
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 cuniculus*) (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 dingoes, 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 virtu-

ally 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 canadensis* 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 km²) 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

Table 1. Capture Efficiency of Canids Attacking Prey.

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

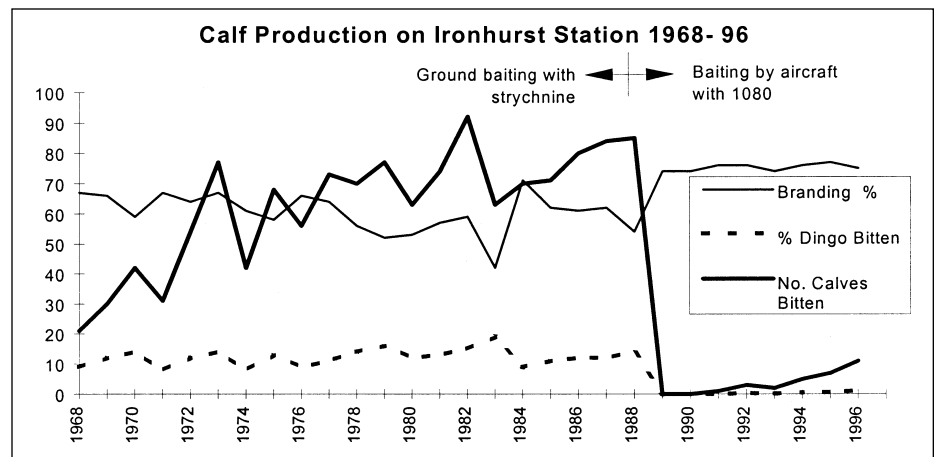
Table 2. Predation loss of calves in baited and non-baited portions (>400 km²) of the same property (from Allen, In Preparation).

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

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 counter-productive. 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

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 km² 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.

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.

Neospora caninum is a protozoan that causes abortion in infected beef and dairy cattle herds. The prevalence of *N.*

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 ²	>50 000 km ²
Mean Branding Rate (SE)	(1978-87) 57.3% (2.5)	(1988-96) 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)

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 (Land-

mann 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

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

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 con-

ducted 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 (*Beettongia 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 cam-

aign 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 (400km²,

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

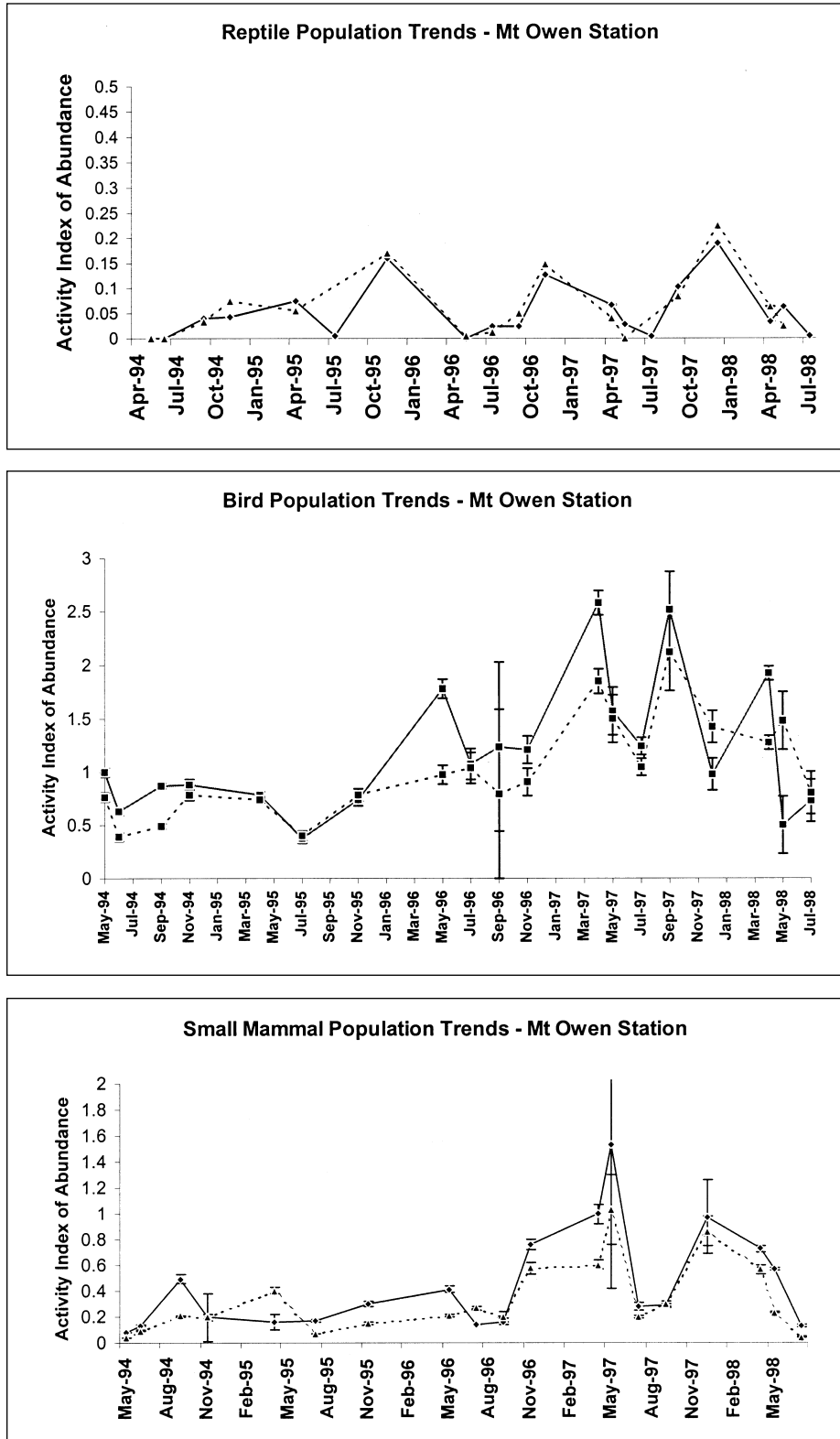
Significant similarities and differences exist between the canids involved in livestock predation, their status, hunting behavior, impact and management in North America and Australia. Similarities include:

- 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 km² 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.

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