tandem this way to control rabbits and other grass-eating competitors of cattle.

6.4.9 Biological control

At present, there are no biological control agents suitable for use against wild dogs (Section 4.2.7). With the goal to protect dingoes in conservation areas in Australia, it is unlikely that any self-disseminating means of fertility or lethal biological control of wild dogs would ever be sanctioned. Domestic dogs would also require protection against such an agent.

It is possible that with advances in molecular biology, some form of agent could be developed that is specific to dogs, targeting hormones or proteins important in the reproductive process (Tyndale-Biscoe 1994). However, this would need to be bait-delivered to avoid the problems already outlined. There may be little practical benefit of such a bait, unless it was target-specific and could be used in specific areas where toxic baits are perceived as posing too great a risk to other fauna such as quolls (*Dasyurus* spp.).

6.4.10 Livestock insurance and compensation schemes

In USA, damage compensation schemes have been instigated for coyote damage to sheep flocks, ungulate damage, and bear (*Ursus* spp.), wolf and mountain lion (*Puma concolor*) predation (Wagner et al. 1997). Such schemes recognise the national benefits of conservation of native wild animals (such as the dingo) without farmers bearing the costs associated with the presence of those animals.

An alternative to spending money on control of wild dog populations and barrier fences is the introduction of compensation schemes. These may be self-funding, funded by government agencies or by a combination of rates and subsidies. There are risks associated with compensation schemes, as they are reliant on the financial reserves of the scheme and the honesty of claimants. Self-funding schemes, with in-built checks such as validation of claims by independent agents, potentially overcome the problem of dishonesty but do not address funding limits. A self-funding compensation scheme might best be operated like an insurance program where annual rates (equivalent to insurance premiums) are levied on all holdings including government lands, and distributed to affected landholders in response to losses verified by an authorised person. If no claims are made, the funds might be invested and the rates recalculated. Farmers should be encouraged to minimise damage by rate reductions for predation mitigation and compensation should not be open ended (Wagner et al. 1997). The feasibility and operation of a compensation or insurance scheme requires investigation under the different agricultural systems where wild dog predation occurs before such a scheme is implemented.

6.5 Costs of control

There are a number of techniques for measuring the costs of control programs. The most basic in which all the costs of the control program are added together at the end of the program is adequate for planning in many cases. For example, the helicopter time used for the annual aerial baiting program in north-eastern New South Wales is collated each year so that costs can be projected during planning and price rises accounted for (A. Barnes, NSW Agriculture, pers. comm. 1998). Helicopter time accounts for approximately 50% of the total cost of baiting (Thompson and Fleming 1991) and so is a useful index of costs. Thompson and Fleming (1991) also found a strong linear relationship between the amount of meat used and the total cost of aerial baiting in 1988. Similarly, the costs of fence maintenance and erection could be estimated using the cost of materials per kilometre, the time required, the cost of labour and the distance to be repaired, built or modified.

More complex evaluations of control programs are not commonly attempted. Benefit–cost ratios are simple estimators of the effectiveness or the efficiency of a program (Hone 1994; Case study 2 in Section 7.7.2). These analyses have usually been applied to government-subsidised control programs. For example, in Victoria during the 1980s, much of the control of wild dogs was undertaken by 21 doggers who were employed by the State (Mitchell 1986). A benefit–cost analysis showed that the agricultural benefits were hard to estimate because of the externalities including the absence of livestock production estimates from comparable areas with unmanaged wild dog populations. However, the control program was considered beneficial when productivity gains needed to break even were compared with the productivity gains that were experienced in areas where control occurred. A number of problems associated with analysis of cost-effectiveness were raised including that the indicator of cost-effectiveness should be compared over years; and the measurement of effectiveness should not be the simple calculation of the cost per wild dog killed because trapping return for effort decreases exponentially as the population declines towards zero (Mitchell 1986).

'Graziers commonly regard their control activities as an insurance policy against stock losses.'

Marginal analysis (Leftwich and Eckert 1982; Hone 1994; Box 3 in Section 7.4) aims to allow a producer to estimate the increased margin (profit) from an enterprise that can be made from different levels of input. However, marginal analysis appears to be of limited use for evaluating the economics of control methods for wild dogs because of the high variability in the nature and extent of predation. For example, the flexible nature of wild dog society, prey switching, and surplus killing all affect the relationship between wild dog abundance and livestock predation, that is, the damage function. Fleming and Nicol (unpublished data 1999) have evidence from northern New South Wales that, while the damage function is significantly linear, the function is a poor predictor of damage at different densities of wild dogs. Thomson's (1984a) data indicate that, in Western Australia, where sheep and wild dogs co-occur, predation of sheep is inevitable. This is the underlying assumption of control strategies aimed at reducing wild dog abundance and buffer zone strategies (Thomson 1984b; Fleming 1996a). The variability of damage makes marginal analyses of control methods difficult (Box 3 in Section 7.4).

Another method of evaluation is to compare the cost of control with the potential savings. This is a comparison of costs with potential benefits rather than achieved benefits. For example, a survey of participants in the 1988 aerial baiting program on the Northern Tablelands of New South Wales costed that single operation at $152 750 (Thompson and Fleming 1991). The cost per participant was $540 of which $350 was subsidised by the New South Wales Government in recognition of the control that private landowners conducted in government lands. The costs of the aerial control program in 1988 were equivalent to the loss of 7.5 wethers per landholder (Thompson and Fleming 1991) and this was the potential benefit.

The cost per unit effort of control is another method of estimating the cost of control. Table 5 shows the effort expended on control of wild dogs in a number of surveys in northern New South Wales. The Table shows that the amount of labour expended on wild dog control decreased after the advent and widespread use of aerial baiting in north-eastern New South Wales. Greater value can be gained from such comparisons if the potential and real benefits are calculated simultaneously.

Most commonly, graziers regard their control activities as an insurance policy against stock losses. That is, if control is not exerted, damage will occur and continue to occur until the offending dog is removed, so that money spent now is money saved later. The second assumption underlying control programs is that there is a positive relationship between the abundance of wild dogs and the probability of damage. Where buffer zones are used, the assumption is that reducing the population of wild dogs in the buffer will reduce the impetus for emigration of wild dogs to the adjacent grazing land where predation then becomes inevitable (Thomson 1984a). If these are the underlying assumptions, then the strategy must be to achieve the greatest reduction in the probability of predation for the lowest possible cost. The cost is not open-ended; funds for wild dog control in this case are usually allocated on the basis of how much a particular program costs and available cash flows.

Table 5: The effort expended for the control of wild dogs by landholders in north-eastern New South Wales. Data were collected from members of Wild Dog Control Associations or equivalent organisations.

Year	Major method of control	Control effort (hours/property/year)	Source
1962[a]	Dog-proof fencing, hunting, trapping	39.3	New England Rural Development Association (undated c. 1966)
1981	Aerial baiting (fixed-wing aircraft), fencing	15.9	Schaefer (1981)
1985	Aerial baiting (fixed-wing aircraft), fencing	12.5	Saunders and Fleming (1988)
1988	Aerial baiting (helicopter), fencing	11.6[b]	Thompson and Fleming (1991)

[a]First aerial baiting conducted in 1962 but widespread use did not occur until after 1965.

[b]Control effort for aerial baiting alone.

6.6 Environmental and non-target issues associated with 1080 baiting

6.6.1 Environmental risks

The environmental fate of 1080 has been studied more extensively than any other vertebrate pesticide, particularly in New Zealand, where possum (Phalangeroidea) and rabbit control accounts for approximately 70% of the world-wide use of the toxin (Eason et al. 1998). These authors report that sodium fluoroacetate does not bind to soil constituents and is detoxified quickly by soil organisms, the rate depending on soil temperature and moisture. Only very small quantities are absorbed by plants so there is a negligible risk of poisoning herbivores. None of 857 surface water samples collected immediately after aerial baiting programs for rabbits or possums exceeded the acceptable (New Zealand) concentration for drinking water of five parts per billion. Because of very low concentration of 1080 applied to the environment, and the rapid biodegradation of the toxin, wild dog baiting is very unlikely to cause environmental hazards.

6.6.2 Risks to non-target species

McIlroy (1981) tested a number of native species potentially at risk of poisoning during 1080 baiting campaigns. On a weight-for-weight basis, native mammals are more tolerant of 1080 than dogs. Birds and reptiles are even more tolerant. In Western Australia, King (1989) assessed the northern quoll (*Dasyurus hallucatas*) as being the species most likely to be at risk during baiting campaigns for wild dogs. King radio-tracked a sample of northern quolls during a wild dog baiting campaign and found that all survived, despite conditions of apparent food shortage and potentially enhanced vulnerability. He concluded that populations of northern quolls faced little risk from wild dog baiting campaigns. This also appears to be the case in parts of north-eastern New South Wales where spotted-tailed quolls (*Dasyurus maculatus*) are still abundant after three decades of baiting (B. Harden, unpublished data 1999).

In eastern Australia, the spotted-tailed quoll is considered potentially at risk during baiting campaigns against wild dogs and foxes (Smith et al. 1992; Belcher 1998). Adult female spotted-tailed quolls weigh up to four kilograms and males to seven kilograms, and reach maximum weight in their third year (Belcher 1998).

McIlroy (1981) estimated their 1080 LD_{50} at 1.85 milligrams per kilogram (95% confidence limits of 1.28–2.68) and suggested an LD_{100} at 2.56 milligrams per kilogram. On that basis, a single fresh wild dog bait (6 milligrams of 1080) contains an LD_{50} for spotted-tailed quolls less than 3.2 kilograms, or an LD_{100} if less than 2.3 kilograms in weight. The complete ingestion of one fresh wild dog bait then has the potential to kill a spotted-tailed quoll juvenile of either sex or a small adult female. However, the toxicity of fresh meat wild dog baits declines rapidly after injection of the 1080, reducing the risk to spotted-tailed quolls. In the Australian Capital Territory, McIlroy et al. (1988) estimated that a wild dog bait contained an LD50 for an average-sized (2.8 kilograms) spotted-tailed quoll for 4–15 days after placement in winter but only 2–4 days in summer. In a similar experiment during winter in forest in north-eastern New South Wales, Fleming and Parker (1991) estimated the same reduction in toxicity occurred within two days of bait placement.

1080 ingested by the mother can be transferred in the milk to suckling young. McIlroy (1981) found that more pouch young brushtail possums (*Trichosurus vulpecula*) died than their mothers at each dose level of 1080 he evaluated. Eight pouch young of one northern quoll also died after their mother received a sub-lethal dose, although the five young of a spotted-tailed quoll survived in similar circumstances.

Captive spotted-tailed quolls can locate, excavate and consume fresh meat and non-poisoned commercial fox bait buried to depths of less than about ten centimetres (Belcher 1998; Murray 1998). However, the extent of bait uptake by spotted-tailed quolls during wild canid baiting programs is unclear. In north-eastern New South Wales, Fawcett (1994) and Fleming (1996a) both reported that few buried meat baits were taken by spotted-tailed quolls during baiting programs for the control of wild dogs. Fleming (1996a) concluded spotted-tailed quolls were not as readily attracted to bait stations as wild canids and appeared reluctant to remove buried bait from bait stations. In two extensive Victorian trials with buried non-poisoned commercial fox bait, Murray (1998) also reported low visitation rates by spotted-tailed quolls, and was uncertain that bait was taken by the quolls. While these results indicate that spotted-tailed quolls may take some baits during wild dog baiting programs, they provide little insight into the extent and severity of any impact of baiting programs on spotted-tailed quoll populations. That question can only be answered by field-based research that directly examines bait uptake and the effect on populations.

'It may be possible to target wild dogs and foxes preferentially in areas where they co-occur with quolls.'

Smith et al. (1992) also suggested that poisoning programs to control wild dogs might adversely affect the viability of critical body weight range (CWR) mammals (35–5500 grams) by allowing mesopredator release of fox populations (Sections 3.2 and 3.6). However, Fleming (1996a), at sites in north-eastern New South Wales, showed that fox populations experienced greater impact from a ground-based replacement-baiting (Section 6.4.4) than did populations of wild dogs, and that the remaining populations of wild dogs were more abundant than those of foxes.

The management of wild canids, in areas where spotted-tailed quolls occur, requires thought. Spotted-tailed quolls are likely to have different foraging and movement patterns to wild dogs and foxes, and may be more independent of roads and cattle pads than wild canids (Fleming et al. 1996; Fleming 1996b). Consequently, it may be possible to target wild dogs and foxes preferentially in areas where they co-occur with quolls by using bait buried at bait stations along roads and tracks, as these are commonly used by wild dogs and foxes (Harden 1985; Catling and Burt 1995).

Marks et al. (1999) are investigating the possible benefits of using the M-44® device to distribute 1080 in a more target-specific way. Less 1080 is required and the positioning of the distribution device can be modified to encourage wild dogs to trigger the device and obtain a full dose. Both these factors would reduce the potential for quolls to be fatally poisoned during wild dog control. These devices can also be used to apply cyanide.

7. Strategic approach to management

Summary

There are four stages in a strategic management program for wild dogs at the local and regional level: (1) problem definition; (2) developing a management plan; (3) implementing the plan; and (4) monitoring and evaluating progress.

***Defining the problem** is the first stage of strategic management planning. This involves identifying who has the problem with wild dogs, what the problem is, when, where and why it happens and how much it costs.*

The costs and benefits of reducing the agricultural impact of wild dog predation can be measured in dollars. In some situations, sufficient information is available to estimate the point where the costs of undertaking dog control equal the benefits. However, each situation must be reviewed individually because interactions between wild dog social behaviour and predation may make conventional economic analyses inappropriate.

*The second stage in strategic management planning is the development of a **management plan.** This requires setting management objectives that should include interim and long-term goals, a time frame for achieving them and indicators for measuring performance. Developing a management plan also requires the selection of appropriate management options. Options for pest control include local eradication, strategic management, reactive management or no dog control. A management strategy is then developed that prescribes what will be done and who will do it. The management strategy also describes how the selected control techniques will be integrated and implemented. Strategic management of wild dogs is based on the concept of adaptive management, in which the management plan is flexible, responding to measured changes in economic, environmental and pest circumstances. Economic frameworks are needed to assess the value of alternative strategies to manage wild dogs.*

In some situations, management plans that include conservation strategies for dingoes are required so that potentially conflicting goals can be encompassed. A management plan may need to integrate control and conservation techniques into a systematic program. Consultation between stakeholders and clear identification of the goals of management programs is critical for avoiding conflicts between stakeholder groups with different legal obligations and objectives. Consultation and partnership encourages mutual ownership of a problem and results in ongoing participation and cooperation, group reinforcement, improved communication and enhanced efficiency and allocation of resources.

*Wild dogs have large home ranges and often traverse boundaries between lands managed by different stakeholders. Group action is an essential element of the **implementation** of management plans. Management requires partnerships between stakeholders if it is to be effective. Programs must be flexible enough to account for the different legal obligations and different ecological, social and economic imperatives of stakeholder groups.*

***Monitoring and evaluation of outcomes** occurs at different levels throughout the implementation and on completion of actions. Operational monitoring, where the costs of actions are recorded and reviewed during the program, ensures that the management plan is executed in the most cost-effective manner. Performance monitoring assesses the effectiveness of the management plan in meeting the agricultural production or conservation objectives that were established in the management plan. Evaluation of data from both forms of monitoring enables the continuing refinement of the management plan, where necessary. Real and hypothetical examples of the strategic management of wild dogs in agricultural production scenarios are presented.*

It is the responsibility of government agencies to encourage best practice management and evaluation and monitoring of existing

management and new technologies. Extension services can play an important role in the coordination of diverse stakeholder groups when planning and implementing management programs. For effective, goal-orientated management to occur, knowledge of current best practice and new technologies has to be available to management groups, with extension officers having a central role in knowledge transfer.

7.1 Strategic approach

The four steps that constitute a strategic approach to the management of wild dogs are: defining the problem; developing a management plan; implementing the plan; and monitoring and evaluating progress (Figure 1). The strategic approach to pest management incorporates adaptive management principles recommended by Walters (1986). In passive-adaptive management (Walters and Holling 1990) a single strategy is selected, implemented, monitored and evaluated, and adapted according to the success or otherwise of the strategy. The active-adaptive approach puts up a number of alternative strategies which are all implemented, monitored and evaluated, and adapted according to which strategies work best (Walters and Holling 1990). The latter technique is more experimental and requires standardisation of monitoring and effort across strategies, replication of strategies and, ideally, nil-treatment areas where no control strategy is imposed. The challenge for managers is to use the information in this book, and considering how the land is being used, to develop a strategic management plan to address the damage caused by wild dogs. This chapter explains how this might be achieved, and describes its special features for wild dogs in agricultural and conservation areas. The flow chart in Figure 1 outlines the steps required to follow the strategic approach and case studies from a cattle breeding enterprise in north Queensland and from sheep grazing areas in north-eastern New South Wales demonstrate how the strategic approach can be implemented.

7.2 Defining the problem

The first stage of the strategic approach to managing the impacts of dingoes and other wild dogs is to define the problem at hand. This is more complex than simply measuring the impact in terms of predation. There are six components of problem definition (Figure 1) that must be identified for a strategic approach. The questions asked are 'who, what, when, where, why and how much?' Problem definition may be complex where predation of livestock occurs in land adjoining conservation areas. Here, a balance is required, so it is crucial that the problem is adequately defined before control activities begin.

7.2.1 Agricultural impacts

Wild dogs adversely affect agricultural enterprises by reducing profits through decreased yields or increased costs (Section 3.1). The losses associated with predation and harassment of livestock by wild dogs have been measured on occasions, as have the costs associated with control activities (New England Rural Development Association c.1966; Schaefer 1981; Thomson 1984a, 1986; Fleming and Korn 1989; Thompson and Fleming 1991). To make wise decisions about management it is necessary to estimate the point at which the costs of wild dog control are equal to or are less than the benefits of the control (that is, the break-even point).

7.2.2 Human and animal health impacts

Wild dogs are known to be associated with diseases of people and livestock (Section 3.3). Reducing the levels of hydatid infection in endemic zones may be the objective of wild dog management and the benefit–cost ratio for this needs quantification. The presence of free-roaming dogs may place the success of a campaign to eradicate hydatids from domestic dogs and livestock in jeopardy. In such cases, the presence of wild dogs will need to be incorporated in the hydatid control campaign. Similarly, eradication of rabies or other exotic diseases of domestic dogs will rely to some extent on the management of wild dogs.

Attacks on humans by wild dogs can reduce the number of visitors coming to popular conservation reserves (for example, Fraser Island). The occurrence of attacks needs measuring so that performance objectives can be set. Needless-to-say, zero attacks is the usual objective.

7.2.3 Conservation

The presence of dingoes has unpriced value (Sinden and Worrell 1979). Various techniques can be used to estimate a monetary value for unpriced values. These monetary equivalents have not been calculated for dingo conservation, but, where the control of dingoes and other wild dogs in areas of the interface of government and grazing lands is deemed necessary, the intrinsic (Sinden and Worrell 1979) and contingent values (Wilks 1990) of dingoes should be included in the cost–benefit analysis.

Before economic frameworks can be used to assist meeting conservation goals, the value the community places on the conservation of the dingo, and other native species vulnerable to predation by dingoes, should be estimated. This would require research. The cost and effectiveness of implementing wild dog control techniques to protect conservation values also needs to be assessed so that the most cost-effective management strategies for meeting community conservation values can be determined. This would only be the case if scientific data verified that controlling wild dogs actually protected conservation values, and that the costs of such control equated with the contingent conservation benefits.

7.3 Developing a management plan

7.3.1 Identify management objectives

The implementation of a strategic approach to managing wild dogs requires the clear identification of the different goals of stakeholders. These include the general public, local communities, welfare groups, landholders and government agencies. Legal obligations differ between stakeholder groups and so do management objectives. The essential element in identifying objectives for wild dog management is to involve all the relevant stakeholders so that different goals can be raised and debated and compromises reached.

The final management objectives are a statement of planned achievements which are usually agricultural or conservation benefits. It is desirable that all stakeholders agree on the final objectives. Once the objectives have been set, they need to be defined in terms of outcomes which can be measured by performance criteria (Section 7.3.6).

7.3.2 Partnerships

After identifying agreed objectives for wild dog management, the next step is to create a genuine partnership and cooperative action between stakeholders. The impacts of wild dogs must be seen as a community problem to be solved by and for the community; they are not someone else's problem to be solved by the government or the next-door neighbour. They are also problems of all land managers upon whose land the wild dogs live. Integrated approaches to wild dog management are only possible through partnerships between government and private partners where mutual respect and inclusion prevail.

Predation of livestock is the problem of graziers and the conservation of dingoes is the responsibility of government agencies as proxy for the wider community. The involvement of the appropriate government agencies as stakeholders is crucial when control is proposed near or on public lands.

The involvement of other interest groups such as animal welfare groups and dingo preservation societies should be encouraged. This involvement ensures that management practices are responsive to community attitudes and in turn, that the wider community understands the limitations that are often inherent in the management of vertebrate wildlife. Although complete agreement may not be reached between groups, conflict can be avoided by both sides being aware of the other's position and acknowledging their right to hold that opinion (Pretty 1994).

The need for cooperative partnerships for the control of wild dog predation has long been recognised and this is reflected through the long history of group control schemes. Many have been formalised in legislation and some control activities are not permitted without evidence that control is to be undertaken by recognised groups. Cooperative action between land managers is an essential strategy for effective wild dog management because wild dogs have large home ranges and management needs to be applied synchronously to a relatively large area if it is to be effective (Section 7.3.5). This requires the collective action by groups of adjoining property owners. The crucial first step is to create a genuine partnership and cooperative action by land managers, governments and others who will benefit from the management or have some other stake in the outcome.

'Management needs to be applied synchronously to a relatively large area if it is to be effective.'

These stakeholders come from diverse backgrounds, and may have different responsibilities and requirements that may cause conflict. There is more potential for conflict between stakeholders in wild dog management than for any other vertebrate pest species. In many areas, wild dog–livestock problems occur at the interface of agricultural and government lands, and property owners may wish to control wild dogs on the government land. However, that may be a conservation reserve where the conservation authority has a responsibility to conserve dingoes, or it may have populations of threatened species that are at risk from wild dog control methods. Private property owners may also oppose baiting on their properties, limiting the potential for large-scale strategic baiting programs.

In such cases, management may fail unless acceptable, alternative control methods can be integrated into the management plan and deployed in these areas. Compromises are easiest to reach when there is a clear and well-articulated statement of each stakeholder's position from the beginning of the planning process. In the case of government agencies, policy on wild dog management should be formulated through extensive public consultation and be articulated through clear operational guidelines to staff. In this way, each stakeholder will understand the constraints under which others are operating and the actions that may be possible in any given situation. The inability of agency representatives to meet these criteria is one contributor to serious conflict over wild dog management.

One of the major advantages of coordinated group control is that it provides a forum where these different interests and responsibilities can be aired and compromises reached. Other advantages of group control are that it can:

- better integrate a range of control methods into the management plan
- respond more effectively to wild dog predation
- facilitate awareness and peer pressure on those unconvinced of the need for wild dog management
- make more effective use of resources such as fencing materials, baits and aircraft
- provide the basis for more effective, long-term management of wild dog predation.

All stakeholders need to be involved at all stages from the beginning of the planning process through to the implementation and evaluation of the plan if they are to have ownership of both the problem and its solution. The group may need to collect and present information necessary to meet the legislative and policy requirements of government agencies. For example, in New South Wales, aerial baiting can only be carried out by a recognised group such as a Wild Dog Control Association (WDCA). Aerial baiting on conservation reserves requires specific approval subject to the conditions of the *Threatened Species Conservation Act 1995*, and wild dogs cannot be controlled on conservation reserves unless National Parks and

Wildlife Service policy is met. In such circumstances there are advantages in establishing the group on some formal basis to facilitate participation by both government and non-government participants.

'Groups need to develop both strategic and reactive management plans.'

An example of where a formal approach to planning and implementing broadscale aerial baiting has generally worked well is in north-eastern New South Wales (Thompson and Fleming 1991). In a sense, the strategic approach is facilitated by the regulatory requirements of the approval process. These force the various parties to acknowledge their different objectives and responsibilities, resulting in the main in an acceptance of these differences from which grow respect, compromise and cooperation. The process is also assisted by the fact that most WDCAs are decades old and have well established group dynamics, and by increasing cooperation between National Parks and Wildlife Service and its neighbouring landholders on both wild dog control and a range of other issues.

Groups need to develop both strategic and reactive management plans (Section 7.3.4), and to clearly define the roles and responsibilities of stakeholders in the implementation of these plans. This is particularly important if there is to be a rapid and effective management response to wild dog predation.

7.3.3 Government as stakeholder

Government agencies have a legitimate interest in managing vertebrate pests, including the impacts of wild dogs. Predation of livestock is often associated with landholdings adjacent to government lands including State forests and national parks. In those States and Territories where dingoes are protected, governments are involved through their legislative responsibilities. However, Williams (1993) cautioned that management by government agencies should not be perceived as a subsidy by landholders. Such a perception has been shown to reduce stakeholder participation in rabbit control. In a small study conducted in the New England area in New South Wales, Schaefer (1981) showed that the cost of predation by wild dogs was capitalised into the value of the land. Therefore, additional subsidies in the form of government funded pest control on private land would be difficult to justify.

'The State should be seen as a good neighbour in its response to impacts of wild dogs, yet ensure the conservation of dingoes where it must.'

Different government agencies within a State or Territory may have potentially conflicting responsibilities. This emphasises the need for cooperation between all stakeholders. Management of wild dogs on government lands needs to be integrated with management on adjoining private lands. The State should be seen as a good neighbour in its response to impacts of wild dogs, yet ensure the conservation of dingoes where it must. Government support for group management can increase the probability of achieving successful outcomes. Government-funded facilitators and extension specialists can provide expertise wanted by coordinated groups (for example, Landcare groups) (Chamala and Mortiss 1990). A program to develop an integrated approach to the management of wild dogs in the south-east of New South Wales, the Australian Capital Territory and north-eastern Victoria, which incorporates the efforts of 14 landholder and government bodies, was only made possible through Commonwealth Government support which allowed the employment of a project coordinator and trainees (P. Fleming, D. Jenkins Australian Hydatids Control and Epidemiology Program and H. Cathles, Yass Rural Lands Protection Board, unpublished data 1998).

Much of the responsibility for the regulation of pesticides used for vertebrate pest control is vested in government agencies. Hence, governments should also be responsible for ensuring appropriate training of field staff using the pesticides.

The role of extension services

The strategic approach to managing the impacts of wild dogs incorporates the adoption of a variety of control and evaluation and monitoring techniques. Traditionally, State and local government extension services have been the conduit for information transfer to landholders. Extension officers still play an important role in assisting the adoption of new and more effective techniques by land managers.

In addition to maintaining the flow of new information to managers, extension officers often act as facilitators and coordinators for activities within and between groups. Given the central role of extension people in the management of vertebrate pests, their continued training and education is important. Many State government agencies (for example, Agriculture Western Australia and the Queensland Department of Natural Resources) place emphasis on developing the extension skills of their staff. These organisations ensure that all field staff with an advisory role receive training, either through dedicated Technical and Further Education Courses or regular in-service courses. Extension training should focus on the theory and practice of extension as well as technical knowledge (Appendix B). Officers should be trained in individual and group communication skills, including problem and goal identification, conflict resolution, and negotiation. Once the objectives of the individual or group being addressed are identified by the advisory officer, transfer of knowledge and the implementation of coordinated management programs are more likely.

7.3.4 Select management options

The five options for the management of wild dogs are eradication, strategic control, reactive control, conservation or no wild dog control (Figure 1) (Braysher 1993).

There are three criteria that must be met before eradication can be considered: (1) at all densities, wild dogs can be killed more quickly than they can breed; (2) there is no immigration into the controlled area; and (3) all wild dogs are at risk from the control methods used (Bomford and O'Brien 1995). Eradication of wild dogs is unlikely to be feasible except at the local level or where habitats have been grossly changed by agricultural practices. In much of the wild dog-affected area of north-eastern New South Wales (for example, Wongwibinda Wild Dog Control Association area described by Fleming (1996a), dog-proof fencing provides a barrier against immigration. Usually, few wild dogs breach the fence. Any wild dogs that encroach upon the area enclosed by the fence are pursued until they are killed. Because wild dogs are birth pulse animals, it is usually possible to kill the dogs inside the fence before they breed and thus achieve local eradication. Wild dogs have been eradicated from the sheep/wheat belt of south-eastern Australia through widespread control campaigns in the 1800s combined with broad-scale changes to the landscape by clearing for crops. Eradication is undesirable where dingo conservation is desired.

Strategic control implies that sufficient knowledge is available to take precautionary actions to prevent livestock predation or the spread of wild dogs from source areas into intensive grazing areas. Reactive control is conducted in response to predation, observations of increased abundance of wild dogs or observations of wild dogs in sheep areas. Strategic approaches may include reactive control as part of the overall plan. Management for the conservation of dingoes is complex.

Management options

Most management of wild dogs falls into two main categories: strategic and reactive (Box 2; Table 6). Reactive management can also be categorised into: one-off, where control measures are conducted in response to a specific problem until the problem is solved; and constant, where control options are conducted on a continual basis usually because no strategy to prevent predation has been planned. There are a number of management options available to landholders and groups (Chapter 6). A mechanism is required in the planning process to help decide the best course of action. The simplest approach to this is a decision-making framework comprising a progressive

Table 6: A decision table of strategic (S) and reactive (R) control measures for wild dogs in New South Wales. Similar constructs can be formulated for different States and Territories incorporating appropriate policies and laws.

Control method			Control type	Appropriate situations	Constraints
Baiting	Ground	Bait lines	S	Alternative to aerial placement during strategic baiting	Generally less than two kilometres (and never greater than five kilometres) inside public estate area; baits average 100 metres apart.
			R	In response to stock losses	Generally less than two kilometres (and never greater than five kilometres) inside public estate area; baits average 100 metres apart; (for example, NSW limit of 50 baits per property per day unless otherwise approved).
		Bait station	R	Alternative to aerial placement during strategic baiting. In response to stock losses	Must be near boundary of public estate; 1–2 baits per station
			S	High risk areas which warrant more continuous control	Must be near boundary of public estate; 1–2 baits per station
	Aerial (not available in all states)	Bait lines	S	For agreed strategic control in areas with a history of losses	Helicopter only in eastern New South Wales, fixed-wing aircraft in Western Division. Placement less than two kilometres (and never greater than four kilometres) from public estate boundary; baits average 100 metres apart on public estate areas, 25 metres elsewhere; Ministerial approval required in NSW
			R	In response to stock losses	Helicopter only in eastern New South Wales, fixed-wing aircraft in Western Division. Placement less than two kilometres (and never greater than four kilometres) from public estate boundary; baits average 100 metres apart on public estate areas, 25 metres elsewhere; Ministerial approval required in NSW – rarely possible because of time required to obtain approval
Trapping			R	In response to stock losses where a small number of dogs and their routes are known	Requires an experienced trapper; licence required in some areas
			S	Long-term population reduction in small areas	Requires an experienced trapper; licence required in some areas, labour intensive
Shooting			R	In response to stock losses when other methods have failed; may also be useful for individual problem dogs	Most successful when an experienced operator is used
Barrier fencing			S	At edges of sheep country	Expensive to construct; continued maintenance required

series of decision points (Box 2). Normally such an approach requires that there be only one criterion (question) for each decision. The criteria which apply at each decision point are listed below. When a management action results, the form of that action is shown in the diagram, and the information needed to implement the action can be found by referring back to the control methods (Section 6.4).

An alternative aid to making decisions about the most appropriate control techniques to exert in a particular situation is a decision matrix (Caughley et al. 1998; Norton 1988). To construct a decision matrix, the known alternative control options are listed in the first column and questions relating to technical feasibility, likely success, economic desirability, environmental safety, and political and social acceptance are listed across the first row. Each question is answered for each control method with a 'yes', 'no' or question mark. The most desirable option has the most 'yes' answers, provided that the method works or is expected to work.

7.3.5 Develop management strategy

Once the management option has been decided, a strategy is needed to achieve it. Strategies for the management of dingoes and other wild dogs prescribe what is to be done, when it is to be done, in what order and how often it is done and who does what. The strategy also prescribes how selected control techniques will be integrated. Table 6 and Box 2 can be used to assist in deciding what actions are required to achieve the selected management option (Section 7.3.4). For example, if the selected option is strategic control with reactive control when necessary, a buffer zone or baited zone strategy may be chosen. The buffer might be achieved primarily by an existing exclusion fencing, with seasonal ground baiting programs to reduce abundance outside the fence and to establish the buffer. The strategy will therefore include identification of who maintains and checks the fence to ensure that it is dog proof, who conducts the ground baiting programs, the frequency at which the fence is checked and the baitings occur, and the monitoring regime. Reactive control might be targeted trapping when an incursion by wild dogs into the area protected by the fence is detected in the regular monitoring program. Who undertakes the reactive trapping and who pays is also decided beforehand and the owners of private and public lands or their employees or third parties such as contractors and control associations are selected and allocated their tasks and responsibilities.

The management strategy also defines the size of the treatment area. Plans to manage wild dogs must be for defined areas of land and can be at any scale — national, State, regional, district or property. Management planning requires determining the right size for a management unit. Selection of an appropriate size management unit will often be a trade-off between several factors, such as:

- Risk of reinvasion if the management unit is small — dingo home ranges may cross property boundaries and dispersing dingoes can travel long distances (Section 2.4) so it is often necessary to conduct wild dog control over larger areas such as several neighbouring properties or on properties plus adjacent government land.
- Economies of scale for management of larger units — for example, some expensive dog control techniques such as exclusion fencing (Section 6.4.1) and aerial baiting (Section 6.4.4) are best undertaken over large ares because the costs to individual properties are lessened.
- Commonality of topographic area and community of interest — the advantages of small community groups working together to solve a problem in a local area (Section 7.3.2) may be lost if the chosen management area is too large or extends beyond a manageable topographic unit or common community of interest. Stakeholders lose interest if a project appears too large to solve or is outside their area of familiarity (that is, it is 'someone else's problem').

The management strategy also defines the timeframe for management. The timeframe is set according to the management option(s) chosen. For instance, reactive control can occur immediately if the problem is current

Box 2: A decision-making framework for wild dog control

A decision-making framework comprising a progressive series of unambiguous decision points can help landholders and groups to decide what course of action to take in response to historical and present problems with wild dog predation. This framework may assist managers who are able to monitor livestock regularly and may not apply in all situations. Normally this approach requires that there be only one criterion (question) for each decision. To simplify the representation of the framework, in some cases criteria have been grouped at appropriate decision points. To prevent ambiguity in these cases, the groupings are such that a 'YES' decision requires that ALL criteria have a 'YES' answer. Thus a single 'NO' results in a 'NO' decision. The result at each decision point leads to either a further decision point or to a management action. The flowchart in Figure 14 will help users work through the framework.

Using the decision-making framework

This framework works like a botanical key. Start at 1 and work through until a 'YES' decision is reached. A 'YES' decision requires ALL criteria within the question to be answered YES.

1. Present losses?

Criteria	Stock losses are presently occurring
	These are caused by wild dogs from within the property and/or adjacent lands. (This is relevant to determine whether other agencies and neighbours should be involved in management. Losses are unlikely to be caused by wild dogs more than one home range width from such adjacent lands [about ten kilometres in south-eastern Australia])
If NO	Go to 2 (Strategic management)
If YES	Go to 1a

1a. Barrier fence?

Criteria	Barrier fence separates wild dogs and stock
If NO	Take actions to stop stock losses (go to 3)
If YES	Go to 1b

1b. Fence secure?

Criteria	The fence is wild-dog proof
If NO	Repair the fence THEN take action to stop losses (go to 3)
If YES	Take action to stop losses (go to 3)

2. Past losses? (Strategic management)

Criteria	Stock have been lost in the past two years
	These are caused by wild dogs from within the property and/or adjacent government lands. (Losses are unlikely to be caused by wild dogs more than one home range width from such adjacent lands (say 10 kilometres in south-eastern Australia))
If NO	No further actions or decisions are necessary
If YES	Go to 3

3. Strategic management?

Criteria	Losses are of sufficient size and frequency to justify management
	There is a high risk of future stock losses
	Losses will be reduced by strategic management on the property and/or adjacent lands
If NO	No further actions or decisions are necessary
If YES	Go to 4

4. Constant management?

Criteria	Losses occur at any time throughout the year
	Intermittent forms of strategic control have failed
	The severity of losses justifies the high cost of continuous strategic management
If NO	Go to 5
If YES	Go to 4a

4a. Erect barrier fence?

Criteria	It is practical to erect a barrier fence (consider electrification)
	The fence can be built on or very near to relevant boundary
	The location of the fence on the Service boundary will prevent the wild dogs responsible for losses from reaching stock
	Capital funds are available to erect the fence
If NO	Go to 4b
If YES	Erect the fence

4b. Employ dogger?

Criteria	Trapping is consistent with agency policy
	Employing doggers is consistent with agency policy
	A skilled and reliable dogger is available
	Recurrent funds are available
If NO	The problem should be rethought from 4
If YES	Employ dogger

5. Wild dog movements known?

Criteria	The movements of wild dogs in relation to stock losses is sufficiently understood to effectively and efficiently deploy intermittent strategic or reactive management
If NO	Collect movement information THEN go to 6
If YES	Go to 6

6. Baiting allowed?

Criteria	Baiting is possible and consistent with government regulations
	Baiting is consistent with agency policy
If NO	Go to 8
If YES	Go to 6a

6a. Ground baiting possible?

Criteria	The area is accessible by a ground vehicle
	Only a relatively small amount of bait is required in a small area
If NO	Go to 7
If YES	Spread baits from a ground vehicle

7. Aerial baiting

Criteria	The area is in rugged country with steep ridges and gullies or the area is in terrain that is difficult to access because of distance
	A large quantity of bait is required over a large area
If NO	Go to 8
If YES	Spread baits by helicopter in mountainous terrain (for example, eastern New South Wales). Spread baits by fixed-wing aircraft in extensive, flatter terrain. Adhere to ministerial requirements if needed

8. Trapping allowed?

Criteria	Trapping is allowed under government and agency policy
	There is a skilled and reliable dogger available when required
If NO	The problem should be rethought from 6
If YES	Strategic trapping should be used when it is necessary, employ a dogger

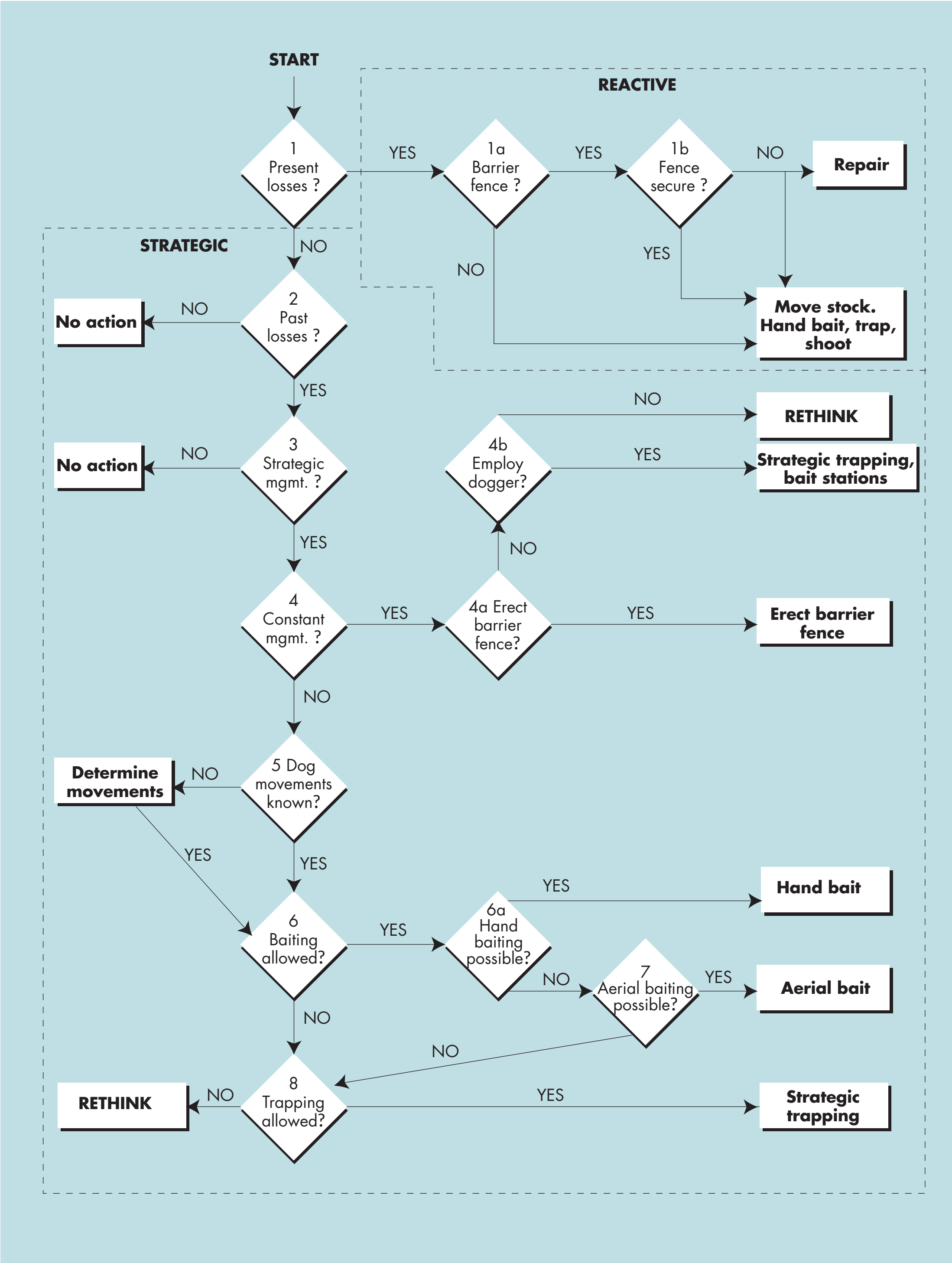

Figure 14: A decision-making framework for devising a plan of management for reducing predation of livestock by dingoes and other wild dogs in eastern Australia.

or can be budgeted for against the contingency of a future increase in predation. Strategic management can be ongoing, regular, or occasional and may be implemented immediately or according to a planned schedule. Short and long-term timeframes and achievement dates are defined in the management strategy.

7.3.6 Define performance criteria

Performance criteria are a list of measurable factors which will be used to determine if the management objectives are met once the management strategy is implemented. Because relationships between wild dog density and the damage they cause are often complex and variable (Box 3, Step 3), it is important that the management plan includes a monitoring component. Monitoring will allow the results of strategic action to be compared with the situation preceding the action and with historical data, or with sites with no management or with different management strategies.

Agricultural performance criteria

Agricultural performance criteria are usually defined in terms of reduced losses or increases in production. For example, where calving percentages are consistently 85% in a region and the dog-affected properties in question yield 80%, a performance criterion might be to increase calving percentages to the regional average over the next five years. In this case, the time frame is set long enough to encompass a range of expected seasonal conditions and their likely effect on fecundity in the herd. However, setting quantifiable and realistic performance criteria for management is complex. For example, the scale of the problem and the control effort that is to be applied need consideration. The large home range of wild dogs in relation to the stocking rate and size of sheep properties in south-eastern Australia means that management groups rather than individuals must decide on objectives. Conversely, large cattle stations in central and northern Queensland and the Northern Territory may cover many wild dog home ranges so the scale of an effective control program might be one property – although immigration of dogs into a 'sink' property may actually result in increased impact (Section 3.1). The performance criterion here might be to reduce calf losses to a predetermined break-even level, which is set by the area of the property, the value and cashflow of the enterprise, and the expected level of control per unit of control effort. Economies of scale are important and the economics of group control are more complex than for individuals.

If conventional economic analyses cannot be used to account for intangible values and other complexities it may be best to provide a management group with as much information as possible and let them decide what change in yield or loss should be set. The managers then apply a level of control that experience or intuition predicts will lead to the production goal. Monitoring and evaluation (Section 7.6) will allow the adaptive management process to set new levels of control to achieve the goals. This process allows the unpredictability of predation and the landholders' attitude to risk to be included in the decision-making process and for the plan to progress.

Conservation performance criteria

The setting of conservation performance criteria is even more complex than those of agricultural production. Unpriced valuations are required to take into consideration the tourism potential and inherent/contingent value of dingoes to Australians. It is important to assess whether a level of hybridisation is acceptable to the general public. It is unlikely that the majority of people would knowingly pay to visit national parks to see a feral dog. Once such decisions are reached, performance criteria can be set. An example of a performance criterion for dingo conservation might be that the proportion of pure dingoes in a population in a defined area remains above a pre-defined percentage for the next ten years.

7.4 Economic frameworks

Economic frameworks are needed to assist managers in assessing the relative value of alternative control strategies and the relative benefits compared with other risks that must be managed (Hone 1994). Such frameworks require: definition of the economic problem; data on the relative costs and benefits of different management strategies; an understanding of why the actions of individual land managers may not lead to optimal levels of control; and assessment of the means by which governments might intervene to overcome identified market failures. Land managers can use such economic frameworks to select the most appropriate management strategy for their circumstances.

Box 3: Economic framework for wild dog management

Simple stepwise approach

Land managers who wish to determine the optimal economic strategy for managing a problem caused by wild dogs could use the following stepwise approach (modified from Bomford et al. 1995).

Step 1. Desired outcomes

Identify desired outcomes and estimate a dollar value for each of these. Where outcomes are the protection of commodities (Section 3.1), such as reduced wild dog attacks on livestock, this should be reasonably easy. Where outcomes are difficult to measure or intangible, such as the protection of biodiversity or threatened native species (Section 3.6), land managers may be obliged to estimate how much they consider is an acceptable amount to spend to achieve that outcome.

Step 2. Control options

List all control options and how much they would cost to implement (Section 7.5). Control options can be different techniques or combinations of techniques, or different levels or frequencies of application of techniques. It is important that the options for control are expressed as activities that a manager can select either to do or not to do.

Step 3. Density–damage relationships

Estimate the relationship between wild dog density and damage for each resource damaged by dogs (Figure 15). Such relationships allow managers to estimate the likely benefit for a given control effort. For example, if a control program reduces the density of wild dogs by 50%, how much will this reduce the incidence of attacks on calves? These relationships may be complex or there may be multiple relationships. For example, if wild dogs switch to different prey and/or change from hunting singly to hunting in packs, the slope or position of the line relating density and damage may shift at the density where this occurs. Also, young inexperienced dogs may inflict a different level of damage than an equivalent density of experienced older dogs. There is anecdotal evidence that young dogs may be more likely to attack livestock than older dogs which have the skills to prey successfully on kangaroos (*Macropus* spp.) (Section 3.6; Allen and Gonzalez 1998). Surplus killing and changes in hunting strategy will also affect the relationship.

In Figure 16 there is a significant linear relationship between wild dog density and damage to cattle but there is high level of scatter of the data points around the fitted line. This means that, although the relationship is linear, the line is a poor predictor of the likely damage caused by a given density of wild dogs. The poor fit of the line is partly because some individual dogs cause far more damage than others (Section 3.1) and just a few dogs may inflict high levels of damage on some properties. This is particularly true for sheep properties where surplus killing by wild dogs occurs (Section 2.3.4). In other areas, the density of older dogs in stable packs might be quite high and yet attacks on calves may be minimal (Allen and Gonzalez 2000).

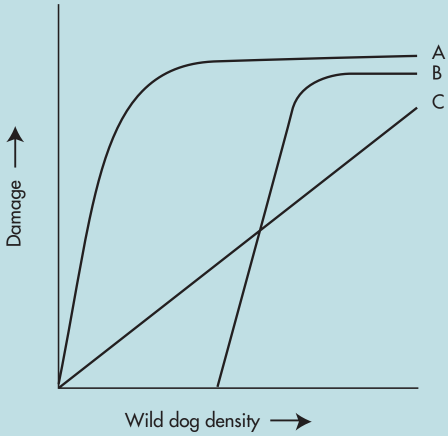

Figure 15: Some hypothetical relationships between dog density and damage. Density–damage relationships are highly variable for wild dogs and there may be multiple relationships. Just a few dogs might inflict high levels of damage on some sheep properties but as the density of wild dogs increases, damage levels off, resulting in line A. On some cattle properties, damage levels might be low or nil when dogs are in low densities and are individually hunting for small prey, but if dog numbers build up and they start to hunt in packs for calves, damage might increase sharply (line B). Line C would occur when an incremental increase in the density of wild dogs resulted in a proportional increase in predation losses (Figure 16).

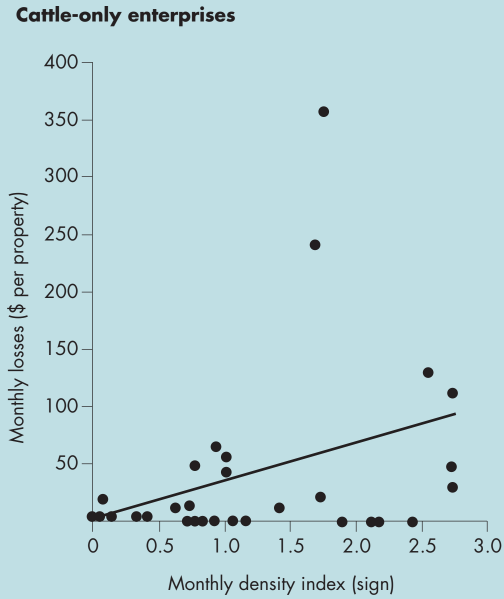

Figure 16: The relationship between density of wild dogs and the damage caused by wild dogs to cattle enterprises in north-eastern New South Wales. The index of wild dog density relied on observations of their sign and hence losses were sometimes sustained at 'zero' density. Data from Fleming and Nicol (unpublished data 1999).

Hence managers may need to collect and assess their own data on dog abundance (Section 6.2) and establish which dogs (mature dogs with established territories, or newly arrived young dogs) do the damage. This information, together with records of damage levels, will enable managers to determine density–damage relationships for their own circumstances.

Step 4. Control efficiency

Estimate the control efficiency of each control option. That is, how much will a given effort using a particular control option reduce wild dog damage? Most current control programs inherently assume that the density–damage relationship for wild dog predation of livestock is a simple linear function (Line C in Fig 15) and that a given control effort will result in a commensurate reduction in wild dog abundance and damage. Clearly, this is not always the case.

Step 5. Benefit–cost relationships

Use the information from Steps 1-4 to estimate costs and benefits of implementing each control option, including options which combine more than one technique, or the option of implementing no dog control (Table 7; Section 7.6.2). Costs will be the cost of implementing each control option, and should include costs of monitoring pests and planning. Benefits will be the value of the reduction in damage to the valued resource caused by implementing control (that is the desired outcomes listed under Step 1 above), plus any profits (for example, profits made from tourists who pay to look at pure dingoes if a decision is made to conserve them).

Different pest management options will generate a variety of benefit–cost relationships. Estimates of benefits and costs can be discounted back to net present values (usually using a discount rate equivalent to the interest rate the landholder pays on financing the control operation). This will reduce the value of costs and benefits accruing in the distant future relative to those accruing in the near future.

Step 6. Marginal analysis

Plot both the incremental change in the cost of wild dog control (marginal costs of control) and the incremental change in the cost of damage (marginal costs of damage) caused by wild dogs against the level of control activity contemplated (Figure 17). For example, marginal costs might be changes in the cost of finding and removing an extra wild dog that occur as wild dog density is reduced. An example of marginal benefits could be changes to livestock losses that occur as wild dog density is reduced. Where the two lines cross is theoretically the optimal level of pest control (Hone 1994). Further increases in control activity will not cause commensurate reductions in damage, so at higher levels of control beyond this point, costs will exceed savings in reduced damage.

The problem for managers is that they often do not have good information on the density–damage relationship, or this relationship is highly variable. This makes it hard to estimate the position of the marginal benefits line which in turn means the optimal control point is hard to establish. Even if managers can make a good guess on an optimal wild dog density to aim for, it is not usually practical with most control techniques to simply cut off control efforts at some pre-determined wild dog density. It is preferable to have a range of control strategies ranked along the x-axis, For example, different frequencies of trapping could be put along the x-axis. The associated cost and benefit values for implementation would be plotted for each strategy, so a manager could then select which strategy (level of control) is optimal, for example, the optimum trapping frequency.

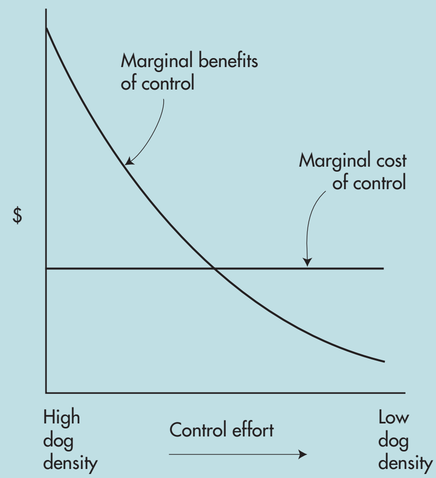

Figure 17: A marginal analysis of wild dog control. The marginal costs are the costs of incrementally increasing the level of control effort. The marginal benefits are incremental changes in the level of damage caused by wild dogs at different levels of control effort. The optimal level of control is where the two lines cross. Units on the x-axis are level of control effort (for example, trapping frequency) not wild dog density.

Step 7. Pay-off matrices

Construct a table listing all the control options and their associated costs and benefits (economists call this a pay-off matrix). For example, the costs and benefits of no dog control, ground baiting at waterholes, and widescale aerial baiting with 1080 (sodium fluroacetate) could be compared. Managers may wish to construct different matrices for different conditions, such as different stocking densities, seasonal conditions, or commodity values for wool, lambs or calves. Managers will also need to consider timescales when constructing these matrices: what time span is covered and how will this affect costs and benefits?

These matrices can then be used to select the option(s) which best meet the managers' goals. If the manager is risk averse, the best options will be those that bring in reasonable returns (benefits in relation to costs) under the widest range of conditions (that is, in most seasons and with a wide range of commodity prices). If the manager's priority is to maximise profit, the preferred options will be those that are likely to give the highest returns on investment, even though there may be some risk of having no returns or even a loss if the seasons and prices go badly.

Pay-off matrices can also be used by a land manager to compare returns on investment in pest control with returns on using the money for some other purpose, such as capital investments, increasing stocking rates and pasture improvement.

Steps 1–7 complete the basic model. One way of improving accuracy may be to replace single estimates with a range of possible values, and give associated probabilities for each value in the range.

The model can also be made more accurate by adding additional features. Incorporation of such additional features will make the model more complex, but including at least some of them may be necessary to make it accurate enough to be useful:

- Social benefits could be included in Step 1, such as:

  - off-site effects and good neighbour relations — (Sections 7.3.2 and 7.3.3).

  - conservation of pure dingoes (Sections 3.3, 4.1 and 4.4).

  - animal welfare management — animal welfare organisations would like the suffering caused by harvesting or control techniques considered as a cost that is taken into account in vertebrate pest management decisions (Choquenot et al. 1996: Section 4.2). Alternatively, wild dog control can alleviate the suffering caused to prey, reducing the welfare costs to the community.

- Risk management for spread of disease by wild dogs could also be included in Step 1.
- Effects of government intervention could affect value of benefits (in Step 1) or costs (in Step 2).
- Indirect effects of pest control (for example, controlling wild dogs may lead to an increase in kangaroo numbers) could be included as interaction effects in Step 3.
- The form in which benefits come may be significant to a manager (Step 5). For example, cash 'bonuses' for dingo scalps may be more attractive as immediate cash for spending, than future money from increased lambing percentages, which may be committed in advance to servicing debts or meeting farm running costs.

Ideally, land managers could use this stepwise approach to optimise the control effort, but often capital is constrained by competing demands and sub-optimal amounts are available. The processes outlined are sensible and relatively simple ways of balancing competing demands. We recognise that managers will have incomplete knowledge of the information necessary to fully complete many of these steps. Some projects funded by the Vertebrate Pest Program and the National Feral Animal Control Program in the Bureau of Rural Sciences aim to collect some of these data. Even where information is incomplete, the exercise of attempting to complete the process, and recording the assumptions and best guess estimates that are made, may prove a useful aid to decision making for wild dog and dingo management.

Even where sufficient information exists to enable simple marginal or other economic analyses of different dog control options, valuing the reductions in yield caused by wild dog predation is not straightforward. For example, the economic cost of predation of a merino ewe can be simply estimated by the potential value of its wool and its replacement cost, yet valuing the contingent loss of its cumulative genetic value is not simple. This is particularly so when the sheep involved are from a stud or commercial breeding enterprise. More complex economic models are needed to include the intangibles of predation on sheep production.

By contrasting the marginal ratios of different approaches on a common measure of benefit, for example, decreasing loss of biodiversity, or increasing farm income, break even points can be established and the allocation of resources can be optimised. In such cases, managers have to prioritise where control will be conducted. Accurate information to support many of the decisions needed for this process will almost always be absent and managers will often have to make 'best guess' estimates. However, the process will give defensible decisions especially if they are empirically tested by monitoring the outcomes. For example, sheep graziers might need to estimate the losses caused by wild dogs, both immediately, through predation on livestock, and longer term, through reducing reproductive success and genetic advancement of the flock or herd. In this case, future losses would need to be discounted at some appropriate rate (commonly 5% per year). The costs of control would also need to be assessed, examining different control strategies to see which are cheapest and most effective. Alternative options and opportunity costs would also need to be examined.

More complex models

A more complex analysis of the economics of wild dog management is possible through linear programming. In linear programming, the underlying function (in our case the relationship between damage and pest density) and its constraints are assumed or known to be linear (Luenberger 1984). By fitting known values to the function and the constraints, and solving the equations, control is optimised in terms of cost. For example, in a regional linear programming model of serrated tussock (*Nassella trichotoma*) control in New South Wales, Jones and Vere (1998) maximised the regional gross margin of control of this weed within the constraints of soil fertility and rainfall. Their model incorporated a linear relationship between the density of serrated tussock and the reduction in wool production and carrying capacity, and subject to an array of rainfall regimes and soil fertilities. Linear programming is not applicable if the functions are not linear and is limited to short-term evaluations. This process is probably most useful at the policy-making and program-funding level.

A problem with marginal analysis and with linear programming is that they are simplistic and do not include pest population dynamics. The inclusion of population dynamics in weed control models has shown that control should be instigated at lower thresholds than predicted by the simple threshold models often used in marginal analyses (Bauer and Mortensen 1992). Stochastic dynamic programming (SDP) models attempt to link biological and economic data in such a way that accounts for the variability of the biological components. One advantage of these models is that the population dynamics of the subject pest can be incorporated. Without these components, models underestimate the long-term costs of not taking control action. Ignoring the rate of increase of a population results in a lower level of instantaneous control than is optimal. This decreases the long-term economic benefits of control and results in greater long-term costs of control (R. Jones, senior research economist, NSW Agriculture, pers. comm., 1999). As with linear programming, SDP is complex and best used by experts to evaluate management strategies and to aid policy and funding decisions. An example of SDP is a CD-ROM rabbit control simulation model which considers interactions between rabbit numbers, pasture production and sheep flock performance accounting for climatic stochasticity (Bureau of Rural Sciences/Centre for Agricultural and Regional Economics 1999). The model is based on a New South Wales Tablelands grazing system and takes into account uncertainty in the wool production system, rabbit population dynamics and the effectiveness of rabbit control options. Numerous simulations can be run to show the expected or average improvement in farm gross margin resulting from rabbit control across a range of environmental conditions. Rabbit control will not always be profitable because competition with sheep for pasture will not always be a problem. A SDP model for wild dog management would have greater uncertainty than that for rabbit control because of the much higher variability in density–damage relationships for wild dog impact on sheep production.

7.5 Implementation

When the management plan is completed, implementation can start. It is usually desirable to involve as many stakeholders as possible in the implementation stage. The value of the group approach in the implementation of a pest management plan (Section 7.3.2) has been discussed in detail in the earlier guidelines for managing rabbits (Williams et al. 1995) and feral pigs (Choquenot et al. 1996).

Maintaining commitment and enthusiasm among all stakeholders is essential. Good communication between all participants throughout the implementation of the management plan will ensure that difficulties are identified and addressed early, and if necessary support or peer group pressure can be provided if some people have problems implementing their part of the plan (Section 7.3.2). Rapid communication of the results of the monitoring of performance indicators is also important so people see the rewards of their efforts which will motivate them to continue. If monitoring shows that expected benefits are not occurring this also needs to be communicated rapidly so the stakeholders can decide if the objectives or the management plan need to be modified (Figure 1).

7.6 Monitoring and evaluation

Monitoring enables the continuing refinement of a control strategy in relation to the set objectives. It is important to distinguish between efficiency (operational objectives) and effectiveness (performance objectives) as management can be efficient but ineffectual. For example, 75% of wild dogs might be killed efficiently for little cost, but this strategy would fail if there was no concurrent reduction in predation or increase in production.

A management plan must have operational objectives (for example, 'was the planned management action carried out efficiently?') and performance objectives ('did the management action achieve the resource protection goals used to justify management action?'; that is, 'were the performance criteria met?').

7.6.1 Operational monitoring

Records need to be maintained describing what was done, how many wild dogs were killed or what proportional reduction of abundance index was achieved (Section 6.2), where, for how long, by whom, and at what cost. Measurements need to be taken and reported routinely. Reports should include details of number of properties treated per year, money allocated, total number of wild dogs killed, number of wild dogs killed per unit effort, number of wild dogs remaining, the cost per unit reduction and mapping of data.

The results of operational monitoring will be used to assess the efficiency of the management strategy. They will be useful for answering such questions as:

- Were the best people chosen to undertake the fieldwork?
- Were the selected techniques applied at the best times and did they reduce wild dog densities to desired levels?
- What were the costs? Were there cost overruns? Can budgets be reallocated to reduce costs?

7.6.2 Performance monitoring

Performance monitoring measures the effect of management of the resources to be protected, by comparing the outcome of management against performance criteria. For example, 'how well have we achieved our goals?; or, 'have we increased our calving percentage to the regional average?'. To answer these types of question, production records need to be kept and compared with the values preceding implementation of the management plan. Most performance measures can be assessed by landowners or pest managers. Measures of more complex ecological relationships may require interpretation by experienced researchers. Performance monitoring usually requires a long-term perspective, and some experimental and scientific rigour for results to be interpreted and transferable.

The results of the performance monitoring will be used to assess the effectiveness of the management strategy against the objectives defined in the management plan. They will be useful for answering such questions as:

- Were some or all of the objectives met? Why or why not?

- Were the objectives met within the timeframe? Should the timeframe be changed?
- Should the problem definition or management objectives be changed (Figure 1)?

7.7 Case studies of the strategic planning process

These case studies are to demonstrate strategic planning methods. The first case study is from an extensive cattle enterprise in north Queensland. The authors were unable to find suitable data to provide a case study for the sheep industry. Instead, a hypothetical case study of a benefit–cost analysis has been provided.

In the cattle case study, there has been an ongoing problem of predation by wild dogs and below average livestock production. A major change from individual-based control programs to coordinated group activities occurred, and records of production and losses before and after the change enables monitoring of the progress towards objectives. The program has run over more than ten years.

7.7.1 Case study 1 — Extensive cattle enterprise in north Queensland

This case study draws on real data from an extensive cattle enterprise in north Queensland (from Allen et al. (1997); Allen and Gonzalez (1998)). Although the enterprise did not undertake a formal planning process, the data are used here to demonstrate the strategic approach to wild dog management. The specific objectives and assessments against those objectives were hypothetical but the responses to control are real.

The site

The site is a 52 000 hectare property in the wet–dry tropics near Cape York in northern Queensland which has an annual rainfall of about 900 millimetres. The property is an extensive breeding cattle enterprise. Feral horses, kangaroos and wallabies (*Macropus* spp.) have been controlled on the property.

Defining the problem

From 1968 to 1988, branding percentages on the property were between 42% and 70% and of these, the percentage of calves that had been bitten by wild dogs ranged from 8% to 19%. The property was baited at least annually with strychnine baits laid around waterholes from 1968 to 1988. Over that time, because of pasture improvement and better management, there was a gradual increase in the number of cattle and in the number of calves branded. The branding percentage and the percentage of calves bitten by wild dogs both remained fairly constant but the potential branding percentage for the region was not being reached.

Objectives

Although specific production goals were not set, the general objectives over the 20 years prior to 1988 had been to maximise branding percentage and income. For the purpose of this example, the specific goals from 1988 were to:

- increase the average branding percentage to the potential levels for the region (80%)
- reduce the number of calves bitten by wild dogs to below 2%.

Management options

There were three options in 1988:

- The **'no dog control'** (Section 7.3.4) option was not appealing because bitten calves were strong evidence that predation by wild dogs was significant.
- Although there had been a steady increase in the number of calves branded during the existing **strychnine baiting program** based at waterholes,

improved general management had increased the number of breeders being run. This confounded the measurement of the effectiveness of the baiting program. However, as there had been a steady increase in calf turnoff, the baiting program might have been at least partly responsible.

- In 1988, **cooperative aerial baiting** using 1080 baits was being encouraged by neighbours and government inspectors in the region and elsewhere. This alternative was attractive because inaccessible areas of the property could be baited and being involved in a joint community program was regarded as a responsibility to the community. Although aerial baiting was expensive, the spectacular increases in returns reported on the bush telegraph would more than cover the expense.

Implementation

In cooperation with neighbouring cattle stations, approximately 50 000 square kilometres were baited in 1988 using a fixed-wing aircraft and 1080 meat baits. The problem and its solution were 'owned' by the landholders involved and the government's contribution was through the Regional Inspector (from the then Rural Lands Protection Board) who was responsible for adding poison to the baits and advising and coordinating the group.

Monitoring, evaluation and outcomes

Records of rainfall, calving percentages (at branding), bites to calves by wild dogs and wild dog control activities have been kept from 1968 to the present. At the 1989 branding, the number of bitten calves dropped to zero and the highest-ever branding percentage to date (approximately 75%) was achieved. In the eight years following the first aerial baiting, branding percentages have averaged 75.3% (*s.d.* = 1.2%) and have not been below 70%. The percentage of bitten cattle was less than 1.2%. If the goals had been to reach the potential branding percentage for the region, the program has fallen short; however, large increases have been achieved and 320 additional calves have been produced per year. The baiting program did achieve the objective of reducing the percentage of bitten calves to below 2%.

The stocking rate of the property and the effect of greater calf survival will need to be assessed over the next few years to determine if the extra calves are drawing on the pasture capital of the station. Monitoring and evaluation should continue and alternative strategies be planned in case there is a trend towards decreasing effectiveness.

Authors' comment

Although there was no equivalent area where wild dogs were not controlled against which to compare these results, the circumstantial evidence for the success of the aerial baiting strategy was strong and certainly strong enough to convince most landholders of its value. Conversely, studies undertaken in other smaller areas of central Queensland (800 to 9000 square kilometres baited) have shown that, although wild dog numbers were reduced, there was no concurrent reduction in calf losses and in some cases calf losses increased (Allen and Gonzalez 1998). In response to those findings, the manager of one of the studied properties in central Queensland has not baited since 1997 (Allen and Gonzalez 2000). Scale differences, behavioural and age structure changes in baited populations of wild dogs, differences in repopulation, the level of population reduction or combinations of these (Allen and Gonzalez 1998) may explain the contrasting results between the northern property and those where smaller areas were baited. Allen and Gonzalez (2000) recommended that for full value to accrue from aerial baiting, cooperative projects covering large contiguous areas are preferable to smaller, single or part-property efforts.

7.7.2 Case study 2 — Hypothetical case study of benefit–cost analysis for sheep properties

To undertake a benefit–cost analysis, data on the value of production, cost of wild dog control and control effectiveness are required. An example of a benefit–cost analysis for wild dog control on sheep properties is shown in Table 7. In the table, hypothetical values are given for production parameters, wild dog control costs and sheep losses for two wild dog control strategies:

- Wild Dog Control Strategy 1: trapping, reactive ground baiting, fence maintenance and opportunistic shooting; no baited zone.
- Wild Dog Control Strategy 2: baited zone (applied by aerial baiting) as well as fence maintenance, opportunistic shooting and reactive ground baiting.

The benefit of these two strategies in reducing wild dog impact is determined by comparing them against two hypothetical percentage stock losses (16% and 33%) when no wild dog control was applied.

Process

In this hypothetical case, it was assumed that the relationship between damage and the density of wild dogs is linear and hence the relationship between benefit–cost ratios and sheep losses is also linear (Figure 15, Line C).

To estimate the break-even points (the points at which the benefits equalled the costs), linear functions were drawn for benefit–cost ratios at different percentage losses for the two strategies (Figure 18). Using the equations of the lines, the break-even points were estimated by determining when the benefit–cost ratio (y-axis) equalled one.

In general, it is better to use long-term average losses than single year figures because of the large variability in predation that is experienced between years.

Analysis

The hypothetical benefit–cost ratios were better for Strategy 2 than Strategy 1 (Table 7, Figure 18) because the percentage predation experienced and the relative costs were lower in Strategy 2. The control effort in both strategies was beneficial when compared with the hypothetical percentage losses where no control effort was expended. The benefit was greater when the imposition of the baiting zone was the primary control strategy. For Strategy 1 (no baited zone), break-even would have been achieved if expected losses were 9.6%, whereas Strategy 2 (with baited zone) was beneficial if expected losses were above 4.0%. Aerial baiting is also likely to have a greater impact on wild dog populations, but targeted baiting/trapping may be more effective in removing individual dogs which are causing problems in localised areas.

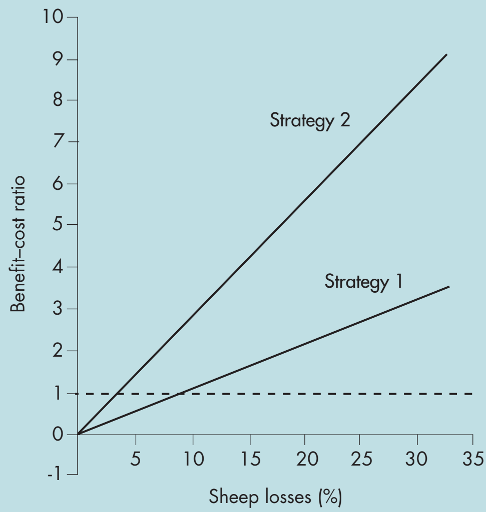

Figure 18: An example of benefit–cost ratio analyses showing the benefit–cost of effort to control wild dogs including a baited zone (Strategy 2 in Table 7) and control effort without a baited zone (Strategy 1 in Table 7) for sheep graziers in north-eastern New South Wales. Benefit–cost ratios below 1 (dotted/dashed line) are uneconomic.

The benefit–cost analysis is clearly dependent on the per head value of the livestock and the potential activity — that is, the frequency of attacks and number of sheep maimed or killed during attacks — of individual dogs that may be killed as a result of control effort. The latter is difficult to predict because relationships between wild dog densities and livestock predation levels are highly variable (Box 2, Step 3) and dependent on a wide range of factors including availability of alternative food, social structure of dogs and activity of individual dogs.

Table 7: Hypothetical benefit–cost comparison of two wild dog control strategies using two sets of sheep productivity data. (Hypothetical annual percentage losses experienced in the absence of control extrapolated from Thomson (1984a); sheep production and control effort figures for Strategy 1 extrapolated from NERDA (undated c. 1966) and those for Strategy 2 extrapolated from Thompson and Fleming (1991) and Fleming (1996b); average hourly wages are from Consumer Price Index figures, Australian Tax Office (unpublished data 1996).

Parameter	Wild dog control Strategy 1[1]	Wild dog control Strategy 2[2]	No control (16% losses)	No control (33% losses)
Mean sheep numbers (head per property)	1030	1030	1030	1030
Greasy fleece weight (kilograms per head)	3.7	3.7	3.7	3.7
Value of sheep ($ per head)	42.4	42.4	42.4	42.4
Annual mean sheep killed by wild dogs (head per property)	25.6	11.2	165	340.4
Annual control effort (hours per property)	185.6	100	0	0
Cost of predation ($ per property)	1085	475	6996	14432
Cost of control ($ per property)	2975	1790	0	0

	Benefit-cost ratios[3]	
Control	**@16% annual losses**	**@33% annual losses**
Strategy 1	1.46:1	3.29:1
Strategy 2	2.87:1	6.15:1

[1]Strategy 1: Control with no buffer-zone

[2]Strategy 2: Control with a buffer-zone

[3]Benefit–cost ratio is calculated by dividing the benefits (cost of predation when there is no control minus cost of predation under a particular control strategy) by the *total costs* of the control strategy. The *total costs* of the control strategy are the cost of control effort plus any predation costs that are still incurred despite the control effort.

8. Deficiencies in knowledge and practice

Summary

Although there is much knowledge about the ecology, behaviour and effects of predation by dingoes and other wild dogs, some topics require further research to enable best practice management to be implemented. There are also knowledge deficits relating to the conservation of dingoes, the effects of control programs on populations of non-target animals and the interactions between wild dogs and feral cats, foxes and native carnivores. These knowledge deficiencies are not listed in priority order.

8.1 Assess relationship between wild dog abundance and predation of cattle

Deficiency

A poor understanding of the relationship between wild dog density and the predation of cattle in extensive cattle areas.

Developments required

Measurement of predation of cattle and wild dog density is required in different regions. This can be done during normal wild dog control programs. As for sheep enterprises in the eastern highlands, the costs of the 'no dog control' option requires evaluation (Section 7.3.4).

Consequences

If consistent relationships exist between wild dog density and predation of cattle, marginal analyses have more credibility and become very useful in best practice management. Negative relationships between cattle predation levels and wild dog density would indicate that control of wild dog populations was disadvantageous and should be discontinued and alternative strategies used, or that control should be coordinated over larger areas.

8.2 Assess relative effectiveness and efficacy of baiting strategies

Deficiency

The relationship between the cost of control (particularly aerial and ground baiting) and the impact of wild dog predation on the profitability of livestock (particularly sheep) in the eastern highlands is unknown. This knowledge is essential for decisions about the continuing expenditure on wild dog control, dingo conservation and the suitability of some lands for grazing enterprises. If possible, areas where no wild dog control is exerted should be incorporated in the assessments so that the costs of the 'no dog control' (Section 7.3.4) option can be evaluated and benefit–cost ratios of different control programs can be compared against no action.

Developments required

Experiments to evaluate the relative costs and benefits of the various methods of wild dog control.

Consequences

Improved management decisions relating to wild dog control, conservation and the profitability of grazing enterprises. If the relationships between wild dog density and predation are tenuous or highly variable, the continued use of all control strategies that reduce dog abundance in sheep areas are justified provided they fall within budget allocations.

8.3 Assess effect of Rabbit Calicivirus Disease on dingo predation of livestock

Deficiency

The introduction of rabbit calicivirus has had a varied impact on rabbit numbers with the greatest reductions being in arid and semi-arid areas (rainfall less than 300 millimetres). The effect of reduced abundance of rabbits on wild dog predation of cattle and native animals and on wild dog population abundance is poorly known.

Developments required

The interaction of rabbit calicivirus on rabbit populations and the subsequent effects on wild dog predation of cattle and native animals requires research.

Consequences

Prey abundance may be an important indicator of the probability of wild dog predation of livestock. If so, understanding of predator–prey relationships and the effects of Rabbit Calicivirus Disease on rabbit populations is essential.

8.4 Investigate feasibility of compensation schemes for wild dog predation

Deficiency

A self-funding insurance or compensation scheme has been suggested to reimburse landholders for livestock losses. Such schemes could be a substitute for control or an adjunct to reduced levels of control. The feasibility and function of such schemes has not been investigated.

Developments required

The feasibility and operation of self-funded compensation schemes require investigation under different agricultural systems where wild dogs occur.

Consequences

Determination of the likely success of compensation or insurance schemes as an alternative management strategy for wild dogs.

8.5 Train vertebrate pest control operators and managers

Deficiencies

There is a need for training packages to inform field operatives and managers of the strategic approach to wild dog management and the conservation issues relating to hybridisation.

Developments required

The information contained in this book provides a starting point for the development of training packages for field operatives and managers. These should be continuously updated to account for changes in legislation and new research findings.

Consequences

Soundly-based management will be implemented and the results of new research will be incorporated into management plans.

8.6 Improve public awareness of agricultural production, conservation and animal welfare issues for wild dog control

Deficiency

Public perceptions of vertebrate pest control programs are often based on incorrect premises or worst-case scenarios. Many people are not fully aware of the range of agricultural and conservation reasons for wild dog control. There is also misinformation about the use and safety of poisons, and in particular the characteristics of 1080 (sodium fluoroacetate) (Sections 4.2.4 and 6.4.4) that make it the poison of choice for controlling wild dogs. Although considered a humane poison by many researchers and managers, there is a perception by many in the wider community that 1080 causes painful deaths. There is increasing community interest in the need for, and humaneness of, control techniques used on pest animals. These issues require extension to the broader community.

Developments required

Education and media programs to extend information on the welfare issues of wild dog management. Include animal welfare issues associated with wild dog control in school curricula.

Consequences

More techniques for management of wild dogs that include non-lethal strategies will be available.

Better informed public debate about the conservation, livestock production and animal welfare issues relating to the management of wild dogs.

8.7 Develop species-specific and more humane control techniques for wild dogs

Deficiency

The increasing interest of the wider community in animal welfare requires that more humane methods of control for pest animals be continually investigated. For example, the use of strychnine on trap jaws is the presently accepted and recommended method for minimising the suffering of dogs held in traps. Strychnine causes a quick yet painful death.

Developments required

Development and monitoring of new and improved techniques to minimise or eliminate the potentially adverse effects of control measures on the welfare of wild dogs and non-target animals is needed. For example, a fast-acting more humane poison for use as a substitute for strychnine on trap jaws requires investigation. The economic viability of new techniques will need to be assessed.

The use of deterents to minimise interactions between wild dogs and people is untested. Alternative management tools such as livestock guarding dogs and toxic collars have been tried in other countries but their application and benefit–cost analyses for Australian conditions are unknown.

Consequences

Ongoing assessment and improvement of animal welfare aspects of wild dog control. The most humane methods of control will be used for managing wild dogs and the welfare of non-target animals will not be compromised during control programs.

8.8 Assess economic importance of hydatids in wild dogs

Deficiency

The relationship between wild dog populations and the prevalence of hydatidosis (causal agent *Echinococcus granulosus*) in livestock has not been fully investigated. At local levels, it is known that hydatidosis in cattle is sometimes associated with grazing lands adjacent to or within country inhabited by wild dogs; however full epidemiological studies have not been completed. The economic importance of hydatid infection in livestock remains unclear and strategies to prevent or reduce their occurrence are yet to be formulated.

Developments required

Research is needed to estimate the economic importance of hydatid infection in wild dogs and associated livestock.

Consequences

Development of strategies to prevent or reduce the occurrence of hydatid infection in wild dogs and livestock.

8.9 Assess the role of disease induced mortality in wild dogs

Deficiency

A poor understanding of disease and parasite-induced mortality in wild dogs.

Developments required

The role of various parasites and diseases on the mortality of wild dogs and the impact of this on population dynamics in different environments requires research.

Consequences

A better understanding of disease and parasite-induced mortality in wild dogs.

8.10 Assess the role of wild dogs if rabies were introduced

Deficiency

A question that is raised by the fact that dingoes came to Australia from Asia is, 'Why is there no rabies (Rhabdoviridae) in Australia? What is different here compared with similar habitats and fauna types in Asia?'

Developments required

Modelling using demographics and estimates of rabies transmission coefficients will provide useful indicators of the likelihood of rabies becoming established in wild dog populations. Further research is needed on the demographics and interactions of commensal dogs and wild dogs in the more settled areas of eastern Australia and in northern Australia.

Studying the ecology and demographics of dingoes in Asia will assist in understanding why rabies is not endemic to Australia or what to do if it is introduced to Australia.

Consequences

Understanding the ecology and demographics of dingoes in Asia will assist in rabies contingency planning.

8.11 Assess risks to non-target species of 1080 poisoning

Deficiency

Although there is evidence indicating that the poisoning of wild dogs with 1080 is likely to have little impact on non-target populations, this requires confirmation in eastern Australia. The potential impact of 1080 baiting for wild dog control on populations of non-target carnivorous species (including phascogales (*Phascogale* spp.) and spotted-tailed quolls, (*Dasyurus maculatus*)) is the main factor potentially limiting the use of 1080 (and particularly aerial baiting) to control wild dogs in eastern Australia.

Developments required

Scientific assessment of 1080 baiting programs on populations of non-target carnivorous native animals in a variety of environments. Investigation of the potential of alternative baiting strategies (bait substrate, placement of baits and timing of baiting) to reduce non-target risks.

Consequences

A scientific basis for improved risk management for non-target species in areas where wild dogs are baited.

8.12 Assess the ecological effects of wild dog control on feral cat and fox populations

Deficiency

There have been few investigations into the ecological relationships between feral cats, wild dogs and foxes (*Vulpes vulpes*). The effect of controlling wild dogs on the abundance of other predators requires further study.

Developments required

Research to assess the factors influencing the dynamics of feral cat and fox populations and the interplay of these factors with wild dog control. Relationships between wild dogs and these carnivores require research to enable better management for conservation.

Consequences

Best practice management of wild dogs, foxes, and feral cats can be based on scientific data rather than unsubstantiated assumptions.

8.13 Assess the interactions of wild dogs and native carnivore populations

Deficiency

Inadequate understanding of the interplay of wild dog control with the factors affecting populations of native carnivores, particularly quolls (*Dasyurus* spp.).

Developments required

Research to assess the factors influencing the dynamics of native carnivore populations and wild dog populations, and the interplay of these factors with wild dog control.

Consequences

Improved management for conservation of native carnivores in areas of wild dog control.

8.14 Assess effects of wild dog abundance on macropods

Deficiency

The control of wild dogs in forested areas of south-eastern Australia may have caused populations of kangaroos and wallabies (*Macropus* spp.) to increase with concomitant grazing impacts on agricultural and forestry enterprises. On some holdings, a balance is attempted between calf losses due to predation by wild dogs and the benefits that predation on macropods may have in reducing grazing pressure.

Developments required

Predator–prey relationships between wild dogs and their macropod prey require investigation in south-eastern Australia.

Consequences

Knowledge of predator–prey relationships in cattle country of south-eastern Australia will allow for management strategies that balance an acceptable abundance of macropods with acceptable level of predation of calves.

8.15 Assess the values of dingo conservation

Deficiency

Economic frameworks are needed to assist the community in meeting dingo conservation goals. Better management of budgets relating to the conservation of dingoes can only be achieved if the unpriced values of dingoes are estimated enabling marginal analyses and cost–benefit analyses of conservation strategies. The contingent and inherent values the community places on the conservation of dingoes have not been established.

Developments required

Establish the contingent and inherent values of dingoes to the wider community.

Consequences

Estimation of unpriced values of dingoes will enable marginal analyses and cost–benefit analyses of conservation strategies to determine the most cost-effective management strategies for meeting community conservation objectives.

8.16 Develop a method to identify genetically pure dingoes

Deficiency

If governments enact legislation to conserve dingoes (Section 5.3.3) while controlling other wild dogs, non-destructive methods to distinguish between dingoes and other wild dogs are required. For example, conservation programs on Fraser Island would require the capture of all wild dogs over time to enable their genetic purity to be assessed, with subsequent release or destruction depending on their genetic status. At present, there is no consensus applicable to the whole country on what constitutes a 'pure' dingo.

Developments required

Techniques to differentiate between dingoes and other wild dogs are being developed and the continuation of this work should be encouraged. A national decision must be scientifically made on what genotype and/or phenotype constitutes a pure dingo.

Consequences

Policy decisions and management strategies for conservation of dingoes depend on the ability to differentiate between subspecies of wild dogs. Without a method of differentiating that can be applied to live animals, conservation strategies are impossible to implement. A national policy on the genotype required for genetic purity will enable conservation to advance; without such a policy, dingo conservation is a lost cause.

8.17 Improve knowledge about genetics of wild dogs

Deficiency

Information on the taxonomic status of wild dogs throughout Australia is required, especially in climatically different regions where races of pure dingoes may occur.

Developments required

Public awareness of the issue of hybridisation, a rapid method of field assessment of pure dingoes, and strategies and techniques for the removal of hybrids and free-roaming dogs from areas of pure dingoes are required. The adequacy of refugia on islands and the mainland to allow populations of pure dingoes to be maintained naturally needs investigation.

Consequences

Genetic assessment of regional variations in dingo populations and self-sustaining populations of pure dingoes.

8.18 Assess the ecological role of dingo hybrids

Deficiency

Although the role of dingoes in central and northern Australia is understood, the role of wild dogs in eastern Australian environments is less well known. Also, it is unknown whether the increased proportion of hybrids will change the ecological role currently held by dingoes.

Developments required

Scientific investigations are required to understand the similarities and differences between dingoes and hybrids and whether these differences will alter predation rates on native fauna and livestock.

Consequences

If the roles of dingoes and hybrids are different, a new suite of management decisions will be required. Balancing the requirements for control and conservation in management plans requires knowledge of potentially different ecological roles of dingoes and other wild dogs.

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Appendix A: Parasites and pathogens recorded from wild dogs in Australia (after Corbett 1995a) and their potential effects on wildlife, humans and livestock (after Kelly 1977).

Organism	Locality recorded	Site of infection	Affects humans?	Affects wildlife?	Affects livestock?
Cestodes					
Tapeworms					
Echinococcus granulosus	Queensland NE NSW SE Highlands	Small intestine	yes	yes	yes
Taenia ovis	Probably widespread at very low levels	Small intestine	no	?	yes
Taenia hydatigena	SE Highlands	Small intestine	no	no	yes
Taenia pisiformis	Central Australia SE Highlands	Small intestine	no	yes	no
Taenia serialis	SE Highlands	Small intestine	no	yes	no
Dipylidium caninum	Queensland SE Highlands	Small intestine	yes	no	no
Spirometra erinacei	Queensland Central Australia SE Coastal	Small intestine	yes	yes	no
Undetermined species	North Australia Barkly Tableland	Small intestine	no	no	no
Nematodes					
Hookworms					
Uncinaria stenocephala	SE Highlands	Small intestine	yes	no	no
Ancylostoma caninum	SE Highlands Queensland SE Coastal	Small intestine	yes	no	no
Undetermined species	North Australia	Stomach/ intestine	no	no	no

Organism	Locality recorded	Site of infection	Affects humans?	Affects wildlife?	Affects livestock?
Nematodes					
Roundworms					
Toxacara canis	SE Highlands	Small intestine	yes	no	no
Undetermined species	Central Australia North Australia	Small intestine	no	no	no
Heartworm					
Dirofilaria immitis	North Australia Barkly Tableland SE Highlands	Right ventricle and pulmonary artery	yes	no	no
Lungworm					
Oslerus osleri	SE Highlands	Trachea	no	no	no
Whipworm					
Trichurus vulpis	SE Highlands	Caecum and large intestine	no	no	no
Spiruroid					
Cyathospirura dasyuridis	SE Highlands	Alimentary tract	no	yes	no
Thorn-headed worm					
Acanthacephala sp.	Barkly Tableland	Stomach	no	no	no
Viruses					
Canine distemper					
Paramyxovirus	Central Australia Barkly Tableland	Respiratory tract	no	no	no
Canine Hepatitis					
Adenovirus	Central Australia Barkly Tableland	Liver	no	no	no
Protozoa					
Coccidia					
Isospora rivolta	SE Highlands	Alimentary tract	no	no	no
Eimeria canis	SE Highlands		no	no	no

Organism	Locality recorded	Site of infection	Affects humans?	Affects wildlife?	Affects livestock?
Protozoa					
Sarcosporida					
Sarocystis sp.	Queensland SE Coastal	Striated muscle and heart muscle	no	?	?
Giardia					
Giardia sp.	SE Coastal	Gastrointestinal system	yes	?	?
Insects					
Biting lice					
Trichodectes canis	SE Australia	Skin	no	no	no
Undetermined speices	Barkly Tableland Central Australia	Skin	no	no	no
Fleas					
Ctenocephalides canis	Probably widespread	Skin	yes	no	no
Ctenocephalides felis	Probably widespread	Skin	yes	no	no
Echidnophaga myrmecobii	Central Australia Barkly Tableland	Skin	no	yes	no
Undetermined species	North Australia	Skin	no	no	no
Marchflies					
(Tabanidae)	Widespread	Skin	yes	yes	yes
Kangaroo flies					
(Hippoboscidae)	SE Coastal	Skin	no	no	no
Mosquitoes					
(Culicidae)	Widespread	Skin	yes	yes	yes
Blowflies					
(Calliphoridae)	Widespread	Wounds	no	no	yes

Organism	Locality recorded	Site of infection	Affects humans?	Affects wildlife?	Affects livestock?
Ticks					
Ixodes holocyclus	SE Coastal high-lands	Skin	yes	yes	yes
Rhipicephalus sanguineus	Central Australia North Australia	Skin	no	no	?
Amblyomma triguttatum	Queensland	Skin	no	yes	?
Mites					
Sarcoptic mange					
Sarcoptes scabieri	Widespread	Skin	yes	yes	no
Demodectic mange					
Demodex folliculorum	Central Australia	Sebaceous glands and skin follicles around eyes and nose	yes	no	no
Pentastome Arthropod					
Tongueworm					
Linguatula serrata	SE Australia Central Qld	Nasal cavities	no	?	?
Fungus					
Ringworm					
Microsporum canis	Central Australia	Skin	yes	yes	yes
Leech					
Hirudo sp.	SE Highlands	Skin	yes	yes	yes

Appendix B: Getting the best out of extension: 20 recommendations to help integrate education and extension into wild dog management

(after Andrew 1999)

The following recommendations, combined with available extension materials, will help wild dog management coordinators incorporate effective education and extension into their programs. The recommendations are drawn from pest animal projects that were supported under the Bureau of Resource Sciences' Vertebrate Pest Program (1993–1996) and are aimed at government officers, researchers, extension officers and community members involved in group management. The recommendations are not in priority order although they have been grouped so that similar issues are listed together.

1. *Wild dog management is essentially a social issue.*

While it is true that effective management of wild dogs requires a certain baseline of scientific and technical information, the actual process of management is a social one involving the ideas, activities and relationships of landholders and agency representatives. This means that there is often no predictable and generalisable right or wrong answer to questions to do with management. The values and views of people should be considered and debated as part of the process of management.

2. *Agency representatives who deal with landholders need to have personal qualities, commitment and experience that are respected by the landholders they are working with. It is also important that agency representatives see their interactions with landholders as long-term relationships. Many landholders have seen a 'turnover' of government staff and extension officers and they sometimes have to repeat the same messages to consecutive government representatives. Agency representatives also need to respect the personal qualities and experience of landholders.*

This is perhaps one of the most crucial aspects of a project which involves different interest groups. Relationships between people are complex and interpersonal relationships are central to the success of projects. Projects and working arrangements can stall or fail because of personal clashes. Persistence and patience, conflict resolution abilities and a sense of humour are important attributes of good extension officers and other government officers. Extension and other government officers involved in land management issues need to develop and sustain a genuine level of familiarity and trust with the landholders that they seek to support. This genuine familiarity and trust takes time to develop. Landholders live within social settings with often long-established communication patterns. It is unrealistic to expect to be able to gain worthwhile insights into a social setting with a single, short visit.

3. *Most projects and programs need to be conducted over long periods. Consequently, project managers need to be responsive to change.*

Most farmers and graziers view their enterprise as a long-term business. Many are third, fourth or even fifth generation property owners and consider the significance of their decisions and practices on their children and grandchildren. Some see governments as only being interested in the short-term and with little commitment to the long-term viability of the agricultural sector. Projects need to reflect a commitment to long-term outcomes and must consider changes that occur within government sectors and farming and grazing communities.

4. *Landholders are ultimately responsible for 'on the ground' decisions about land management involving their land. In the long run, landholders will determine whether programs and actions succeed or fail.*

Wild dog management within the agricultural sector is mainly the responsibility of landholders. Therefore they must have a major role in decision making if strategies are to be successful. Nevertheless, they do need to actively consult other groups and individuals with a major interest in the management of wild dogs.

5. *Management options for wild dogs must be seen to be practical by landholders.*

Wild dog management options must be realistic with regard to equipment, labour requirements and cost-effectiveness, and should fit within routine farm operations. These are the practical considerations that landholders face on a daily basis but are often overlooked by researchers and/or agency representatives who have different timetables.

6. *Encourage the involvement of all stakeholders.*

It is important to attempt to involve anyone who is interested in land management issues and also to attempt to seek opinions from a wide range of community and other groups. Individuals within a community have diverse talents, interests and experience. Managers of different enterprises bring different perspectives to resource management issues. Women have contributed greatly to changes within rural communities and it is now acknowledged that they are equal partners in many rural enterprises. Elder members of communities should not be forgotten, as they often know more about a particular district than anyone else. Different cultural groups and individuals often have different traditional ways of knowing and different ways of doing things that bring a greater range of possible solutions to land management problems. Children also can become involved in projects through clubs, schools or through local events and activities. If funds are available, consider using an independent facilitator to manage diverse views or to bring diverse views together.

7. *Identify and work with key players in the community.*

Within communities there are many landowners who are respected for their land management expertise and innovation. These people are often leaders in their community. Working with these people will help gain an insider's view of local land management issues.

8. *Land management issues attract a range of views: expect and respect diversity of opinion.*

It is not reasonable to expect all landholders and agency representatives to agree on any given issue. Aim for a give and take arrangement and value argument: it is a good way of finding out what people want and feel about an issue. It is reasonable for some people to concede on some points but not on others.

9. *The scientific community, supported by government, should provide accessible information. They should also involve landholders and agency representatives in research and data collection.*

Pest animal management requires support information from research agencies and from landholders. If research is to have practical outcomes then it should include landholder information as part of the research process. Researchers should not regard landholders as just data collectors. They have an essential role in ensuring that the research is testing practical management options. Landholders observations may also provide useful directions for research.

10. *The rights of individual land ownership should be respected and data collected from properties should be treated confidentially.*

Landholders have the right to privacy and to respect of both their land and 'intellectual' property rights. Release of data identifying individual landowners should be negotiated with those landowners in the first instance. Usually, it is the pooled information that is of most value to researchers and agency representatives so that individual landholders are not identified.

11. *Landholders and others often respond differently to written information and questionnaires than to conversations.*

This may simply be because landholders' usual medium of communication is through conversation rather than writing. This point is important to remember when collecting data about peoples' opinions on land management issues.

12. *Sustained direct communication is the most valued and effective form of conveying and receiving perspectives on the management of wild dogs.*

Talking one-to-one with people is the most effective way of getting people involved and maintaining their involvement in a program. Newsletters, field days, local shed meetings, media promotion and talks at local meetings are also encouraged.

13. *Access to information should be efficient and easy.*

All people in a community should be informed about and able to access information associated with land management projects that is relevant to their district. Information could be presented via a number of different means such as: local media, newsletters, mail-outs, presentations at meetings and informal gatherings. Individuals and groups should be provided with a contact list of people with various types of expertise and knowledge that they can call upon if required (for example, indigenous, historical, scientific, financial etc).

14. *Consider ways of getting information to the wider community and other interested groups.*

Many cheap and easily accessible information channels exist to inform other people about projects. Local media will often respond to a story involving local landholders. Displays and notices on bulletin boards and notice boards at local stores, halls and at special events will help spread the news. Write stories for Landcare and other rural newsletters and write to or give talks at meetings of other groups in the district. Word-of-mouth is one of the most important ways of spreading the word about local projects.

15. *Frequent, organised meetings that involve committed representatives from all stakeholder groups are necessary if 'on the ground' change is expected as an outcome.*

Information about the issues to be discussed should be circulated to all stakeholders well ahead of meetings so that representatives may consult with and receive advice from their constituents. Representatives should be people within an organisation or district who have a commitment to consultation and who will give feedback to the people whose views they represent.

The management group size should be determined by the ability of those taking the main responsibility for pest management (those representing stakeholders) to feedback information on a regular basis and receive responses from others and to meet any queries from those whom they represent. Mechanisms for informing all people should be clearly thought out so that representatives do not merely 'rubber-stamp' proposals and actions that their constituents may not know about.

16. *Meetings should always have a clear purpose that relates to the needs of landholders. They should be held at times that suit landholder schedules.*

The best meetings are those that reflect wild dog management developments that have occurred on the ground between meetings, rather than those that can be perceived as purely paper exercises. Meetings should also be held at times that are negotiated with landholders. This includes consideration of seasonal work, day of the week, time of day, and length of the meeting. Try to tie wild dog management meetings into existing meetings such as landcare and bushfire meetings. Often a social event such as barbecue is a useful way of bringing people together. This also gives people time to discuss issues in a relaxed atmosphere.

17. *Wild dog management practices need to be viewed within a broader legal and policy context.*

Governments at all levels should provide broader framework considerations (for example Ecologically Sustainable Development, biological diversity, legislative requirements) within which on the ground pest management practices can be located and to which they can contribute. Plain language versions of these policy statements should be made readily available to all participants.

18. *All costs and benefits need to be considered.*

Whatever technique is used to calculate costs and benefits it should be remembered that different managers have different concerns and priorities. Many aspects of land management and broader lifestyle interests have values that are difficult to quantify in monetary terms and cannot necessarily be generalised. A common difficulty with attempts at cost–benefit analysis is the time it takes and the complexity of some formulas that seem irrelevant to landholders. This is so, particularly for those who consider that the impact of any pest is worth managing or, at the other extreme, those that are completely uninterested in pest management regardless of the demonstrated economic benefit.

19. *The pain and suffering of animals should be considered in decision making.*

Ethical considerations are an aspect of pest animal management that cannot be ignored. Many methods of pest management inevitably inflict pain and suffering on animals. Discussion about this issue and relevant information about various management methods must be considered as part of any pest animal management project if these methods are to be regarded as best practice. The most humane methods available should be preferred.

20. *Cultural and heritage issues should be considered in decision making.*

Many land management decisions affect cultural and heritage sites. Consideration must be given to the relationship between cultural and economic interests as part of any pest animal project.

Some suggested extension materials

a. National pest management guidelines including this publication. Other guidelines are available for rabbits, foxes, feral goats, feral pigs, rodents, feral horses and carp.

Australia's Pest Animals: New Solutions to Old Problems (Olsen 1998)

New Approaches to Managing Pest Animals (an extension folder)

These are available from the Bureau of Rural Sciences in Canberra (internet: http://www.affa.gov.au/outputs/ruralscience.html).

b. State and Territory agriculture and conservation departments provide factsheets on various pest animal issues.

c. Specific local information can be obtained from regional agricultural protection officer and/or park service.

Appendix C: Authors' biographies

Peter Fleming

Peter Fleming is a senior research officer with the Vertebrate Pest Research Unit of NSW Agriculture. Since 1983, he has studied the impacts and management of flying foxes, bird pests, European red foxes, feral pigs and feral goats. Most of Peter's research has been in the highlands of eastern New South Wales where he is primarily interested in assessing the impacts of wild dogs on livestock production and the improvement of management strategies for wild canids. Peter has published over 60 research and extension articles about vertebrate pests. He is currently researching the interactions of feral goats and domestic livestock for exotic disease contingency planning, and is also responsible for an integrated program for wild dog management in south-eastern New South Wales and the Australian Capital Territory.

Laurie Corbett

Dr Laurie Corbett is a specialist in ecosystem assessment and management with over 30 years field experience studying the ecology of vertebrate predators and their prey, fire ecology and the management of feral animals. He has extensive knowledge of canids, felids, raptors and reptiles in Australia, Scotland and south-east Asia and is recognised as a world authority on dingoes. He is the author or co-author of more than 140 publications, of which over 50 specifically relate to wild dogs. Formerly with the CSIRO Division of Wildlife & Ecology, Dr Corbett is currently a principal ecologist with EWL Sciences Pty Ltd, based in Darwin.

Robert Harden

Robert Harden is the Vertebrate Pests Team Leader in the Biodiversity Research Group of NSW National Parks and Wildlife Service. He has more than 30 years of research experience of the ecology and management of wild dogs in the eastern highlands of NSW and has published many research and extension articles on vertebrate pest management. His recent research includes the development of management strategies for introduced rodents on Lord Howe Island, the rehabilitation of the Lord Howe Island woodhen, the management of feral goat impact in the eastern highlands of NSW and the impact of fox baiting on spotted-tailed quolls.

Peter Thomson

Peter Thomson is a research scientist with over 20 years field experience working on the ecology and management of canids in Australia. Much of his career was devoted to a long-term study of dingoes in the north-west and Nullarbor areas of WA, and in more recent years, to various studies relating to the control of foxes. He has published numerous articles and scientific papers on dingoes and foxes. He leads the Vertebrate Pest Research group of Agriculture Western Australia and is currently involved in studies on a number of different pests.

Abbreviations and Acronyms

ANKC	Australian National Kennel Council
ANZFAS	Australian and New Zealand Federation of Animal Societies
APB	Agriculture Protection Board (Western Australia)
APCC	Animal and Plant Control Commission, South Australia
AGWEST	Agriculture Western Australia
BRS	Bureau of Rural Sciences (formerly Bureau of Resource Sciences)
CALMWA	Department of Conservation and Land Management (Western Australia)
CPUE	Catch-per-unit-effort
CWR	Critical Weight Range (mammals weighing 35–5500 grams)
DNA	Deoxyribonucleic acid
ESD	Ecologically Sustainable Development
GPS	Global positioning system
NERDA	New England Rural Development Association
NFACP	National Feral Animal Control Program (a NHT program)
NHT	Natural Heritage Trust
NLP	National Landcare Program
NPWS	National Parks and Wildlife Service (New South Wales)
PWC	Parks and Wildlife Commission (Northern Territory)
QDNR	Department of Natural Resources (Queensland)
RLPB	Rural Lands Protection Board (New South Wales)
RSPCA	Royal Society for the Prevention of Cruelty to Animals (Australia)
SCARM	Standing Committee on Agriculture and Resource Management
s.d.	Standard deviation
SDP	Stochastic dynamic programming
VPC	Vertebrate Pests Committee
WDCA	Wild Dog Control Association (New South Wales)
WDDB	Wild Dog Destruction Board (western New South Wales)

Glossary

1080: Sodium fluoroacetate. An acute metabolic poison without antidote; particularly toxic to canids.

Bait: Attractive substance fed to pest animals that can be used to carry a poison or contraceptive or to lure animals into traps.

Bait mound: Specialised bait station where bait is buried in the centre of a mound of friable soil to minimise bait removal by non-target animals.

Bait station: A specific site used for the repeated placement of bait.

Biocontrol (biological control): Control of pest populations using a specific biological agent such as a virus, bacterium or predator (for example, myxomatosis).

Biodiversity: Biological diversity. The natural diversity of living things, usually defined at three levels: genetic, species and ecosystem.

Blastocyst: Early, multicellular stage of embryo development in marsupials at which development is postponed. Delayed implantation of the blastocyst in the uterus allows birth to correspond with seasonal flushes of food or the loss of an embryo or pouch young.

Bounty (bonus): Predetermined reward paid on presentation of evidence (for example, scalp) of the destruction of an animal (for example, wild dog).

Canid: A member of the family Canidae comprising 13 species of wolves, jackals, dogs and foxes.

Carnivore: A flesh-eating animal or a member of the Order Carnivora.

Carnivora: Order of mammals including wolves, dogs, foxes, otters, cats, weasels, bears, raccoons, civets and hyenas.

Carrying capacity: Density of an uncontrolled population of animals that is in equilibrium with their natural resources and competitors.

Chromosome: Threadlike structure in the nucleus of a cell which carries the genetic material (genes) of heredity.

Commensal dogs: Wild dogs (including dingoes, domestic breeds and hybrids) living in close association with but independently of humans (for example, dingoes foraging in rubbish bins at camping grounds on Fraser Island).

Competition: A number of organisms of the same or different species using common resources that are in short supply (exploitation competition), or organisms seeking a common and abundant resource harming each other in the process (interference competition).

Conservation values: Values attributed to maintaining biodiversity, including the preservation of viable populations of native species and natural communities over their natural range, preservation of wilderness and prevention of land degradation.

Conspecific: A member of the same species.

Contingent value: The unpriced value that people place on maintaining things such as open space, clean air and endangered species. The social value of these things is often poorly represented by the market value of the land where they occur. Contingent value can be estimated by asking consumers of their willingness to pay to maintain a resource.

Correlation: Statistical relationship between two or more variables where a change in one variable is reflected in a proportional change in the other.

Critical weight range (CWR) mammals: Australian mammals with live weights between 35 grams and 5500 grams that are believed to be more vulnerable to extinction by predation.

Curvilinear relationship: Curved line relationship between two or more variables.

Demographics: Statistics relating to population dynamics, including birth rates, mortality rates, age and sex ratios.

Density dependence: Regulation of the size of a population by mechanisms that tend to retard population growth as density increases and enhance population growth as density declines.

Dingoes: Native dogs of Asia selected by humans from wolves. Present in Australia before domestic dogs. Pure dingoes are populations or individuals that have not hybridised with domestic dogs or hybrids.

Discount rate: The rate used to calculate the present value of future benefits or costs. It is calculated using the reverse equation to that used to calculate interest rates on invested money.

Dispersal: Movement of an animal away from its birth or breeding site.

Dispersion: The spatial pattern of a population of organisms relative to one another.

Distribution: The geographical area (range) in which a group of organisms occurs.

Diurnal: Active during the day.

DNA: (deoxyribonucleic acid) The genetic material in the cells of most living organisms, which is a major constituent of the chromosomes in the cell nucleus.

DNA fingerprinting (or mapping): A technique in which an individual's DNA is analysed to reveal the pattern of genetic material within particular segments. This pattern is claimed to be unique to individuals, and closely related individuals have similar patterns.

Dogger, dogman: A pest controller who specialises in the removal of wild dogs, usually by trapping or shooting.

Domestic dogs: Dog breeds (other than dingoes) selected by humans, initially from wolves, that usually live in association with humans. This selection process is ongoing.

Ecosystem: Ecological system formed by interaction of living things and their environment.

Efficacy: Ability to produce desired effects.

Efficiency: The accomplishment of desired effects in relation to the effort (or cost) expended to produce those effects (often expressed as a rate).

Endangered species: Species in danger of extinction and whose survival is unlikely if causal threatening processes continue to operate.

Endemic: Limited to a certain region, country or group.

Endemic disease: Disease that occurs in a region or country.

Eradication: Permanent removal of all individuals of a species from a defined area.

Exotic: Introduced from another country (for example, exotic species).

Exotic disease: Disease that does not occur in a region or country.

Extant: Still existing; not destroyed or extinct.

Extrapolation: Interpreting data beyond the dimensions within which it is collected (for example, assuming conclusions drawn from data collected in one region will be relevant elsewhere).

Fecundity: The number of live births over an interval of time.

Feral: Domesticated species that has established a wild population.

Feral dogs: Wild-living dogs of domestic breeds.

Fertility: The ability to produce young.

Free-roaming dogs: Dogs that are owned by humans but not always restrained and so are free to travel away from their owner's residence (includes commensal dogs).

Friable: [Soil that is] easily crumbled.

Functional response: Relationship between per capita food intake rate and food availability.

Genotype: Genetic constitution of an organism.

Gestation: Pregnancy.

Global positioning system (GPS): Small device that uses satellite signals to accurately locate the user's position (latitude, longitude and altitude).

Gregarious: Living in groups.

Home range: Area that an animal (or group of animals) ranges over during normal daily activities. The boundaries of the home range may be marked (for example, wild dogs use scent marks) and may (see territory) or may not be defended, depending on species.

Howl up: Wild dogs are lured to a hunter imitating the howling of a dingo.

Hybrids: Progeny resulting from the cross-breeding of two different species or sub-species and the descendants of crossbred progeny (for example, dogs resulting from crossbreeding of a dingo and a domestic dog).

Hydatidosis: Disease caused by hydatid worm (*Echinococcus granulosus*) infection.

Immunocontraception: A form of fertility control where a substance that triggers an immune reaction causes sterility or reduced fertility in affected animals.

Indices of abundance: Field signs that can give a relative measure of dog abundance (for example, howls, fresh droppings, tracks, bait acceptance).

Ingested: Taken orally.

Intangibles: Values that cannot be numerically quantified (for example, that for which it is difficult to estimate a money value).

Interference competition: see Competition.

Isopleth: A line drawn on a map through points having the same numerical value for any element (for example, an isobar joins points with the same barometric pressure).

Karyotype: Number and structure (gene sequence) of the chromosomes in the nucleus of a cell. All the cells in an individual have the same karyotype (except for sperm and egg cells).

Latent period: The time lag between an action and a response.

LD_{50}: Dose (per kilogram of body weight) that will, on average, kill 50% of treated animals.

LD_{100}: Dose (per kilogram of body weight) that will, on average, kill 100% of treated animals.

Linear programming: A mathematical modelling approach that uses simultaneous linear equations for optimising decisions under resource limitations. A linear programming problem has a linear objective function (for example, to maximise whole-farm gross margins from livestock production) and a set of linear constraints (for example, the density of wild dogs, enterprise type, labour and capital resources) arranged in an array.

Linear relationship: Straight-line relationship between two or more variables.

Lure: Attractant (usually an odour-producing substance) which is used to enhance the effectiveness of baiting programs or to attract an animal to a trap site.

M-44 ejector: mechanical ejector for delivering encapsulated toxin to canids. The device is triggered by the canid pulling on bait material connected to the ejector. This releases a compressed spring within the ejector which drives a rod through a toxin capsule, propelling the contents of the capsule into the animal's mouth. The advantages of this system are that devices can be left loaded as sentinel stations, without degradation of the toxin over time. The pull pressure can also be adjusted so that it is only likely to be triggered by canids and the device ensures that the full complement of toxin is ingested to reduce sub-lethal poisoning.

Marginal benefits: The shift in benefit values that occur as incremental changes are made in the factor(s) which affect level of benefits (for example, changes to livestock losses that occur as wild dog density is reduced).

Marginal costs: The shift in cost values that occur as incremental changes are made in the factor(s) which affect level of costs (for example, changes in the cost of finding and removing an extra wild dog that occur as wild dog density is reduced).

Mark–recapture: Technique of live catching, tagging, releasing and then recapturing animals, and using a formula to estimate population size from the proportion of recaptured animals that are tagged.

Market failure: Occurs when resources are not allocated efficiently through the use of the market, that is, when the costs and benefits to society are not equated by the natural market forces of supply and demand (for example, unsustainable use of natural resources or development of social inequities).

Mesopredator release: The process whereby the removal or loss of higher order predators results in the increase in abundance of and substitution by lower order predators. The negative impacts of mesopredators on small mammal populations may be greater than the higher order predators.

Monoestrus: Having a single oestrus period in one sexual season or year.

Morbidity rate: Proportion of a population affected by disease for a given time interval. Usually expressed as a per capita rate.

Mortality rate: Proportion of a population dying during a given time interval. Usually expressed as an instantaneous per capita rate. In seasonal breeders such as dingoes mortality may be an annual death rate.

Nocturnal: Active at night.

Non-target (animal/species): Animal or species that is accidentally killed or injured by a control measure (for example, domestic dogs or native wildlife caught in wild dog traps).

Oestrus: The phase of the female reproductive cycle when they are fertile and ovulation occurs, sometime referred to as 'sexual heat'.

Opportunistic feeding: Non-selective feeding occurring when the opportunity arises.

Pack: A social grouping of canids, usually genetically related. Wild dogs may hunt as a whole pack, as a sub-group or individually.

Per capita: Per head of population (for example, food consumption per sheep is per capita food consumption).

Pest: Harmful, destructive or troublesome organism.

Phenotype: The characters of an organism due to the interaction of genotype and environment.

Population: Groups of animals of a particular species occupying an area where they are subject to the same broad set of environmental or management conditions.

Population dynamics: The process of numerical and structural change within populations resulting from births, deaths and movements.

Population limitation: A factor is limiting if a change in the factor produces a change in average or equilibrium density of a population. For example, predation by wild dogs may limit the density of a prey population if abundance of the prey is higher when wild dogs are absent.

Population regulation: A factor is regulating if the percentage mortality that it causes increases with population density (sometimes called density-dependent regulation). For example, a disease may regulate wild dog abundance if it causes higher percentage mortality as wild dog density increases.

Predator: An animal that kills other animals for food.

Prevalence: The number of instances of disease, or related attributes (e.g. infection or presence of antibodies) in a known population at a designated time, without distinction between old and new cases.

Prey: An animal hunted or seized as food by a flesh-eating animal.

RANGEPACK: A computer software package (produced by CSIRO) with modules that aid management decisions for livestock enterprises, particularly for those in the arid zone. Modules include *Herd-Econ*, which models herd dynamics and property economics, *Climate* that uses past rainfall data to model the probability of rainfall events and *Paddock*, which predicts grazing patterns within paddocks.

Pro-oestrus: Preparatory phase of the oestrus cycle when the female reproductive system is active but preceding ovulation (egg release).

Reactive control: Control activities in response to the presence of or damage by vertebrate pests.

Regression equation: An equation which describes the relationship between two or more variables.

Species: Group of interbreeding individuals not breeding with another such group and which has characteristics that distinguish it from other groups.

Species-specific: Affecting only the targeted species.

Standard deviation (*s.d.*): The standard deviation of a sample is an estimate of its variability around a mean value, and is calculated from the square root of the variance (s^2):

$$s.d. = \sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 / n-1}$$

where x_i = value of each measurement from $1-i$; $\bar{x}$ = sample mean; and n = sample size.

Strategic control: Using historical evidence and current knowledge to devise strategies that prevent damage caused by vertebrate pests before damage commences.

Stochastic: Incorporating some degree of natural variation which has a mathematically calculable probability.

Stochastic dynamic programming: A mathematical approach to modelling the effects of problems (such as weeds, pests or harvest rates) on production systems, which incorporates measured uncertainty (stochasticity) and the dynamics of the population (of weeds, pests or resource). The objective function is often specified as the present value of the expected returns, which may include the decision makers' risk preference.

Subspecies: Group of individuals within a species, having certain characteristics which distinguish them from other members of the species, and forming a breeding group.

Surplus killing: Predatory activity where prey are attacked and killed in excess of the immediate and short-term food requirements of the predator (Kruuk 1972b). Surplus killing behaviour may result in a number of surviving prey showing injuries.

Sustainability: Continuing in present form and at current level in the longer term.

Sustained control: Continued control in the longer term.

Territory: The area occupied by an animal, or by a pair or group of animals, which it or they will defend against intruders. 'Territory' and 'home range' are synonymous for some canids.

Transect: A line (linear plot) through a study area on which data collection occurs.

Trap night: One trap set for one night (for example, if three traps were set for two nights each, this would be six trap nights).

Top order predator: Animal at the top of the food chain. These animals are only preyed upon by other top order predators including humans.

Ungulate: Hoofed herbivore such as the horse, goat, sheep, pig and antelope.

Unpriced value: Values for things that are not exchanged in regular markets and as such do not have a monetary price, for example, scenery.

Varanid: The family Varanidae comprises a group of about 30 species, generally known in Australia as goannas.

Vertebrate: Animal with a backbone.

Wild dogs: All wild-living dogs, including feral dogs, dingoes and hybrids.

Wilderness: Land that has been essentially unmodified since European settlement.

x-axis: The horizontal axis on a graph.

y-axis: The vertical axis on a graph.

Zoonoses: Diseases that are transmitted between animals and humans.

Index

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Managing the Impacts of Dingoes and Other Wild Dogs is the first book to provide a comprehensive review of the history and biology of wild dogs in Australia, the damage they cause, and community attitudes to their management.

Australia's wild dogs include dingoes, introduced around 4000 years ago, feral domestic dogs and hybrids between the two. They are widely distributed throughout Australia. Predation and harassment of stock by wild dogs causes millions of dollars worth of losses to Australian sheep, cattle and goat producers each year. There are also opportunity costs in areas where sheep are not grazed because of the high risk of wild dog predation. For this reason, wild dog control is a significant expense for many pastoralists and government agencies. Yet conservation of pure dingoes is also important and is threatened by their hybridisation with feral domestic dogs on the mainland.

Key strategies for successful wild dog management are recommended by the authors, who are scientific experts on wild dog management. The strategies are illustrated by case studies.

Managing the Impacts of Dingoes and Other Wild Dogs is an essential guide for policy makers, pastoralists, conservation reserve managers and all those interested in wild dog management.