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Review of Canid Management in Australia for the Protection of Livestock and Wildlife — Potential Application to Coyote Management

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Introduction

Australia has two introduced canid species — European red foxes (*Vulpes vulpes*) and wild dogs (which include dingoes, *Canis lupus dingo*, feral domestic dogs *C. l. familiaris* and their hybrids). Foxes were introduced into mainland Australia in the 1860s and quickly spread (Rolls, 1984; Jarman 1986). This dispersal and establishment is believed linked with the introduction and spread of European wild rabbits (*Oryctolagus cunniculus*) (Saunders et al., 1995). Except in Tasmania, where previous introductions appear to have been unsuccessful, and in northern Australia, where the climate is unsuitable and rabbits are essentially absent, foxes have become established throughout in virtually all habitats including urban and residential environments (Saunders et al., 1995). Within decades of their introduction, legislation was enacted proclaiming them as pests to agriculture, and more recently, as a key threatening process to endangered small mammals (NSW National Parks & Wildlife Service, 2001). This status has been enshrined in subsequent legislation and strengthened by virtue of foxes being an introduced pest species rather than a native animal.

Dingoes are thought to have arrived in Australia from Southeast Asia about 5000 years before present (Corbett, 1995a). A number of reports have reviewed the origins, ecological significance of dingos, and their morphological and genetic relationship to domestic dogs. Interested readers are referred to Newsome et al. (1980) as one example. Like foxes they are also found in virtually every habitat across the Australian continent and are absent from Tasmania (Fleming et al., 2001). However, because of their longer association with Australia, they are often regarded as a "native" species (Davis, 2001). Wild domestic dogs have been present since the first European settlement in 1788 (Fleming et al., 2001) and hybridization with dingoes has been occurring ever since (Corbett, 1995a, 2001). Despite the native status of dingoes, all wild dogs and foxes are regarded and managed as pests on agricultural lands, i.e. outside of conservation areas. Pure dingoes alone are afforded legislative protection in areas set aside for conservation (Fleming et al., 2001; Davis and Leys, 2001) yet feral dogs and hybrids effectively enjoy the same legislative protection in conservation areas as dingoes, because they cannot be managed separately.

Impact of Canids on Livestock Production: Wild Dogs

Wild dogs cost the grazing industries of Australia millions of dollars annually in production losses and control expenses (Fleming et al., 2001; Whan, 2003). Production losses are highest in the sheep industry, followed by the cattle and the goat industries (Fleming and Korn, 1989), reflecting the relative numbers of the three livestock species nationally (Meat & Livestock Australia Limited, 2000). Sheep and goats are more vulnerable to wild dog predation than cattle. This is primarily due to two factors: (a) the fleeing and mobbing behavior of sheep and goats in response to the presence of wild dogs; and (b) the hunting style of wild dogs and the efficiency at which wild dogs handle sheep and goats.

The movement of prey is an essential stimulus for eliciting predation by canids (Fox, 1969). Big horn and Dall sheep (*Ovis canadiensis* and *O. dalli*) of North America scatter in the presence of wolves (*Canis lupus lupus*), their fleeing behavior eliciting an attack response by wolves (Mech, 1988). Domestic goats and sheep have been selected from wild species and also flee in the presence of wild dogs. However, unlike their wild caprinid relatives that can take refuge from predators amongst the rocky, rough terrain found in their natural habitat (for example Dall sheep, Frid, 1997), domestic sheep and goats have no defensive behaviors of consequence. The instinctive reaction to flee is disastrous for domestic livestock because they seldom have quality refuge available and their fleeing behavior triggers wild dog attacks. In addition, Australian merinos, which comprise approximately 75% of the national flock of 104 million sheep (Meat & Livestock Australia Limited, 2000), are particularly susceptible because their second anti-predator response is to circle and form a mob. As they circle, more of those on the outside of the moving mob are exposed to the predator (Fleming, 2001) and surplus killing, where one dog is responsible for predation in excess of nutritional requirements (for example Andelt et al., 1980), often occurs. Because of surplus killing, the damage experienced by sheep producers is not related to the density of wild dogs, excepting that no damage occurs in the absence of wild dogs (Fleming, 2001).

Thomson (1992) observed that wild dogs easily out-paced sheep subsequently attacking 66% of the sheep they chased. This level of capture efficiency is exceptionally high relative to other prey and at the higher end for other predators (Table 1). In fact, many of the sheep in Thomson's (1992) study were chased and outrun by wild dogs but not attacked, the pursuing wild dog breaking off to pursue another sheep. Thomson concluded that there was no advantage for wild dogs to cooperatively hunt sheep.

Characteristics of wild dog predation include:

- Relatively few of the sheep and goats killed or mauled by wild dogs are eaten;
- Of those sheep and goats that are eaten, generally little is consumed; and
- All wild dogs that enter sheep or goat grazing lands will eventually attack or harass sheep and goats.

This scenario has resulted in respective State and Territory Governments independently developing management policies that regard sheep or goat production as being incompatible with the presence of wild dogs. In contrast, attitudes of beef cattle producers towards wild dog predation are diverse (Allen and Sparkes, 2000). Part of the reason for this diversity is the defensive behavior of cattle in response to the presence of wild dogs — adult cattle cooperatively defend calves and/or charge wild dogs (Thomson, 1992; Corbett, 1995a). This defensive behavior of cattle discourages wild dogs resulting in fewer attacks. Consequently, even though wild dogs are more efficient at chasing and killing calves than preferred natural prey such as kangaroos (Table 1), they infrequently do so.

Studies comparing calf loss, subsequent to confirmed pregnancy diagnosis, in beef cattle herds depastured in 1080 baited and non-baited paddocks (>400 km^2) in far north and southwest Queensland showed that in most years wild dogs do not cause detectable predation losses (Table 2). Curiously, this study also found that when wild dog populations were baited on part of the property, annual predation losses increased both in frequency (number of years predation loss is detected) and magnitude (percentage of calves killed by wild dogs). As one naturally assumes reducing pest numbers consequently reduces the impact of that pest, these results were quite unexpected.

The study showed calf losses occurred when prey populations were low, when below-average, annual rainfall had preceded, and most importantly, when baited areas had been re-colonized by wild dogs (Allen, In Preparation). The study concluded that young, dispersing wild dogs were likely to re-colonize after baiting, and were more predisposed to attacking calves than stable wild dog populations. Thus, attempts to reduce predation losses by controlling wild dogs on individual cattle properties may not only be ineffective but counterproductive. For example, for twenty years 1968 to 1987 baiting programs were conducted on Ironhurst station throughout the year yet they continued to see bitten calves (Fig. 1). When wild dog management changed in 1988 to an annual, large-scale, coordinated-baiting program involving multiple properties

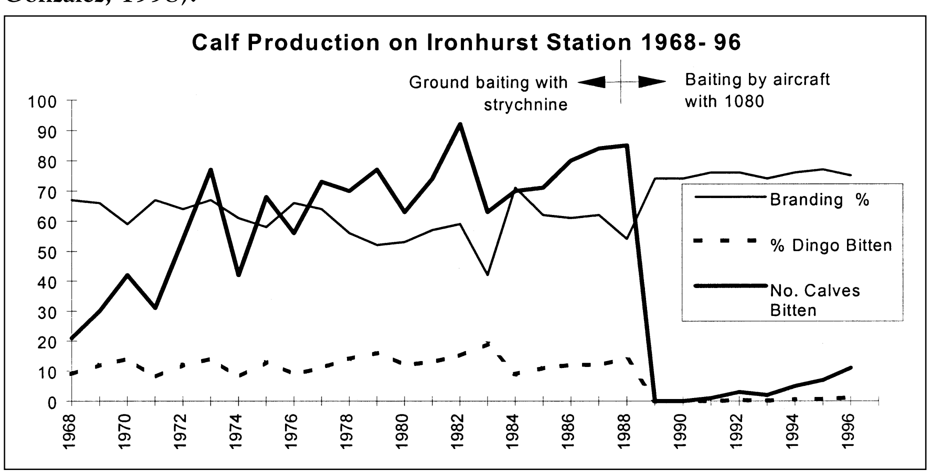
Table 1. Capture Efficiency of Canids Attacking Prey.

Canid	Prey	Capture Efficiency	Reference
Wild Dogs	Sheep	66%	Thomson 1992
Canis lupus dingo,			
C.l. familiaris	Cattle (*Bos* spp)	14%	Thomson 1992
	Kangaroos (*Macropus* spp)	9%	Thomson 1992
Wolves	Elk (*Cervus elephus*)	15-26%	Mech et al. 2001
Canis lupus lupus	White-tailed deer (*Odocoileus virginianus*)	25-63%	Kolonosky 1972
African hunting dogs	Ungulates (mostly *Gazella thompsonii*)	85%	Estes and Goddard 1967

Table 2. Predation loss of calves in baited and non-baited portions (>400 km^2) of the same property (from Allen, In Preparation).

Site/Date	Predation Loss Baited Area	Predation Loss Non-Baited Area
Mt Owen/ 1994	Nil Detected	8.8%
Mt Owen / 1995	15%	Nil Detected
Mt Owen 1996	Nil Detected	Nil Detected
Mt Owen / 1997	Nil Detected	Nil Detected
Strathmore/ 1995	11.3%	Nil Detected
Strathmore/ 1996	32.1%	Nil Detected
Strathmore / 1997	Nil Detected	Nil Detected

Figure 1. Changes to the branding rate and number of calves bitten on Ironhurst Station subsequent to major changes to dingo control technique. (From Allen and Gonzalez, 1998).



mean-annual-branding rate increased by 18% simultaneous with a substantial decrease in bitten calves (Table 3). Similarly, in the Brindabella Ranges immediately west of Canberra in the Australian Capital Territory, a cooperative ground baiting and trapping program that included about 850 km^2 of lands managed by government agencies and private owners achieved a 60% reduction on average annual losses of sheep and goats (Hunt and the Brindabella/ Wee Jasper Wild dog/ Fox Working Group, 2002). These are just three examples that demonstrate a strategic advantage from large-scale, coordinated wild dog control that cannot be achieved through control programs having a single property focus.

Table 3. Calf production and dingo control figures from Ironhurst Station in North Queensland from 1978 to 1996. (From Allen and Gonzalez, 1998).

Control Method	Ground Baiting Single property	Aerial Baiting Several Properties
Poison	strychnine	1080
Area Baited	520 km_	>50 000 km^2
Mean Branding	**(1978-87)**	**(1988-96)**
Rate (SE)	57.3% (2.5)	75.3% (0.4)
Mean Calves Branded (SE)	590.8 (39.4)	998.5 (44)
% Calves Bitten	13.3	0.4
Annual Rainfall (SE)	697 mm (102)	608 mm (84)

A recent independent economic assessment valued the impact of wild dogs in Queensland as A$33 million. (Table 4, Whan, 2003). For sheep, most of the direct losses were from mauled and destroyed livestock, whereas in beef cattle, wild dogs cost A$19 million through their roles as vectors for diseases such as hydatidosis (causative agent *Echinococcus granulosus*) as well as predation. A number of economic assessments of sheep predation by wild dogs in other States have been undertaken and these are reviewed in Fleming et al. (2001). It is difficult to obtain data for the costs and benefits of controlling wild dogs in sheep growing areas because few producers are willing to withdraw wild dog control so that damage can be assessed (Fleming et al., 2001). Nevertheless, in four surveys undertaken in New South Wales between 1961 and 1985, losses of sheep in wild dog affected areas ranged from 0.7 to 1.33% in the presence of control (Fleming et al., 2001). Fleming and Korn (1989) found that 6,400 livestock animals were killed or injured annually by wild dogs. These data were reported to eastern New South Wales control authorities by landholders between 1982 and 1985 and probably represented 31% of the actual losses (Fleming and Korn, 1989). A survey of 809 landholders in the State of Victoria in 1985 indicated that the cost of losses and control activities was about A$2.9 million (Backholer, 1986), which is equivalent to A$5 million in 2003.

Table 4. Summary of direct costs inflicted on the Queensland's rural economy by wild dogs (Whan, 2003).

Participant	Details of Cost	Amount (A$)
Graziers		
Predation losses - sheep	Direct loss	8,771,000
Predation losses - cattle	Direct loss of calves	9,531,000
Disease losses - cattle	Hydatidosis and Neospora	9,400,000
Prevention costs	Baiting (meat, labour, fuel, etc)	616,000
Other control costs	Trapping, shooting, fencing, surveillance	357,000
Sub-total		**28,675,000**
Local Government (based on 28 shires)		
Barrier Fence in 2001-02	$ for $ matching of State contribution to Barrier	700,000
Check fence (3 shires only)	Tara, Waggamba and Inglewood shires	200,000
Bounties and trapping etc	Bounties range from $10 to $100/ scalp	50,000
Baiting (excluded elsewhere)	Meat, mixing, distribution	1,500,000
Sub-total		**2,450,000**
State & Commonwealth		
Barrier Fence	Staff, materials and vehicles, etc	700,000
1080	30 kg @ $400/kg + freight	13,000
Coordination & bait making	27 NR&M officers directly involved	405,000
NR&M Head Office + Res & Development	Planning coordination and extension $265,000 R&D $400,000	665,000
Other govt departments	QPWS and EPA (estimate only)	200,000
Sub-total		**1,983,000**
State total		**33,108,000**

Neospora caninum is a protozoan that causes abortion in infected beef and dairy cattle herds. The prevalence of *N. caninum* infection in Queensland beef cattle is about 15% and corresponds with the distribution of wild dogs (Landmann and Taylor, 2003). The cost to the Australian dairy and beef industries of abortions caused by *N. caninum* infection has been estimated at A$110 million annually (Reichel 2000). However, the role of wild dogs in *N. caninum* infection has not been investigated but is likely to be important, particularly in north Queensland where prevalence is highest (Landmann and Taylor, 2003).

Impact of Canids on Livestock Production: Foxes

In contrast to wild dogs, foxes are of little consequence to cattle production in Australia except as a source of hydatid infection (Jenkins et al., 2000) and perhaps as a source, along with wild dogs, of *N. caninum* infection. Foxes are known predators of lambs but their impact has been little studied. While some studies suggest foxes may take 10 to 30% of lambs in some areas with concurrent negative economic consequences (Lugton, 1993; 1994), fox predation on lambs is often negligible (Greentree et al., 2000) and is regarded as generally insignificant at a national level (Saunders et. al., 1995). Where fox predation is substantial, loss of lambs not only affects the potential income derived from wool and sale sheep but also slows the rate of genetic improvement by reducing the rate of culling for selection.

Impact of Wild Dogs on Wildlife

- The current role of wild dogs in the many Australian ecosystems in which they occur has not been established. Wild dogs probably have a positive impact on wildlife by:
- Suppressing the density of fox populations by limiting the access of foxes to (native) prey resources where the two species coexist (Jarman, 1986; Corbett, 1995a); and
- Preying on feral livestock like goats (Allen et al. 1996, Parkes et al. 1996), pigs and potentially deer (Corbett 1995a), pest species, such as rabbits, feral cats, and hares, and over abundant native animals, such as macropods and emus (Caughley et al., 1980; Shepherd 1981; Robertshaw and Harden, 1987; Newsome et al., 1989; and Corbett 1995a).

Whether wild dogs actually regulate populations of their prey is subject to debate (Corbett, 1995b; Pople et al., 2000). However, the dingo has been implicated as one of the causes of the demise of some endemic marsupials of arid and semi-arid environments prior to cat and fox range expansion into those areas (Corbett, 1995a). Also, the dingo possibly caused the Tasmanian tiger (*Thylacinus cynocephalus*) (Archer, 1974), the Tasmanian devil (*Sarcophilus harrisii*) (Corbett, 1995a) and the Tasmanian woodhen, *Gallinula mortierii* (Baird, 1991) to become extinct on the Australian mainland. The effects of the potential changes in behavior and ecology of wild dogs, caused by increased hybridization, on wildlife is unknown.

Impact of Foxes on Wildlife

In contrast to wild dogs, studies conducted on threatened, vulnerable and endangered wildlife species in the last decade have discovered fox predation is a major cause of mortality threatening biodiversity and species survival (extensively reviewed in Saunders et. al., 1995). In Western Australia, large scale, fox control exercises (e.g. Thomson and Algar, 2000) have been instrumental in the recovery of some threatened mammal species, including numbats (*Mymecobius fasciatus*), woylies (*Bettongia penicillata*), Rothschild's rock wallabies (*Petrogale rothschildi*) and black-footed rock wallabies (*P. lateralis*) (Bailey 1996; Kinnear et al., 1998; Saunders et al., 1995). Fox predation has even been shown to limit recruitment of eastern grey kangaroos (*Macropus giganteus*), the largest and most abundant of the macropods in eastern Australia (Banks et al., 2000).

Canid Management in Australia

Prior to the introduction of the toxicant fluoroacetate (Compound 1080) in the mid-1960s strychnine was extensively used for about a hundred years by graziers to control canids (Rolls, 1984; Allen and Sparkes, 2001). Trapping and fencing were also important methods of wild-dog control. Boundary fences of most sheep-producing properties were constructed of wild-dog-proof netting and the major sheep producing regions were enclosed in a State Government-maintained, Dingo Barrier Fence that stretched thousands of kilometers through Queensland, along the New South Wales border and across South Australia (Fig. 2). The aim of the Dingo Barrier Fence is primarily to prevent the ingress of wild dogs into sheep-production areas from areas where no or less wild-dog control occurs. Its effectiveness is reviewed in Allen and Sparkes (2001).

So intensive was the effort put into wild-dog control and so effective were these methods, that wild dogs were completely removed from core-sheep-production areas of eastern and southern Australia. Nevertheless, the introduction of 1080 brought significant change. Allen and Sparkes (2001) report that within five years from commencing the use of 1080 baiting in Queensland (1968), the use of strychnine baits was suspended because of insufficient demand, and over the decade following 1080 introduction the number of local government-employed wild-dog trappers declined from 57 to four. Similar reductions were evident in the number of trappers employed in northeastern New South Wales (Fleming, 1996a).

For four decades, baits poisoned with 1080 have been extensively used in Australia. They are placed in bait stations or along fence lines and property roads from vehicles, or alternatively,

Figure 2. The Dingo Barrier Fence, a two-meter-high netting fence, stretches thousands of kilometers from Queensland to South Australia and encloses most of Australia's sheep production areas.

dropped from aircraft along inaccessible creeks and ridges — places frequently traveled by wild dogs (Fleming et al., 1996). This practice has been singly the most important canid-control method used in Australia and vast tracts of grazing land have been annually baited. The management of wild dogs relies heavily on 1080 baiting because it delivers a rapid, cost-efficient, and humane reduction in wild-dog populations over areas of sufficient size to prevent re-colonization from uncontrolled populations (Thomson, 1986; Fleming et al., 1996; Fleming et al., 2001). As much of the wild dog control is conducted in remote areas where wildlife is more abundant than in mixed farming and cultivated areas, the reductions in fox abundance that concurrently occur (Fleming, 1996b) are seen as an added benefit.

Trapping for removal is still an essential tool for wild-dog control in the tablelands of southeastern New South Wales and in northern Victoria. Trapping and ground baiting are necessary because the area available to conduct aerial baiting has been reduced over the past 10 years. The perception that spotted-tailed quolls (*Dasyurus maculatus*) might be at risk from canid control (Belcher, 1998) has resulted in a reduction in the area baited by aircraft. However, Körtner et al. (2003) have shown that spotted-tailed quolls are not affected by ground baiting programs for fox control, starvation, disease and predation by foxes and wild dogs being more likely causes of their mortality. Whether baiting for wild dogs endangers spotted-tailed quoll populations has not been determined and is the subject of ongoing research in New South Wales and Queensland.

The control of foxes in conservation areas to protect wildlife resources, in most cases, uses identical methods to those of agricultural areas. Where necessary, large-scale, aerial baiting with 1080 baits is practiced, targeted in those inaccessible areas where vulnerable native species require particular protection from foxes (Bailey, 1996). Recently, foxes were deliberately and maliciously released into Tasmania, which is the largest island refuge for some species, including Tasmanian devils, the Tasmanian woodhen and eastern quolls (*Dasyurus viverrinus*). This led to a widespread and expensive eradication campaign using ground-distributed 1080 baits (Croft et al., 2002). Baiting with 1080-impregnated baits is the cornerstone of fox control for native wildlife protection throughout Australia, and without 1080 most of the recovery and reintroduction programs for threatened species would be impossible to conduct. If 1080 baiting was not available, the consequences for Tasmanian wildlife in the event of further introductions of foxes would be dire. There are no alternative techniques to 1080 baiting that can be applied at equivalent scale and cost, that will reduce fox populations sufficiently to minimize predation on wildlife populations.

Choice of Toxicant

Because native mammals are more tolerant of 1080 than introduced mammals (McIlroy, 1986; McIlroy et al., 1986) and Australia has few medium-sized carnivorous animals that are not introduced pests 1080 is the toxin of choice in Australia. Fluoroacetate occurs naturally in many plants, particularly in Western Australia and northern Australia, and most animals evolved in these areas have consequently developed tolerance to it (McIlroy, 1986). The high tolerance of most native animals and the high sensitivity of canids mean that very small doses are used (3 to 10 mg total per individual) to cause the death of wild canids and hence the hazard to non-targets is limited further. Many Australian plants and soil microbes break down and utilize 1080 (Twigg and Socha, 2001). Laboratory trials have demonstrated that some dasyurid species (for example, the mouse-sized fat-tailed dunnart, *Sminthopsis crassicaudata*, Sinclair and Bird, 1984) are able to detect and avoid 1080. Populations of western quolls (*Dasyurus geoffroii*), which are tolerant to 1080, have been shown to benefit from fox control with 1080 baits, assumedly because competition and direct predation by foxes and wild dogs are removed (Bailey, 1996).

Populations of reptiles (principally goannas *Varanus* spp), birds and rodent-sized mammals (principally dunnarts, *Sminthopsis* spp.), carnivorous species potentially "at risk" from 1080 baiting, were studied in non-baited areas, and adjoining populations located in 1080-baited areas of similar size (400km^2, Allen, in preparation). No immediate or chronic impacts of baiting were seen (Fig. 3). Their populations increased and decreased responding to seasonal conditions but showed identical patterns with and without baiting.

Occasionally, strychnine and cyanide are used under permit for special applications, including the poisoning of trap jaws to prevent the slow death of trapped canids through dehydration or hyperthermia and for research where canid carcasses are required. As these toxins do not have all of the advantages of 1080, their use is uncommon and restricted.

Application to Canid Management in North America

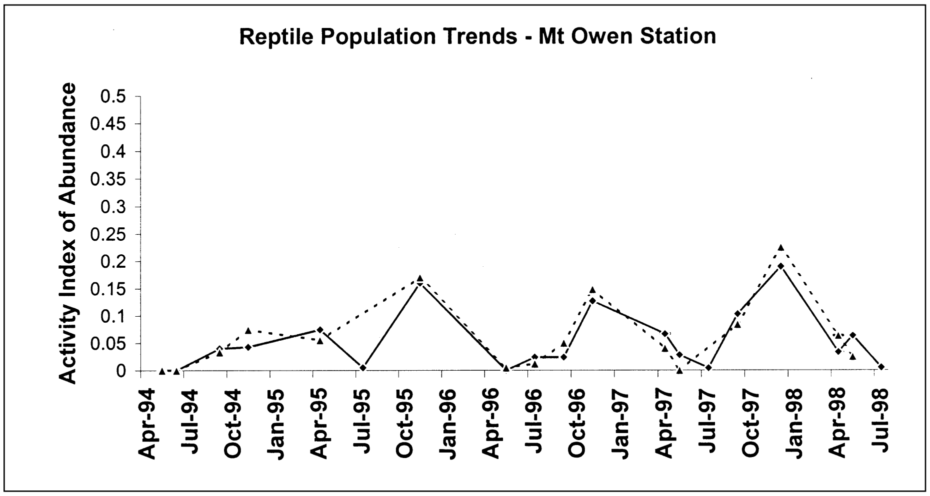
Significant similarities and differences exist between the canids involved in livestock predation, their status, hunting behavior, impact and management in North America and Australia. Similarities include:

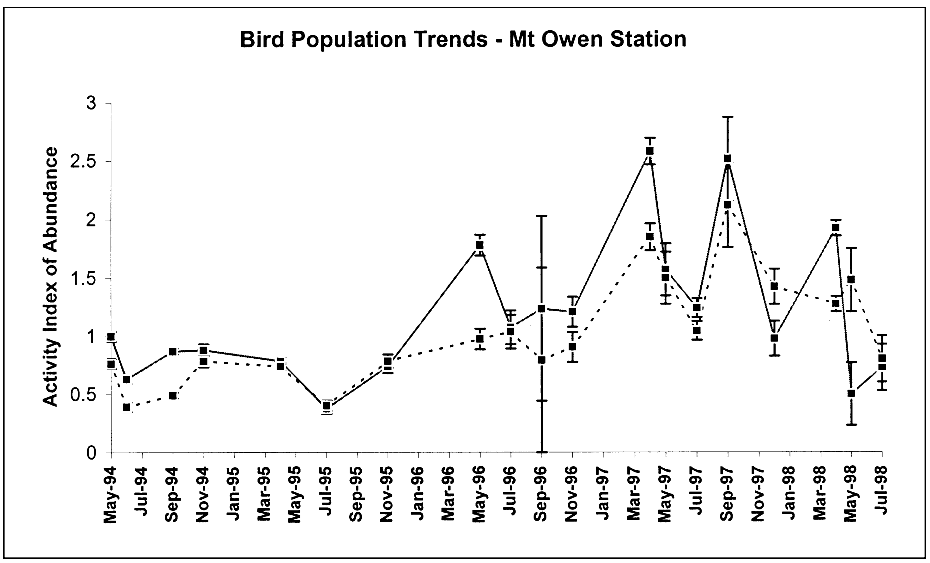
- Similar sized canids (wild dogs are several kilograms heavier than coyotes on average) or are similar or identical species (foxes);
- Sheep and goat production are the most vulnerable industries to economic loss from canid predation and harassment;
- Dispersal and rapid re-colonization of controlled populations quickly negates the impacts of canid control on individual properties; and
- Canid control methods are generally identical with the exception of poison baiting in Australia,

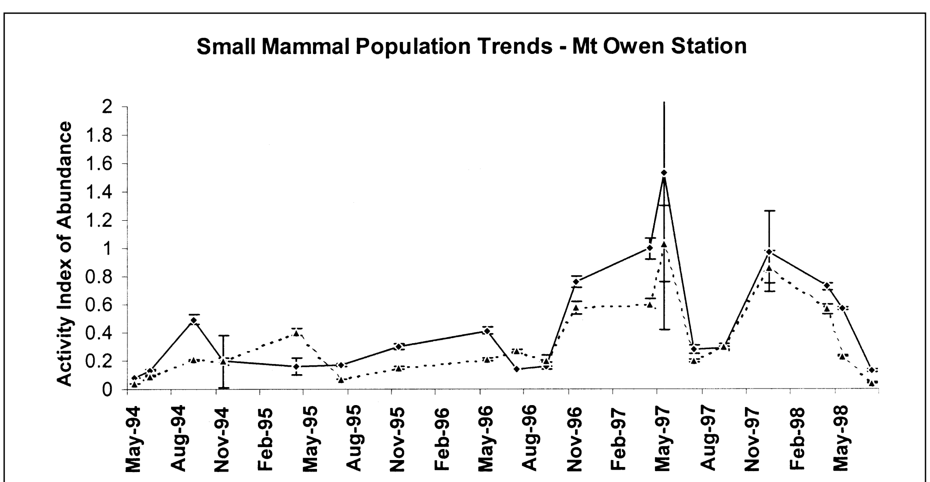
Differences in canids and management between North America and Australia include:

- The hunting style of wild dogs coupled with the fleeing and mobbing behavior of sheep results in sheep and goat losses in a higher order of magnitude compared to coyotes;
- Foxes, wild domestic dogs and dingo-domestic dog hybrids are introduced species and regarded as pests to agriculture and conservation in Australia. Their "introduced pest" status ensures greater public support for control programs. In contrast, coyotes and red foxes are native carnivores in North America, although their ranges have

Figure 3. Population trends (including 95% CL) of reptiles (principally goannas, *Varanus spp*), ground foraging birds and small mammals (principally carnivorous dunnarts, *Sminthopsis* spp) in adjoining baited (broken line) and non-baited areas (solid line) illustrating that potentially "at-risk" wildlife are not affected by canid baiting programs. The 400 km^2 baited area was at least annually ground and aerially baited with 800 to 2000 10mg 1080 single-dose meat baits 1994 to 1998. Drought conditions prevailed before 1995 and this was followed by three consecutive years of above-average rainfall.







expanded since European settlement;

- There are no wolves or other large carnivores in Australia; wild dogs are the largest. The largest extant marsupial carnivore is the Tasmanian devil, which is mostly a scavenger and no longer occurs on mainland Australia;
- All Australian canids are proclaimed by legislation as pests to agriculture. Consequently, resource managers are legally obliged to control the abundance and spread of canids;
- Australia's native wildlife is relatively tolerant of 1080, while the target canids are extremely sensitive to 1080. This allows baiting practices to more specifically target pest species in Australia. North America has a relative large number of native carnivores potentially at risk from toxicants;
- Unlike the North American sheep and goat industry, the grazing industry in Australia is a significant contributor to the nation's economy and consequently commands more favorable treatment from resource management agencies;
- In Australia, management of wild canids is population-based with control of individuals occurring opportunistically or in response to predation of livestock that is unresolved by large-scale control; and
- There is a trend in Australia toward cooperative, strategic wild canid management programs that are: large-scale; aimed at preventing impacts rather than reacting to impacts; and jointly funded by all affected stakeholders.

Considering the similarities and differences in canid management between North America and Australia, two key factors seriously compromise the efficiency and economics of sheep and goat production in North America. These are:

1. An absence of an equivalent canid toxicant that has the utility and specificity that 1080 provides in Australia; and
2. The political and legislative support that regulates and protects grazing industries from canid predation in Australia.

Without these key factors Australia could not sustain viable sheep and goat industries, nor could resource managers prevent or mitigate the impacts of canids on threatened or endangered wildlife populations.

Literature Cited

Allen, L. R., Lee, J. and Edwards, J. 1996. Managing Feral Goats and their Impact on Townshend Island in Shoalwater Bay Training Area, in Environmentally Responsible Defense, edited by P. Crabb, J. Kesby and L. Olive, Australian Defense Studies Centre, pp. 79-86.

Allen, L. R. and Gonzalez, A. 1998. Baiting reduces dingo numbers, changes age structures yet often increases calf losses. Australian Vertebrate Pest Control Conference 11:421-428.

Allen, L. R. and Sparkes, E. C. 2001 The effect of dingo control on sheep and beef cattle in Queensland. Journal of Applied Ecology 38:76-87.

Andelt, W. F., Althoff, D. P., Case, R. M. and Gipson, P. S. 1980. Surplus-killing by coyotes. Journal of Mammalogy 61:377-378.

Archer, M. 1974. New information about the quaternary distribution of the thylacine (Marsupialia, Thylacinidae) in Australia. Proceedings of the Royal Society of Western Australia 57:43-50.

Backholer, J .R. 1986. A survey of landholders on the wild dog problem in eastern

Victoria: a preliminary analysis. Unpublished report to Land Protection Service, Department of Conservation, Forests and Lands, Victoria.

Bailey, C. 1996. Western Shield: bringing wildlife back from the brink. Landscope 11:41-48.

Baird, R. F. 1991. The dingo as a possible factor in the disappearance of Gallinula mortierii from the Australian mainland. Emu 91:121-122.

Banks, P. B., Newsome, A. E. and Dickman, C. R. 2000. Predation by red foxes limits recruitment in populations of eastern grey kangaroos. Austral Ecology 25:283-291.

Belcher, C. A. 1998. Susceptibility of the tiger quoll, Dasyurus maculatus, and the eastern quoll, D. viverrinus, to 1080-poisoned baits in control programmes for vertebrate pests in eastern Australia. Wildlife Research 25:33-40.

Caughley, G., Grigg, G. C., Caughley, J. and Hill, G. J. E. 1980. Does dingo predation control the densities of kangaroos and emus? Australian Wildlife Research 7:1-12.

Corbett, L. K., 1995a. The dingo in Australia and Asia. Australian Natural History Series, University of New South Wales Press, Sydney.

Corbett, L. K. 1995b. Does dingo predation or buffalo competition regulate feral pig populations in the Australian wet–dry tropics? An experimental study. Wildlife Research 22:65-74.

Corbett, L..K. 2001. The conservation status of the dingo Canis lupus dingo in Australia, with particular reference to New South Wales: threats to pure dingoes and potential solutions. Pp. 10-19. In: A Symposium on the Dingo, edited by C. R. Dickman and D. Lunney, Royal Zoological Society of New South Wales, Mosman.

Croft, D., Balogh, S. and Gentle, M. 2002. Extending the 'Out Fox' landowner involvement program. pp. 27-29. In: Proceedings of the Second NSW Pest Animal Control Conference, edited by S. Balogh, NSW Agriculture, Orange.

Davis, E. 2001. Legislative issues relating to control of dingoes and other wild dogs in New South Wales. I Approaches to future management. Pp. 39-41. In: A Symposium on the Dingo, edited by C.R. Dickman and D. Lunney, Royal Zoological Society of New South Wales, Mosman.

Davis, E. O. and Leys, A. R. 2001. Reconciling wild dog control and dingo conservation under New South Wales legislation. Pp. 108-110. In: A Symposium on the Dingo, Edited by C. R. Dickman and D. Lunney, Royal Zoological Society of New South Wales, Mosman.

Estes, R. D. and Goddard, J. 1967. Prey selection and hunting behavior of the African wild dog. Journal of Wildlife Management 31:52-70.

Fleming, P. J. S. 1996a. Aspects of the management of wild dogs (Canis familiaris) in north-eastern New South Wales. Unpublished Master of Resource Science thesis, University of New England, Armidale.

Fleming, P. J. S. 1996b. Ground-placed baits for the control of wild dogs: evaluation of a replacement-baiting strategy in north-eastern New South Wales. Wildlife Research 23:729-740.

Fleming, P. J. S. 2001. Legislative issues relating to control of dingoes and other wild dogs in New South Wales. II Historical and technical justification for current policy. pp. 42-48. In: A Symposium on the Dingo, edited by C. R. Dickman and D. Lunney, Royal Zoological Society of New South Wales, Mosman.

Fleming, P. J. S. , Corbett, L. K., Harden, R. and Thomson, P. 2001. Managing the impacts of dingoes and other wild dogs. Bureau of Rural Sciences, Canberra.

Fleming, P. J. S. and Korn, T. J. 1989. Predation of livestock by wild dogs in eastern New South Wales. Australian Rangelands Journal 11:61-66.

Fleming, P. J. S., Thompson, J. A. and Nicol, H. I. 1996. Indices for measuring the efficacy of aerial baiting for wild dog control in north-eastern New South Wales. Wildlife Research 23:665-674.

Fox, M. W. 1969. Ontogeny of prey-killing behavior in Canidae. Behaviour 35:18-272.

Frid, A. 1997. Vigilance by female Dall's sheep: interactions between predation risk factors. Animal Behaviour 53:799-808.

Greentree, C., Saunders, G., McLeod, L. and Hone J. 2000. Lamb predation and fox control in south-eastern Australia. Journal of Applied Ecology 37:935-943.

Hunt, R. and the Brindabella/ Wee Jasper Wild dog/ Fox Working Group 2002. Brindabella and Wee Jasper Valleys Cooperative Wild dog/fox control plan, July 2002-June 2005. *http://www.nationalparks.nsw.gov.au/PDFs/brindabella_plan.PDF*. 13th May 2003.

Jarman, P. J. 1986. The red fox - an exotic, large predator, in The Ecology of Exotic Animals and Plants some Australian Case Histories, edited by R.L. Kitching. Wiley, Brisbane. pp 43-61.

Jenkins, D. J., Fraser, A., Bradshaw, H. and Craig, P. S. 2000. Detection of Echinococcus granulosus coproantigens in Australian canids with natural or experimental infection. Journal of Parasitology 86:140–145.

Kinnear, J. E., Onus, M. L. and Sumner, N. R. 1998. Fox control and rock-wallaby population dynamics — II.

An update. Wildlife Research 25:81-88.
Kolonosky, G. B. 1972. Wolf predation on wintering deer in east-central Ontario. Journal of Wildlife Management 36:357-369.
Körtner, G., Gresser, S. and Harden, B. 2003. Does fox baiting threaten the spotted-tailed quoll, Dasyurus maculatus? Wildlife Research 30:111-118.
Landmann, J. and Taylor, L. 2003. Investigation of the prevalence of Neospora caninum in Queensland beef cattle. Final report to Meat & Livestock Australia Limited. Pp 41.
Lugton, I. W. 1993. Fox predation on lambs. Pp 17-26 In: Caring technology: Proceedings of the Australian Sheep Veterinary Society, Australian Veterinary Association Conference. Edited by D. A. Hacker. Pitman_Moore Australia Ltd, North Ryde.
Lugton, I. 1994. Foxes underestimated as lamb killers. Farming Ahead 31:50-53.
McIlroy, J. C. 1986. The sensitivity of Australian animals to 1080 poison. IX. Comparisons between the major groups of animals and the potential danger non-targets face from 1080-poisoning campaigns. Australian Wildlife Research 13:39-48.
McIlroy, J. C., Gifford, E. J. and Cooper, R. J. 1986. Effects on non-target populations of wild dog trail baiting campaigns with 1080 poison. Australian Wildlife Research 13:447-53.
Meat & Livestock Australia Limited. 2000. Handbook of Australian Livestock. Fourth Edition. Meat & Livestock Australia and Livecorp, North Sydney.
Mech, L. D. 1988. The Wolf, the Ecology and Behavior of an Endangered Species, University of Minnesota Press, Minneapolis.
Mech, L. D., Smith, D. W., Murphy, K. M. and MacNulty, D. R. 2001. Winter severity and wolf predation on a formerly wolf-free elk herd. Journal of Wildlife Management 65:998-1003.
Newsome, A. E., Corbett, L. K. and Carpenter, S. M. 1980. The identity of the dingo. I. Morphological discriminants of dingo and dog skulls. Australian Journal of Zoology 28:615-625.
Newsome, A. E., Parer, I. and Catling, P. C. 1989. Prolonged prey suppression by carnivores — predator-removal experiments, Oecologia 78:458-467.
NSW National Parks & Wildlife Service 2001. Threat Abatement Plan for Predation by the Red fox (Vulpes vulpes). NSW National Parks and Wildlife Service, Hurstville.
Parkes, J., Henzell, R. and Pickles, G. 1996. Managing Vertebrate Pests: Feral Goats. Australian Government Publishing Service, Canberra.
Pople, A. R., Grigg, G. C., Cairns, S. C., Beard, L. A. and Alexander, P. 2000. Trends in the numbers of red kangaroos and emus on either side of the South Australian dingo fence: evidence for predator regulation? Wildlife Research 27:269-276.
Reichel, M. P. 2000. Neospora caninum infections in Australia and New Zealand. Australian Veterinary Journal 78:258-261.
Robertshaw, J. D. and Harden, R. H. 1987. Predation on Macropododae: a review. pp 735-753. In: Kangaroos, Wallabies and Rat kangaroos, edited by Grigg, G., Jarman, P. and Hume, I.. Surrey Beatty and Sons, Sydney.
Rolls, E. C. 1984. They all ran wild: the animals and plants that plague Australia. Angus and Robertson, Sydney.
Saunders, G., Coman, B., Kinnear, J. and Braysher, M. 1995. Managing Vertebrate Pests: Foxes. Australian Government Publishing Service, Canberra.
Shepherd, N. C. 1981. Predation of red kangaroos, Macropus rufus, by the dingo, Canis familiaris dingo (Blumenbach), in north-western New South Wales. Australian Wildlife Research 8:255-62.
Sinclair, R. G. and Bird, P. L. 1984. The reaction of Sminthopsis crassicaudata to meat baits containing 1080: implications for assessing risk to non-target species. Australian Wildlife Research 11:501-7.
Thomson, P. C. 1986. The effectiveness of aerial baiting for the control of dingoes in northwestern Australia. Australian Wildlife Research 13:165-176.
Thomson, P. C. 1992. The behavioural ecology of dingoes in north-western Australia. III. Hunting and feeding behaviour, and diet, Wildlife Research 19:531-41.
Thomson, P. C. and Algar, D. 2000. The uptake of dried meat baits by foxes and investigations of baiting rates in Western Australia. Wildlife Research 17:451-456.
Twigg, L. E. and Socha, L. V. 2001. Defluorination of sodium monofluoroacetate by soil microorganisms from central Australia. Soil Biology and Biochemistry 33:227-234.
Whan, I. 2003. Economic Assessment of the Impact of Dingoes/Wild Dogs in Queensland. Draft report to the Department of Natural Resources and Mines by Rural Management Partners, Milton, Brisbane.