Natural Resources and Water
Managing Queensland's natural resources
... for today and tomorrow

Red fox

pest status review

Matt Gentle

December 2006

Acknowledgments

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1.0 Summary

The role of this report is to present the current state of knowledge of foxes in Queensland. This information will assist the Department of Natural Resources and Water (NRW) to identify strategies for future management and to formulate a research program. Little information on fox biology, ecology and impact has been collected from Queensland, so studies from similar situations and habitats within Australia have been presented.

Foxes were first successfully introduced into Victoria in 1855 and rapidly spread across Australia, probably reaching Queensland by the early 1900s (~1907). Currently, they are widely distributed across Queensland with only the far north-west and far tropical north fox-free. They are becoming recognised as urban residents with increasing reports of foxes living within many urban areas.

Opportunistic predators and scavengers, foxes will consume a variety of prey ranging from plant material such as berries and grain, to insects, small mammals, birds, reptiles and carrion. Their consumption is often motivated by availability of prey rather than preference for any one item. This wide dietary range means that foxes are not reliant on any particular food source and can survive and prosper in a variety of habitats.

Foxes are a significant pest animal within Queensland. There are few replicated studies demonstrating the impact of fox predation on Queensland's agricultural enterprises and environment; however, this lack of adequate quantitative information does not mean that damage is not occurring, or is occurring at insignificant levels. Anecdotal evidence suggests that foxes are responsible for significant economic and environmental impact within the state. The main economic damage to agricultural industries is from foxes preying upon domestic stock, including lambs and kids, and contributing to the mismothering of lambs. Many nuisance activities are also reported. It is difficult to estimate the economic cost to these industries since fox predation is difficult to identify and measure, and varies considerably across regions and management practices. However, fox baiting is likely to be cost-effective since only small changes in predation rates are necessary to offset the economic cost of undertaking baiting campaigns.

Similarly, predation is problematic for native animals with foxes implicated in the demise of many ground-dwelling native species throughout Australia. The annual environmental damage caused by foxes in Australia has recently been estimated (conservatively) as $190 million. Despite such estimates being notoriously difficult to define, the estimate does highlight the environmental impact of foxes that is largely unquantified.

Foxes may also be a serious threat to Queensland's livestock industries and human health through being a potential host and vector of endemic and exotic diseases. Rabies is a public health concern in Europe where foxes are the major host of sylvatic (wildlife host) rabies. Rabies would be difficult to eradicate if it ever became established in Australian fox populations.

Urban foxes generally cause little economic damage but can cause significant mischief through such activities as preying upon poultry, digging and defecating in gardens and lawns, stealing pet food, and harassing pets. However, their close association with humans may lead to increased likelihood of transmission of diseases or parasites, such as mange and distemper, to domestic animals. Urban foxes may have a significant social impact through concerns about predation in suburban areas.

Generally, the control methods employed focus on reducing fox density rather than associated damage. The control method used in each situation varies depending on the habitat, the likely interaction with people and animals, and size and location of the areas to be treated. Importantly, the welfare of the fox and potential non-target animals should also be considered in deciding the most appropriate technique for each situation. Poisoning is the most common technique employed, with the safer and more humane fluoroacetate favoured over strychnine. Other lethal methods used include ground shooting, trapping, den fumigation and destruction. Non-lethal methods of reducing damage including exclusion fencing and guard animals (such as alpacas or livestock protection dogs) are also used. Immunocontraception may be an ideal technique if further research and development of the technique is successful. Further investigations of non-lethal methods should be undertaken to assess their cost-effectiveness, especially for large-scale deployment.

2.0 History

The European Red fox (*Vulpes vulpes*) was reported in Australia as early as 1855, but the first successful releases probably took place in southern Victoria in 1871 (Rolls 1969). They were introduced for sporting purposes mainly for hunting with horse and hound. The spread of foxes appeared to closely follow that of the European rabbit, which was introduced a few years earlier. Foxes were recognised as a pest in central and northern Victoria by 1893 (Jarman 1986; Saunders *et al*. 1995), as evidenced by the introduction of a bounty for their control. From there, foxes continued to spread northwards, probably reaching Queensland in the early 1900s (~1907–1910).

3.0 Distribution and abundance

3.1 Distribution

Foxes are found in a variety of habitats worldwide ranging from arctic tundra to deserts, even urban areas (Saunders et al. 1995). This worldwide distribution indicates that foxes will tolerate and adapt to a variety of habitats and climatic conditions.

Foxes are found over the vast majority of Queensland, from the Simpson Desert (Mahon et al. 1998) to the coastal dunes (Limpus and Reimer 1994). Foxes have been seen as far north as Lakeland Downs, 80 kilometres (km) west of Cooktown and occasionally on properties in the gulf savannah country near Normanton (J. Mitchell [NRW] 2004, pers. comm.) but these sightings are rare. The northern limit of fox distribution probably reflects climatic preferences, since foxes do not favour humid, tropical regions (Wilson et al. 1992). The northern limit of their distribution probably fluctuates with seasonal conditions (Jarman 1986; Saunders et al. 1995).

McRae (2004) reports that foxes have historically been either absent or in very low densities on the ashy and Mitchell grass plains of far western Queensland. Mahon (1999) recorded foxes for the first time in 1991 in the northern Simpson Desert following rodent irruptions in his study area. It appears though, that these open, vast, sparsely vegetated habitats are not highly suitable for foxes, and substantial populations only occur in favourable seasonal conditions, such as when prey abundance is unusually inflated. Additionally, foxes may be absent or in low densities when found in areas of high wild dog/dingo density, due to possible competition or exclusion.

The distribution and relative abundance of foxes in Queensland was first assessed in the early 1980s (Mitchell et al. 1982). This information was gathered through interviewing shire council staff and state government officers. At this time foxes were found over most of the southern half of the state, except for the central Dividing Range area (see Figure 1). Only scattered individuals were present in far western areas and north of a line between Mount Isa and Townsville.

Annually since 2002, NRW has estimated the statewide distribution (absent, localised or widespread) and density (occasional, common or abundant) of pest animals and weeds in grid cells across the state. The estimates are based on workshops involving Land Protection officers and local government pest officers throughout Queensland. The 2005 distribution (Figure 2) indicates that foxes occur throughout southern and central Queensland, but are absent in the north-western and north-eastern areas of the state, possibly due to unfavourable habitat or climatic conditions (Jarman 1986; Saunders et al. 1995) (see Figure 2). Fox density ranges from low (occasional) to relatively high (abundant), with the higher fox density areas generally occurring in the eastern areas. Comparisons with the 1981 survey and the 2005 survey suggest that foxes have not spread any further north (see Figures 1 and 2).

Overseas studies indicate that foxes have spread into areas where wolves (*Canis lupus*) have been suppressed (Churcher 1959); a similar competitive interaction/ exclusion may exist between wild dog/dingoes and foxes in Australia. Foxes have colonised most of the central dividing range area previously thought to be free of foxes; this may be have been at least partly due to the suppression of dingo populations in these areas.

The distribution of rabbits may also be important in determining the northern boundary of fox distribution in Queensland. Evidence from the Atherton tablelands indicates that rabbits may be colonising new areas (P. Davis, [NRW] 2004, pers. comm.). Given that, historically, fox distribution appears to closely follow that of the rabbit, there is some concern that this may assist foxes in colonising these areas. These concerns are considerable given the number of susceptible, native prey (such as the endangered northern bettong, *Betongia tropica*) present in these areas.

Foxes have been reported in many cities throughout Australia (Saunders et al. 1995; Marks 2004) and appear to be present in most urban areas within their general distribution. Urban habitats provide a food-and-shelter-rich environment and foxes will readily live in close association with humans. Foxes have also colonised many urban areas in Queensland with frequent reports of foxes residing in major cities and regional towns. Australian studies have indicated that densities in urban areas may be as high as 16 foxes per square kilometre (Melbourne: Marks and Bloomfield 1999), significantly greater than those found in rural areas (see Table 1).

In 1981 foxes were noticeably present in areas of Brisbane, but were not as frequently seen or reported as in recent years (J. Mitchell and S. O'Keeffe [NRW] 2004, pers. comm.) Foxes are becoming recognised as urban residents in the populated south-east corner of Queensland, which is increasingly urbanised. Foxes are frequently seen in cities including Brisbane, Ipswich and Toowoomba, with over 50 reports per month coming from Brisbane residents alone. The capture rate in trapping campaigns undertaken at the Port of Brisbane and other urban areas suggests a high density of foxes (L. Allen [NRW] 2004, and G. Alchin [Brisbane City Council] 2006, pers. comm.)

A further example of the ability of the fox to live in proximity to urban areas comes from the Ipswich local government area, in South East Queensland. In the White-Rock/ Spring Mountain and Flinders/Goolman conservation areas, (close to the rural/urban interface in the Ipswich local government area), monitoring programs to assess the presence and abundance of pest animals have been undertaken since April 2003. Visitation to footprint plots as an index of animal abundance suggests that considerable fox populations exist in these parks (M Panter, [Ipswich Shire Council] and L. Allen [NRW] 2005, pers. comm.). This is not surprising given that the mosaic of adjoining habitats (for example urban, rural, parks and gardens) within South East Queensland would be highly suitable for fox populations.

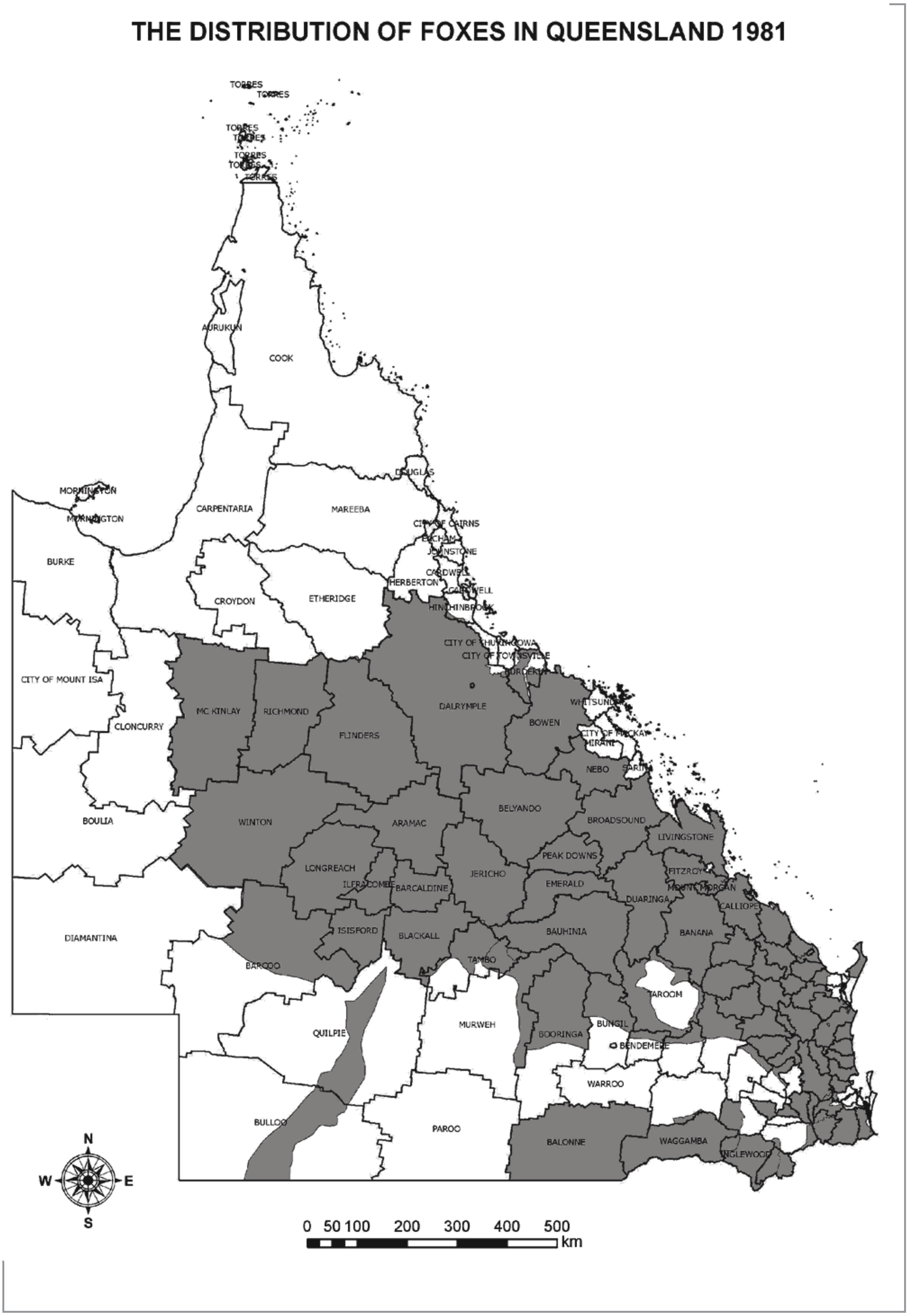


Figure 1 The distribution of foxes in Queensland in 1981 . Source: Based on Mitchell et al. 1982

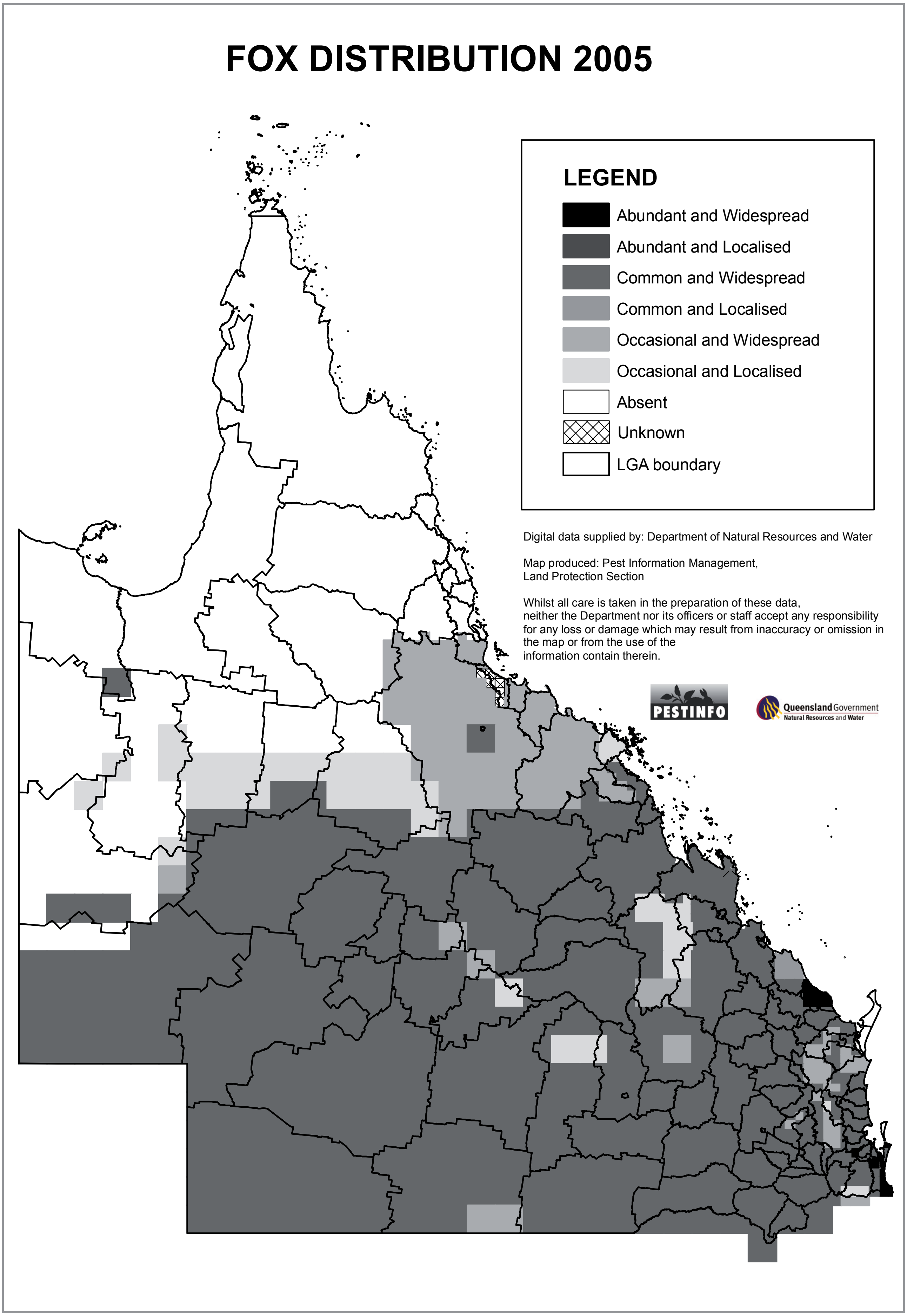


Figure 2 Distribution of foxes in Queensland in 2005. Source: Department of Natural Resources and Mines 2006

3.2 Density

Density estimates of foxes are notoriously difficult to collect and often inaccurate due to their elusive and nocturnal habits. The range of habitats where foxes are found means that a variety of census techniques must be used, often making comparisons with studies undertaken during different seasons, tenuous (Saunders et al. 1995). Table 1 presents fox densities from Australian studies.

Studies in Australia have shown that fox density varies considerably by habitat. Densities range between 0.9 foxes per km^2 in arid areas, between 1.2–7.2 per km^2 in fragmented agricultural habitats, and up to 16 per km^2 in urban areas. Knowledge of fox habitat preferences and other studies undertaken worldwide suggest that density is positively correlated with the productivity of the environment. Little is known about fox density in Queensland, although density in the agricultural areas is probably less than the central and southern tablelands of New South Wales.

Table 1 Fox densities from Australian studies

Foxes per km^2	Habitat	Study
3.0–16.2	Urban (Melbourne Victoria)	Marks and Bloomfield (1999)
1.7–6.0 1.9–5.6	Temperate agricultural (central tablelands New South Wales)	Berghout (2001); Gentle (2005)
1.2–3.0	Temperate agricultural (regional Victoria)	Coman et al. (1991)
4.6–7.2	Temperate agricultural (northern tablelands New South Wales)	Thompson and Fleming (1994)
0.46–0.52	Semi-arid rangeland grazing (Western Australia)	Marlow et al. (2000)
0.9	Arid grazing (Western Australia)	Marlow (1992)
2.0	Semi-arid grazing	Newsome and Catling (1992)
0.2	Dry sclerophyll	Newsome and Catling (1992)

Source: Based on Saunders et al. 1995

4.0 Biology and ecology

4.1 Morphology

The European red fox is a member of the family Canidae, which includes carnivores such as wolves, jackals, and coyotes. Foxes have long, slim bodies, tall slim legs, narrow muzzles, and bushy tails (Jarman 1986). Foxes can vary significantly in appearance; their coat colour ranges between a deep red to lighter shades of ginger-red interspersed with grey or silver. The lower half of the legs and the ear tips are typically black; the under body coat is paler, ranging from white to grey. Darker colour (grey/black) guard hairs on the coat may be present and the tail often has a white tip. Coat condition varies by season, and foxes in the higher altitude areas of south-eastern Australia grow a deeper winter pelt than do foxes in the inland (Jarman 1986). Wild foxes usually only live up to three or four years of age, but can live up to 15 years in captivity.

The body of an adult fox generally ranges between 570 and 740 millimetres (mm) in length, with a tail length of 360–450 mm. Body weight ranges between 4.5 and 8.3 kilograms (kg) (Coman 1983) with an average of approximately 4.5 and 5.0 kg for females and males respectively (Saunders et al. 2002). Both sexes suffer from seasonal fluctuations in bodyweight related to either food and/or reproductive stresses.

4.2 Behaviour and social structure

Foxes are crepuscular, being active mainly between dusk and dawn. However, foxes may also be active at any time during the day.

While foxes are normally solitary, pairs form a close association during the breeding season. In Europe they are reported to form family groups consisting of an adult pair and subordinate vixens from the previous year 's litter. Each family group establishes a territory that is defended against other foxes. The predominant family group composition throughout Australia is probably a mated pair of adult foxes with a litter of cubs.

Scent marking with urine or scats assists in maintaining territory boundaries. Conspicuous objects, such as rocks, trees, fence posts or grass tussocks are typically favoured for marking.

Surplus killing of prey is a common behavioural trait of foxes (Kruuk 1972). This is where foxes kill prey not intended for immediate consumption. The 'fox in the henhouse' is a good example of this, where a single fox can kill many chickens (even hundreds) in the one night. It is believed that surplus killing reflects the behaviour and response of the prey to predation. Animals that behave 'abnormally' or have few predator-defence strategies are more prone to be victims of surplus killing.

Similarly, foxes are known to store, or cache food that is not immediately consumed (Vander Wall 1990) allowing a greater ability to control food availability spatially and temporally. Caching may be a means of securing food from the attention of competitors, including other foxes (MacDonald 1987). Foxes are known to store food in preparation for periods of low food availability and periods when energy requirements are high, such as the birth of offspring (Macdonald 1977) and, in the higher latitudes, in preparation for winter. Caching can occur during periods of temporary food surplus (Macdonald 1976, 1977, 1987); there is evidence that even within foraging sessions, food discovered before satiation is consumed (Henry 1986), whereas food discovered later is cached (Kruuk 1972).This suggests that caching intensity may increase when food availability is high, and/or nutritional demands are low.

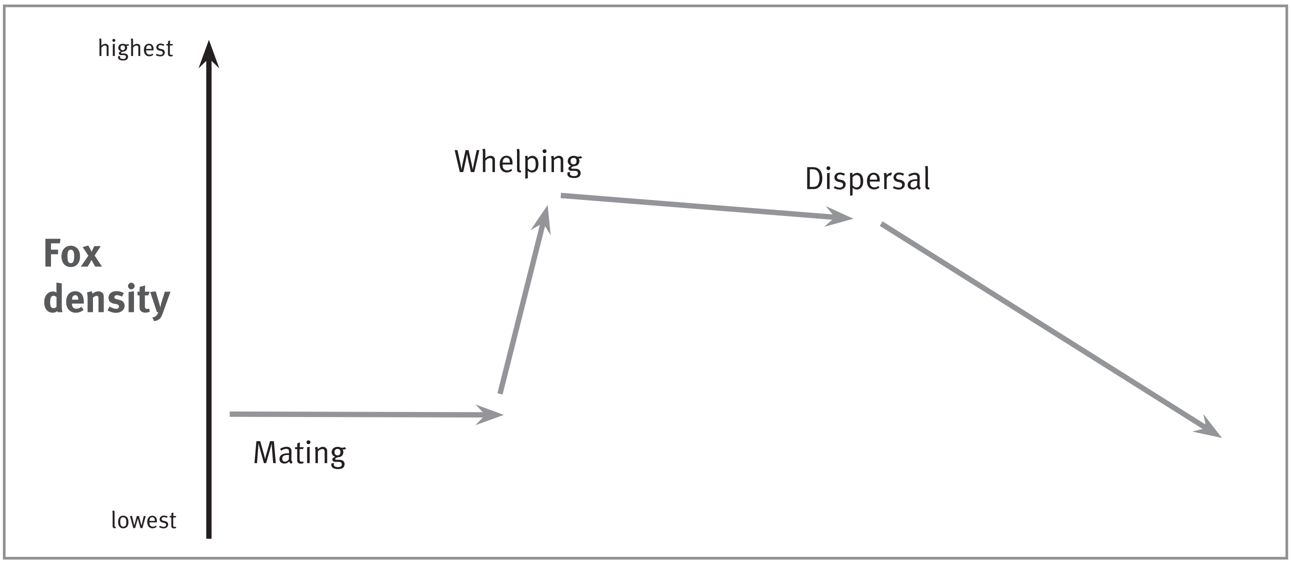
Foxes construct and use dens to give birth and raise their offspring. Dens are typically burrows with single or multiple entrances between 200 and 300 mm in diameter. However, other structures that offer protection, such as logs, shrubs and even thick grass, may be used as natal sites. Vixens usually prepare several dens and cubs may be moved a number of times during the cub-raising period. On reaching about four months of age, cubs, particularly males, will disperse from the den to find their own territory.

4.3 Reproduction

Foxes are monoestrus, reproducing once per year in spring. Females are reproductively active from July to October in south-eastern Australia (McIntosh 1963b; Ryan 1976). The gestation period is 51–53 days, with most cubs born during August and September. The mean litter size is approximately four but ranges between one and 10. Cubs are weaned after about four weeks and become sexually mature after about 10 months. Not all females in a population breed each year. These vixens may assist others in raising cubs and are often called 'helper vixens'. The proportion of non-breeding vixens in the population is highly variable (Englund 1970) but generally increases with population density, probably due to the social suppression of reproduction in large groups. Studies undertaken in New South Wales suggest very few non-breeding females (Saunders et al. 2002), despite a relatively high population density (2–6 foxes per km^2).

Fox density fluctuates considerably throughout the year, with the highest density occurring following whelping and the lowest during the breeding season (see Figure 3). This is because foxes breed only once per year, whereas mortality cumulatively reduces the population size until the following breeding season.

Figure 3 Fox density and the yearly fox cycle



4.4 Habitat preferences, home range and movements

Their worldwide distribution indicates that red foxes will survive in a variety of different habitats, ranging from arctic tundra to semi-arid and arid areas. However, fox density in these environments varies greatly with the more productive environments supporting higher densities. Studies suggest that fragmented landscapes are highly favoured; these habitats offer open areas for foraging with woodland areas for shelter (Jarman 1986).

An understanding of the area used by foxes is essential when planning strategic management programs (Coman et al. 1991). Foxes normally occupy well-defined home ranges with non-overlapping and stable borders. Home-range size is generally proportional to the quantity of resources it contains; habitats of greater productivity result in smaller home ranges (Harestad and Bunnell 1979). Therefore, fox home range studies in specific habitats provide an indication of the productivity of these habitats (see Table 2).

Foxes can travel up to 10 km per day (Jarman 1986). Long distance movements are usually restricted to the dispersal phase, when juveniles disperse to find their own territory. Foxes can disperse considerable distances during this period; straight-line distances of 300 km have been recorded in Australia. A strong positive relationship exists between home range size and dispersal distances (Trewhella et al. 1988).

Fox populations are not static, with seasonal patterns of dispersal resulting in constantly changing population size (Trewhella 1988). The majority of dispersal is by juvenile males from late summer until early winter (Saunders et al. 1995); however, adults are also known to undertake long-range movements to establish or extend territories. Such movements result in recolonisation of areas where foxes have been removed (Kinnear et al. 1988; Saunders et al. 1995), often occurring rapidly.

Table 2 Comparison of home range estimates (hectares) from Australian studies

Habitat	Mean home range (ha)	Reference
Farmland (Victoria)	610	Coman et al. (1991)
Alpine (New South Wales)	550	Bubela (1994)
Forest (New South Wales)	416	Phillips and Catling (1991)
Farmland (New South Wales)	~300	Saunders at al. (2002a)
Semi-urban (Victoria)	45	White et al. (2006)

Source: Based on Saunders et al. 1995

4.5 Diet

Although primarily carnivorous, foxes are opportunistic predators and scavengers and will consume a variety of both plant and animal material. Foxes are mostly solitary hunters and foragers but will occasionally be found undertaking these activities in the presence of other individuals, especially where food sources are localised.

Items consumed are mainly mammalian (McIntosh 1963a; Coman 1973b; Croft and Hone 1978; Palmer 1995) and where present, rabbits make up a large proportion of their diet (Ryan and Croft 1974; Croft and Hone 1978). Other food items commonly consumed include sheep (mostly as carrion); house mice; insects; reptiles and amphibians; birds; grains (e.g. wheat and barley); vegetable matter (including crops); and fruit crops, such as melons, grapes, apples, blackberries (Woolley et al. 1985; Catling 1988; Lugton 1993a; Palmer 1995). The relative frequency of food items consumed changes according to season and location (Croft and Hone 1978), reflecting the abundance of prey more than preference (Ables 1975; Molsher et al. 2000). Foxes are not reliant upon any one food source, and will consume whatever food is available at the time. Fox management by artificially limiting available food would be extremely difficult due to their adaptive culinary habits.

The relative frequency of prey items found in the stomachs of foxes in Western Queensland demonstrates the wide variety of foods consumed by foxes (see Appendix 2).

5.0 Current and potential impacts

5.1 Agricultural impact

Predation

Foxes are recognised agricultural pests, especially as predators to newborn lambs and goat kids. Poultry, particularly unprotected birds, are also at risk; however, losses to commercial poultry enterprises are usually insignificant since the majority are well protected.

Foxes will chase and harass lambs and kids, biting and chewing on the hindquarters and around the neck. Many individuals killed by foxes do not exhibit any external signs of predation, making primary predation difficult to diagnose (Greentree 2000). Skinning the animal may be necessary to provide evidence of predation since puncture marks from teeth and haemorrhaging may only be visible when the skin is removed.

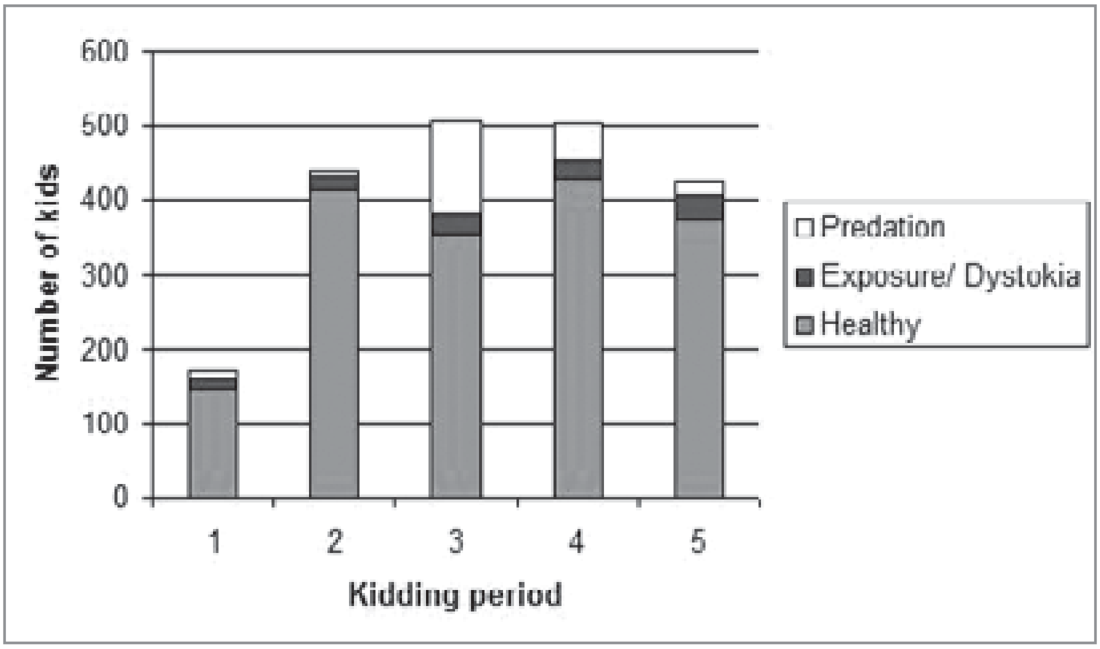
The extent of lamb and kid losses from fox predation is difficult to measure. Not only is there little visual evidence by which to identify it, but other factors, such as variations in flock health and management, and seasonal changes, also affect juvenile mortality and birthing percentages. Additionally, carcasses may simply disappear from the area. Foxes may take weak or sick animals and primary predation may therefore be overestimated; the animals taken may represent a 'doomed surplus' since not all the lambs taken may have survived (Greentree 2000). Such problems have meant that estimates of primary fox predation are usually based on direct observations of a small number of flocks.

Studies have shown that foxes may take up to 30 per cent of newborn lambs (Lugton 1993b; Heydon and Reynolds 2000), although estimates usually range between 0 and 10 per cent. Greentree et al. (2000) attempted to measure lamb predation by foxes through fox removal. The levels of fox predation were variable, with an estimated 0–15 per cent of lambs killed by foxes.

Evidence suggests that predation rates in Queensland are similar to other states. Data from South East Queensland suggest that foxes can be responsible for the death of up to 25 per cent of newborn kids (see Figure 4) although values usually ranged between 1 and 10 per cent (P. Murray, The University of Queensland unpublished data). During this study it was noted that older kids (apart from newborns) were also susceptible to fox predation. Additionally, most kids killed by foxes were only partly eaten; many were only missing specific body parts like the brains or tails.

Rates of predation were low during some kidding periods, but these low levels still represented a considerable loss of income to the producer. These levels were reduced in subsequent years through control programs.

Figure 4 The number and fate of goat kids born during consecutive kidding periods (1997–2000) at The University of Queensland, Gatton.



Source: P. Murray, The University of Queensland

Other damage

Foxes are well-known poultry thieves and will prey on unprotected domestic birds such as chickens, ducks and geese. Foxes are also known to cause damage to various other enterprises including horticultural and intensive livestock producers. Foxes may damage infrastructure, such as irrigation systems in orchards and golf courses, as well as consuming or chewing production items. For example, landholders in the Millmerran district have suffered losses through foxes consuming or chewing rockmelon fruit or stems (R. Curtis, landholder, pers. comm. 2004). Vignerons and stone-fruit producers have reported damage to fruit and chewing of infrastructure such as watering systems in the Stanthorpe area (J. Conroy [NRW] 2004, pers. comm.). Foxes will consume grapes, as evidenced from missing bunches and scats containing grape seeds (See Figures 5 and 6).

Damage from fox activity to micro-irrigation can be expensive with some landholders reporting repairs costing up to $2000 (S. Balogh [NSW Department of Primary Industries] 2004, pers. comm.). Damage due to chewing seems to peak during spring and early summer when fox cubs are active. However, most of the damage to infrastructure is low and constitutes more of a nuisance than a significant financial loss.

Figure 5 Grape vines in the Stanthorpe district, South East Queensland

Close assessment indicated that foxes were responsible for removing entire bunches of grapes

Photo: John Conroy, NRW

Figure 6. Fox scat collected in the vicinity of vineyard in the Stanthorpe, South East Queensland

This particular scat had a high content of grape seeds

Photo: John Conroy, NRW

5.2 Environmental impact

Predation

Many studies have shown that native mammals, birds or reptiles make up most of a fox's diet. This provides evidence that foxes will prey on and consume a wide variety of native prey, but does not indicate whether the impact is significant or measurable upon all prey populations (NSW National Parks and Wildlife Service 2001). It is difficult to determine the effect of fox predation without measuring the response of the affected prey population. Predation may be compensated for through the increased survival of other individuals or may be only a minor source of mortality compared with other factors (NSW National Parks and Wildlife Service 2001). For example, bush rats (Banks 1999) were major prey species of the fox in subalpine ACT, but predation did not appear to have any significant impact upon the prey population.

There have been relatively few studies with adequate replication undertaken to demonstrate the impact of fox predation on the prey population. Priddel and Wheeler (1989) found that fox control significantly increased survival of malleefowl (*Leipoa ocellate*) in western New South Wales. Fox-removal experiments in Western Australia have shown substantial population increases in a variety of marsupial species including rock-wallabies, bettongs and numbats (Kinnear et al. 1988; Friend 1990; Morris 1992 in Saunders et al. 1995). Many vulnerable species appear to persist only in areas where foxes are absent, found in low densities, or in habitats that offer some protection from predation. For example, the bridled nail-tailed wallaby (*Onchyogaela fraeneata*) is found in central Queensland on sites where few foxes are found (Short et al. 2002).

Foxes were responsible for taking 93 per cent of tortoise (*Emydura* sp.) eggs from a Murray River site in South Australia (Thompson 1983), significantly affecting the recruitment of juveniles (Spencer 2000). Foxes have been shown to limit populations of eastern-grey kangaroos (Banks et al. 2000) in south-eastern Australia. Predation of the young-at-foot kangaroos reduced juvenile recruitment resulting in an older population structure.

Fox predation has been listed as a key threatening process under schedule 3 of the Commonwealth *Endangered Species Protection Act 1992* and the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and by the New South Wales Scientific Committee, established under schedule 3 of the *Threatened Species Conservation Act 1995*. A key threatening process is that which threatens, or may threaten, the survival, abundance or evolutionary development of a native species or ecological community. Small to medium-sized ground-nesting birds and non-flying mammals appear to be most at risk from fox predation, particularly those within the 'Critical Weight Range' of 35 g to 5500 grams (g)(Burbidge and MacKenzie 1989). The Commonwealth Endangered Species Protection Act lists 36 species of reptiles, birds and mammals that are under a known or perceived threat from fox predation (see Appendix 3). Of these, 16 species were either historically present or remain present in Queensland.

NSW National Parks and Wildlife Service (2001) concluded that the impact of fox predation on the abundance of the majority of native fauna is unknown but the impacts appear to be greatest for medium-sized ground-dwelling and semi-arboreal mammals, ground-nesting birds and chelid tortoises. Foxes are thought to have had played a major part in the demise and extinction of many ground-dwelling native species in the last 130 years (Short et al. 2002). The fact that foxes will surplus kill (Kruuk 1972) has probably played a major role in the level of destruction. A review of surplus killing of Australian native mammals concludes that many native species lack sufficient defences to guard against an efficient predator such as the fox (Short et al. 2002). This high susceptibility to fox predation would have meant that populations of susceptible prey were decimated as areas were colonised by foxes. Examples of mammals prone to surplus killing attacks by foxes include the burrowing bettong (*Bettongia lesueur*), rufous betting (*Aepyprymnus rufescens*), black-flanked rock wallaby (*Petrogale lateralis*), tammar wallaby (*Macropus eugenii*), rufous hare-wallabies (*Lagorchestes hirsitus*), and eastern barred bandicoots (*Perameles gunnii*). Similarly, ground dwelling birds targeted by surplus killing included black swans (*Cygnus atratus*) and little penguins (*Eudyptula minor*).

It is difficult to determine the level of fox predation on native species, and equally difficult to determine the value of native species. Therefore estimates of the economic cost of fox predation on native species are, at best, rough. With these considerations, the environmental impact of foxes each year in Australia has recently been estimated at $190 million dollars per annum (McLeod 2004). This figure was based solely on the number of birds consumed by foxes per year (190 million) as estimated from the number of foxes currently in Australia (~7.2 million), food intake and occurrence of birds from dietary studies (1 per cent) and a 'value' of $1 per bird. This estimate clearly relies on many assumptions but probably significantly underestimates the true cost since it does not account for other groups (reptiles, amphibians and mammals) lost to fox predation. It also fails to consider the cost of any surplus killing, since it accounts only for items that are consumed, the cascade effects of predation, or the costs of extinction. Regardless, the estimate is useful to provide a conservative estimate of the massive impact of foxes on the environment. It is clear that foxes have a significant impact on Queensland fauna, despite that fact that the impact on many species is unknown or unquantified.

Case study

Fox predation on shore-nesting turtles—Mon Repos and Bundaberg

Beaches in the Bundaberg district, from Elliot River north to Bustard Head, contain the largest concentration of mainland marine turtle rookeries along the eastern Australian coast (Flakus 2002). Along with islands in the southern Great Barrier Reef, these areas encompass breeding sites for most of the endangered loggerhead turtles (*Caretta caretta*) in the South Pacific Ocean (Limpus and Reimer 1994). Specific Queensland studies have shown fox predation to be a major cause of decline in populations of mainland-nesting turtles (Flakus 2002).

Despite the lack of documentation regarding the arrival of the fox and the subsequent predation on turtle eggs, it appears that foxes have been responsible for high levels of predation on *C. caretta* clutches since the 1950s (Limpus and Reimer 1994). No obvious fox predation was occurring at Mon Repos during 1964, but by 1968 about six clutches per night were destroyed by foxes during the major part of the breeding season (Limpus and Reimer 1994). At Wreck Rock, over 90 per cent of clutches laid along the beach suffered from fox predation during the 1970s and 1980s (Limpus and Reimer 1994). Such levels of juvenile mortality are more than sufficient to cause the population to decline; however, the time lag in this case would be substantial given the long generation time (>30 years) in this species. Even if the decline is arrested, these populations will take decades to recover. Past egg and hatchling mortality will compound the substantial decline through the 1980s that was primarily due to incidental mortality by fishing trawlers (Limpus and Reimer 1994).

Operation Out Fox was developed to reduce the threat posed by foxes to loggerhead (*C. caretta*), green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) through a program of fox baiting and community education and involvement. As part of Out Fox, the Queensland coastline between Bundaberg and Town of 1770 is baited to coincide with the turtle nesting (October) and hatchling seasons (January–February) in addition to fox dispersal (April). At Wreck Rock, the level of fox activity has been monitored in conjunction with the level of nesting success and there has been a significant increase in the hatching success of clutches laid as a result of fox baiting programs. Flakus (2002) reported that fox predation on nests had been significantly reduced with less than one per cent of nests lost to foxes or dogs compared to up to 90 per cent in the 1970s and 1980s.

Case study

Bilby reintroduction program—Currawinya National Park

Of the six bandicoot species that once lived in the arid and semi-arid areas of Australia, the bilby (*Macrotis lagotis*) is the only remaining species. Bilby populations declined suddenly in the early 1900s, probably due to direct competition from rabbits and livestock, changing habitat from fire and grazing regimes, and predation from exotic predators. Their current distribution in Queensland is now scattered and isolated, with the main population existing in Queensland at Astrebla Downs National Park, south-west of Winton. The fox has been implicated in the decline of the bilby (see McRae 1994 for review), and the area currently occupied by bilbies is largely devoid of foxes. The absence of foxes from these areas appears to be a critical factor in the persistence of bilbies and probably results from a series of complex factors including unfavourable habitats for foxes, or the possibility that they were excluded by dingoes McRae (2004). McRae (2004) warns that bilby populations could decline rapidly if foxes successfully colonise their remaining habitats.

As a result of the isolated distribution and low abundance of bilbies, the Queensland National Parks and Wildlife Service embarked on a reintroduction program to help recover this endangered species under the National Recovery Plan. Currawinya National Park, near Hungerford in south-west Queensland was chosen for a reintroduction site because it is roughly the centre of their historical geographical range in eastern Australia and the climatic conditions are expected to provide bilbies with a more reliable and diverse food supply than other areas in the arid zone. However, predation by introduced predators is a major cause of mortality in bilby populations, so it was obvious that such predators had to be managed before bilbies could be successfully introduced. As a result, a 25 km^2 (medium and large mammalian) predator-proof enclosure has been constructed in suitable bilby habitat at Currawinya (see Figure 7). Once the enclosure was constructed, predators and other introduced mammals (such as foxes, feral pigs and feral goats) were removed from within the enclosure using a variety of control methods (for example, poison baiting and ground and aerial shooting). Fox removal was particularly critical; laying 1080 bait for foxes is still undertaken periodically despite there being no sign of foxes within the enclosure for over 12 months.

A captive breeding colony of bilbies has been established at Charleville to provide a source of animals for populating the enclosure. The first bilbies were released into the enclosure in late 2005.

Source: QNPWS 2001, McRae 2004 and P. McRae, (QNPWS) 2005 pers comm.

Figure 7 Predator-proof fence at Currawinya National Park

Rabbit regulation

Several studies have suggested that rabbit populations may be regulated by fox predation (Parer 1977; Newsome et al. 1989). However, a predictive model (Pech et al. 1992) indicates that rabbits at high densities escape from predator regulation and foxes would not have a significant impact. Only at low densities would foxes be able to apply enough predation pressure to have a significant impact on rabbit populations (Pech et al. 1992). Results from rabbit studies in western Queensland support these findings (D. Berman, [NRW] 2004 pers. comm.).

Weed

Foxes have been implicated in dispersing seeds from the fruit of a variety of weed species such as blackberries and olives (Coman 1973b). For example, when olives are in season, seeds are regularly found in fox scats in the Adelaide hills (Lowe 1989). Such dispersal of olive seeds could assist the spread of olives into conservation or other areas that should remain olive free. The establishment of feral olive trees represents a significant environmental threat in native forests and woodlands since their dense canopy can shade out other plants (Animal and Plant Control Commission 1999).

Foxes are recognised as an important potential source of seed dispersal in South Australia and undertaking a sustained, co-ordinated fox baiting is part of the recommended code of practice for all olive growers in South Australia. In high-risk areas, fox control measures such as baiting or exclusion fencing should be mandatory (Animal and Plant Control Commission 1999).

This is likely to be an important emerging issue with the expansion of the olive industry in southern Queensland.

5.3 Disease

Foxes are hosts and can act as vectors for exotic and endemic diseases, and parasites. Those known to be in Australia are listed in Table 3. Generally little is known of their occurrence within and impact on fox populations in Australia (Saunders et al. 1995), but many could potentially be transmitted to domestic and/or human hosts.

Foxes are an important end-host of the hydatid tapeworm in some parts of the world, but it appears that the incidence of infestation is very low in rural Australia (Saunders et al. 1995). However, they still may offer risks to human health especially in urban areas (Jenkins and Craig 1992).

Table 3 Parasites and diseases carried by foxes in Australia or known to be carried by foxes in the northern hemisphere and found in Australia.

Name	Parasite/ disease/virus/ fungus	In Australia	Potentially transmitted to domestic animals?
Parvovirus	Viral disease	Yes	Yes
Canine distemper	Viral disease	Yes	Yes
Toxoplasmosis (*Toxoplasma gondii*)	Parasitic disease	Yes	Yes
Sarcoptic mange (*Sarcoptes scabiei*)	Parasitic disease	Yes	Yes
Canine hepatitis	Viral disease	Yes	Yes
Tularaemia (*Francisella tularensis*)	Disease	Yes	Yes
Leptospirosis (*Leptospira interrogans serovars*)	Disease	Yes	Yes
Staphylococcal	Bacteria	Yes	
Encephalitis	Virus	Yes	
Hydatid tapeworm (*Echinococcus granulosus*)	Endo-parasite	Yes	Yes
Helminth parasites (e.g. *Taenia pisiformis, Taenia serialis, Spirometra erinacei, Dipylidium caninum, Toxoccara canis, Uncinaria stencephala, Ancylostoma caninum*)	Endo-parasites	Yes	Yes
Fleas (*Spilopsyllus cuniculi; Pulux irritans; Ctenocephalides canis*)	Ecto-parasite	Yes	Yes
Ticks (*Ixodes ricinus*)	Ecto-parasite	Yes	Yes
Mites (*Sarcoptes scabiei; Demodex folliculorum; Notoedres* spp.; *Otodectes cyanotis; Linguatula serrata*	Ecto-parasites	Yes	Yes
Ringworm (*Microsporum*)	Fungus	Yes	Yes

Source: Pullar (1946); Coman (1973a); Jenkins and Craig (1992); Saunders et al. (1995)

Foxes are a significant carrier of the scabies mite, *Sarcoptes scabiei*, which causes severe itching, excoriation and skin inflammation leading to hair loss and mange. Scabies is a major veterinary problem worldwide, and in Australia, mange has been recorded in domestic animals such as camels and dogs, as well as dingoes and the common wombat (*Vombatus ursinus*). Mange can result in extensive mortality of both foxes and wombats (Bubela et al. 1998; Kemp et al. 2002). Additionally, scabies affects millions of people worldwide in communities where there are inadequate medical facilities and overcrowding. This is evidenced by the very high incidence (up to 50 per cent) of scabies in some Australian Aboriginal communities (Kemp et al. 2002).

Rabies is present on every continent except Australia and Antarctica, and would be a major concern if it ever became established (Saunders et al. 1995; Saunders 1999). The disease is thought to infect nearly all mammal species (Kaplan et al. 1986) although most are dead-end or spillover hosts. It has two major epidemiological cycles: urban rabies with the dog as primary host, and sylvatic rabies with at least one wildlife vector involved (Saunders 1999). Transmission is normally through the bite of an infected animal. Rabies is nearly always fatal following the onset of clinical signs and is responsible for thousands of human deaths each year worldwide. Foxes have an extremely high rate of rabies secretion in saliva compared to other animals (Steck and Wandeler 1980); and in Europe and North America, foxes are the major host of sylvatic rabies. Additionally, the behaviour (especially dispersal) and structure of fox populations ensures that rabies is maintained and spread rapidly. As a result, considerable effort is undertaken to immunise wild foxes against the disease (Wandeler 1988).

Australia relies heavily on quarantine and contingencies to avoid rabies becoming established; the establishment risk is relatively low since it would require an infected animal to be imported. There are potentially a large number of domestic and mammal host species in Australia, but canid species including foxes are likely to be the major vectors of rabies (Newsome and Catling 1992). Eradicating the disease from domestic stock would be relatively straightforward, but the widespread distribution of the fox and the potential for transmission to a number of wildlife hosts would make eradication difficult.

Foxes may be carriers of leptospirosis, a serious livestock disease. Leptospirosis occurs in all parts of Australia but the highest incidence occurs in Queensland and Victoria (Smythe et al. 2000; Queensland Health 2002). Leptospirosis is potentially lethal to cattle, and affects the hepatic, renal and central nervous systems (Hanson 1982; Hartskeerl and Terpstra 1996; World Health Organisation 2003). The source of infection is water or soil that has been contaminated with the infected urine of wild, feral or domestic animals. Rats and mice are the main hosts but the role of foxes is as yet undetermined (Smythe et al. 2000).

5.4 Urban effects

People are becoming increasingly aware of the presence of foxes in urban areas but generally know little about their impacts (J. Morrison [Brisbane Wildlife Preservation Society] 2004 pers. Comm.). Urban foxes may be a general nuisance through harassing domestic animals, eating pet food, raiding rubbish bins, defecating or digging in gardens, chewing infrastructure such as garden hoses and irrigation systems, even shoe stealing. In Britain, complaints of 'unearthly screams' are common during the breeding season (Rural Development Service 2005). Foxes also prey upon native and domesticated animals including unprotected poultry. Although there are reports of foxes fighting cats or dogs (H. Haapakoski [NRW] 2004 pers. comm.), they are unlikely to be a danger to adult cats and dogs (Rural Development Service 2005; Marks 2004). However, foxes can spread parasites and diseases such as mange and distemper to domestic animals and pets (see Table 3). In Britain, the focus has been on developing control strategies for urban foxes due to their potential to act as a vector for sylvatic rabies.

5.5 Benefits of foxes

Foxes are popular with recreational hunters, especially in the south-eastern states of Australia. Most animals are taken by rifle shooting with the aid of a spotlight, but they may be killed with shotguns or other weapons (such as crossbows). Few fox hunting clubs exist in south-eastern Australia (Saunders et al. 1995). Alternatively, animals may be hunted with horse and hound, or small dogs may be used to flush foxes from dens before they are killed by shotguns or larger dogs.

Such hunting usually only provides a non-pecuniary benefit through participation, but some financial return may be obtained through the sale of pelts. The fox fur industry in Australia generated significant export income (Ramsay 1994) but this has declined in recent times due to factors such as fashion shifts, increased supply from other countries, the trend towards farmed furs and the actions of the anti-fur lobby (Saunders et al. 1995). Furthermore, the benefit to Queensland's economy is likely to be low since the fur industry data suggest that nearly all pelts are sourced from the southern states: 60 per cent from New South Wales, 30 per cent from Victoria, and the remainder from South Australia (Saunders et al. 1995).

6.0 Community attitudes and perceptions

People are an integral part of pest management. Therefore, the human dimension of pest species management, or how people's attitudes and behaviour towards pests affect and are affected by decisions made by managers (Purdy and Decker 1989), should be recognised in any pest problem situation. Ignoring socio-cultural issues and managing pest animals on the sole basis of biological and economic decisions has been identified as a major reason why many human-animal conflicts are unsuccessfully resolved (Jones et al. 1998; O'Keeffe and Walton 2001). A greater understanding of the perceptions and attitudes of the public towards pest animal species will ensure that management approaches are satisfactory and acceptable to the public.

Given that foxes reside in many urban areas, it is inevitable that there will be interaction between foxes and people. However, the perceptions of urban residents towards foxes or pest animals in general may be completely different from those of rural residents, affecting their recognition and status as pests. An individual's attitude towards pest animals is a result of a complex array of intrinsic and environmental influences (Jones et al. 1998). For example, familiarity with the animal may lead to either a positive or negative attitude in the individual, depending on experience. Lifestyle may also influence attitudes; rural residents may be less sympathetic towards pest animals than urban residents since their relationship towards animals has been based on direct use or impacts (Hills 1993). Similarly, many problems caused by foxes that are recognised by inhabitants of urban areas may be seen as 'trivial' by rural residents, resulting in different perceptions of the problem status of pest animals. The differences in people's perceptions of pest animals mean that management approaches will be more acceptable to some than to others.

Incomplete knowledge of the biology, ecology and impact of each pest animal often results in misunderstanding or misinterpretation of the options available for control and management of that particular species. Experience from urban pest management suggests that many people may be in conflict with animals that they know little about (Jones et al. 1998). Increasing our knowledge of such processes, and educating the community will result in a generally improved understanding of the management of pest species such as the fox.

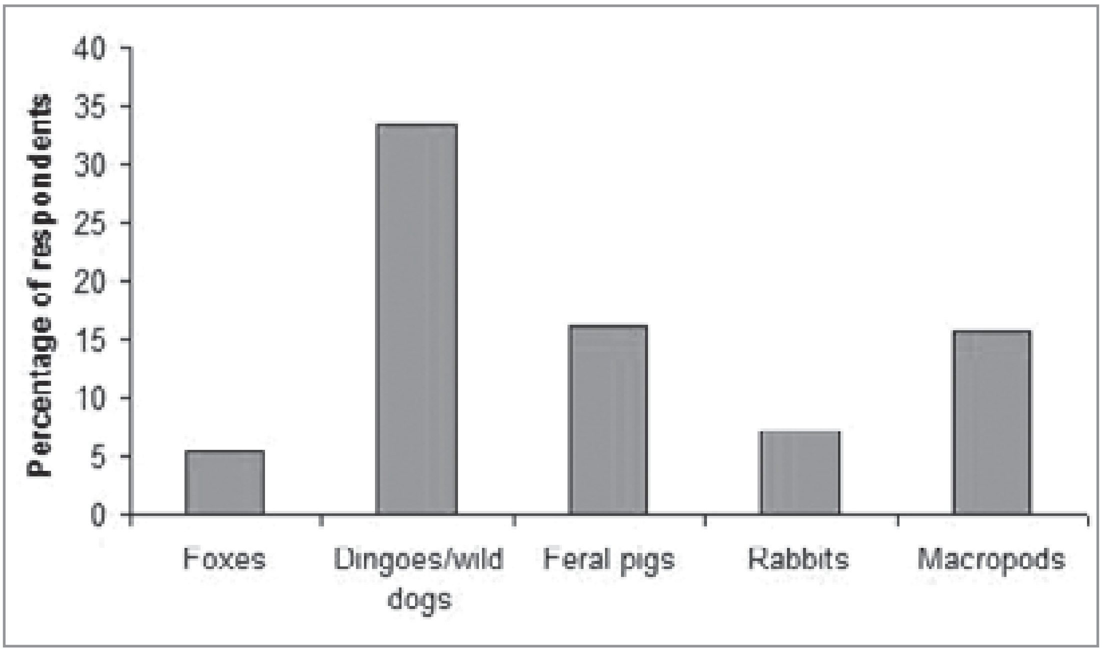
A recent survey undertaken by NRW (Oliver and Walton 2004) assessed the attitudes and knowledge of primary producers and residents of regional centres/country towns towards pest animals. Relevant results from this survey are summarised (see sections 6.1 and 6.2), providing an insight into the perception of the fox as a pest, and the differences between the perceptions of rural producers and town residents.

6.1 Primary producers

Despite little quantitative data about fox damage to Queensland's agricultural industries, many primary producers regard foxes as a major pest species. A survey undertaken of primary producers and residents of regional centres (Oliver and Walton 2004) suggests that foxes are perceived to be pests throughout Queensland, with 5.4 per cent of primary producers rating foxes as the pest animal that causes them the most concern.

Primary producers ranked dingoes and wild dogs, feral pigs, macropods, and rabbits above foxes as the pest animals of most concern (see Figure 8). By region, a greater percentage of primary producers in the south-west are concerned with foxes as their primary pest (7.3 per cent) as compared to 4.9 per cent in the south-east, 4.0 per cent in the central-west, and 2.4 per cent in the north. This is most likely correlated with the main farming activity of the respondents, with a greater percentage of primary producers with sheep (12.5 per cent) reporting foxes as being a main concern than other primary producers activity (Oliver and Walton 2004). However, many beef (3.6 per cent), horticultural (5.1 per cent), mixed grazing/cropping (4.3 per cent) and crop producers (5.8 per cent) still recognise foxes as being a pest. Whether this is due to actual damage inflicted on individual producers, or a wider perception of the environmental damage associated with foxes requires further investigation.

Figure 8 The pest animal species causing most concern to primary producers



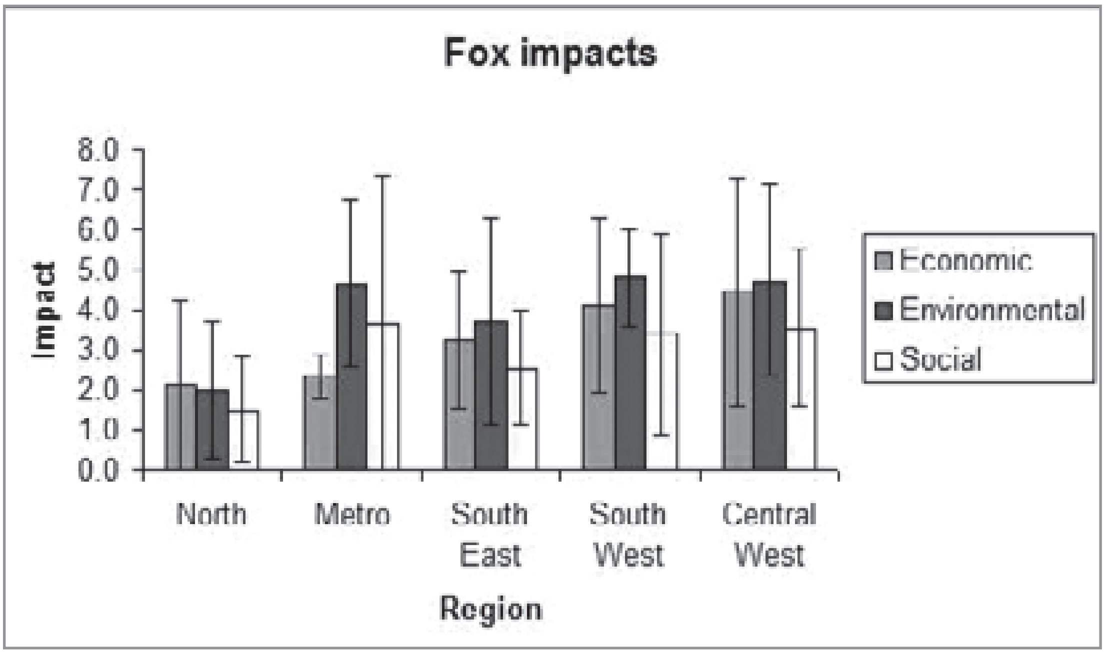
6.2 Urban residents

The survey of town and regional centre residents (Oliver and Walton 2004) indicates that less than one per cent rated foxes as the pest animal causing them the most concern. Domestic cats, domestic dogs and birds were perceived to be the major pests of these areas (See Table 4).

Table 4 The pest animal species causing most concern to regional centres and large country town residents

Pest animal species	Percentage of residents
Feral goats	0
Feral pigs	0.2
Foxes	0.8
Possums	0.8
Macropods	1.4
Flying foxes	1.6
Rabbits	1.8
Dingoes/wild dogs	2.5
Cane toads	3.4
Feral cats	4.8
Other	5.7
Crows/cockatoos	5.9
Domestic dogs	10.3
Domestic cats	11.6

Figure 9 Fox impacts by region of Queensland



The scale of impacts range from 0 to 9, 0 = no impact, 5 = significant impact and 9 = severe impact. Error bars indicate the standard deviation.

6.3 Local government

A survey was conducted to assess the perceptions of local government pest management officers towards the impacts and benefits of vertebrate pests in their respective local government area (LGA) (F. Keenan, Land Protection unpublished data 2004). Fifty-seven of the 125 local governments in Queensland (45.6 per cent) completed and returned the surveys. Foxes were recognised as pests in 64.9 per cent of respondent LGAs. Foxes were perceived to have a significant to severe social impact in 21.6 per cent of LGAs, a significant to severe economic impact in 27 per cent of LGAs, while 40.5 per cent of LGAs assessed foxes as having a significant to severe environmental impact.

Of the sampled LGAs, only three (Bowen, Johnstone and Maryborough) reported no social impact from foxes. Similarly, only three LGAs (Gold Coast, Johnstone and Waggamba) reported no economic impact from foxes and only one (Johnstone) reported that foxes had no environmental impact.

The economic impacts of foxes were generally rated lower in the northern districts than in the metropolitan, central and southern areas respectively, probably reflecting fox distribution throughout the state. Similarly, there was a greater awareness of the impact of foxes in the metropolitan, central and southern areas than in the northern areas (see Figure 9).

Respondents were asked to assess the benefit of undertaking control of each pest animal. A total of 70.3 per cent of local governments perceived a significant to major benefit from undertaking fox control.

Despite the incomplete response from the survey, the results suggest that in many LGAs in Queensland, people are aware of, and are suffering from fox-related impacts. The environmental impacts generally ranked higher overall than both economic and social impacts, although this was not statistically significant. The southern and central areas of the state have a greater perception of fox damage than the northern LGAs, which is most likely correlated with both fox distribution and the types of agricultural activity. More importantly, most LGAs perceive significant (or greater) benefits from undertaking control campaigns.

7.0 Control methods and efficacy

Control methods have traditionally focused on reducing fox population density rather than specifically reducing fox-related damage. Therefore, the preferred control techniques used for any given situation may have been those regarded as being the most effective at killing animals rather than reducing the pest damage. It is essential that pest management is undertaken strategically to ensure that control measures achieve the objectives and goals that are constructed in terms of the response of the 'prey' and not the 'predator' (see Braysher 1993). That is, they reduce lamb predation (for example) by X per cent rather than reducing fox numbers by Y per cent.

The techniques commonly employed on both agricultural lands and conservation areas include poisoning, shooting, trapping, den fumigation and destruction, and exclusion fencing. Alternative management techniques, such as immunocontraception, taste aversion conditioning, and chemical deterrents are continually being researched and will not be addressed here.

7.1 Poisoning

Poisoning foxes through the distribution of poison baits is the most common technique used to reduce fox damage. A variety of poisons have been used (for example, potassium/sodium cyanide and jetting/dipping agents such as fenthion-ethyl ('Lucijet'), but these are illegal and their use incurs heavy penalties. There are currently only two poisons registered for fox control in Queensland, sodium monofluroacetate (1080) and strychnine.

Fluoroacetate

Fluoroacetate is a mammalian toxin commonly used for canid control within Australia. It is favoured for its cost-efficiency (Saunders et al. 1997), relative target selectivity. (McIlroy 1986), and low environmental persistence (Twigg and Socha 2001).

The fluoroacetate mode of action can be summarised as follows: after its consumption, fluoroacetate is converted to fluoroacetyl-CoA, which reacts with oxaloacetic acid to form fluorocitrate. Fluorocitrate blocks the citric acid cycle, inhibiting the ability of cells to metabolise glucose and thus cells fail to respire (Sheehan 1984). Fluoroacetate poisoning is characterised by a variable latent period; symptoms generally appear between 30 minutes and four hours after consumption (Chenowith and Gilman 1946; Egekeze and Oehme 1979; Sheehan 1984; Staples et al. 1995). Mean time to death in foxes is approximately four hours (Marks et al. 2000). Canids are particularly susceptible to fluoroacetate; the LD_{50} of fluoroacetate for foxes is generally accepted as 0.013 mg/kg (McIlroy and King 1990). Native mammals and birds are more tolerant than canids, allowing for some selectivity in its use.

Fluoroacetate is highly water soluble and rainfall will result in leaching from the bait material. Fluoroacetate degrades rapidly in the environment due to the actions of insect decomposers such as maggots and beetles, and soil micro-organisms such as fungi, bacteria and actinomycetes (McIlroy and Gifford 1988; Twigg and Socha 2001). Given sufficient soil moisture, fox baits typically last for between one and three weeks, but may remain toxic for extended periods, up to six months, particularly in hot and dry environments (McIlroy and Gifford 1988; Fleming and Parker 1991; Saunders et al. 2000; Twigg et al. 2001).

Fluoroacetate baiting of foxes began in 1967 (Review of 1080 use in Queensland 1995). There are three bait types used for baiting foxes in Queensland–fresh meat, Foxoff®, and Paks De-fox®, Foxoff®, and De-fox® are shelf-stable, commercially manufactured bait. Foxoff®, weighs either 60 g or 30 g (Econobait®) while De-fox® weighs 24 g. Fresh meat used in baits is generally supplied by the landholder and must contain no bone, fat or have attached skin. Bait meat is usually cattle or horse flesh, but kangaroo, camel, donkey, and goat meat can also be used. The minimum bait size is usually 125 g, but 250 g baits are used in coastal and closely settled areas. Use of the larger bait in these areas may reduce bait removal by non-target animals and so reduce the exposure of domestic pets to baits. All baits contain a nominal 3 mg dose of fluoroacetate, sufficient to allow for some degradation or leaching from the bait substrate (McIlroy and King 1990).

Meat baits are usually injected but may be tumble-mixed with fluoroacetate, depending on the discretion of the land protection officer (LPO) and local government restrictions on impregnation techniques (see Appendix 1). Typically small amounts of concentrated fluoroacetate solution (e.g. 1 ml of 3 mg/ml or 0.5 ml of 6 mg/ml) are injected to reduce the potential for leakage of fluoroacetate solution from the bait. However, solutions are less concentrated than those used in other Australian states (such as New South Wales) to reduce the potential for error in the volume of fluoroacetate solution injected, and the fluoroacetate content in baits. The potential for dosing error is also reduced since all 1080 solutions are tested for concentration before distribution to LPOs.

It is difficult to determine the efficacy of conventional poisoning programs since carcasses are rarely found. The long latent period associated with fluoroacetate poisoning means that fox carcasses can be considerable distances from where baits were laid. Studies have suggested that fluoroacetate baiting can remove up to 90 per cent of the resident fox population (Thompson and Fleming 1994), but may be considerably lower (50 per cent) (Gentle unpublished data). Additionally, there is evidence that palatability of fluoroacetate bait may be reduced when compared to the same bait substrate that is unpoisoned (Gentle unpublished data).

The long-term effectiveness of baiting programs is hampered by the immigration of foxes back into areas from which they were removed. Undertaking control in an additional area or buffer surrounding the area to be protected is shown to be effective in reducing fox immigration into the central core area (Thomson et al. 2000) through creating a 'dispersal sink' (Thomson et al. 1992). This means that immigrating foxes will only penetrate into the buffer zone, leaving the core area protected from reinvasion. Similarly, coordinated baiting campaigns involving a number of landholders are recommended to increase the effective baited area and reducing the potential for immigration.

Recent modelling using fox dispersal distances has indicated that large buffers would be required to counter fox immigration (Gentle 2005). These data support Thomson et al. 2000 in concluding that buffer zones would be impractical where small parcels of land are to be protected. An alternative to controlling over wider areas could be to undertake baiting more frequently or for prolonged periods. For example, ground-based fox baiting is undertaken in many smaller nature reserves in Western Australia four times per year as part of the Western Shield program (Armstrong 1997). However, this may only be necessary where year-round reductions in density are required to protect the prey species. Seasonal reductions in fox density may be all that is required to reduce predation on domestic stock. Lambs and goat kids are at greatest risk from fox predation in the first weeks after birth up until marking. Undertaking baiting when prey is most susceptible may be more efficient than more widespread and frequent control campaigns. More research is required to investigate appropriate strategies for efficient fox control on agricultural lands.

Strychnine

Strychnine is a bitter tasting alkaloid derived from the seeds of a tree, *Strychnos nux-vomica*. The LD_{50} for domestic animals ranges between 0.5 to 3 mg kg^{-1}, with dogs being highly susceptible at 0.75 mg kg^{-1} (Seawright 1989). Strychnine affects the nerve fibres, resulting in violent tetanic convulsions, and asphyxiation through diaphragmatic spasms. Death usually occurs within one hour of commencement of signs (Seawright 1989). A permit must be issued under the Health (Drugs and Poisons) Regulation 1996 from Queensland Health to obtain, possess and use strychnine in Queensland. Permits are usually issued only where fluoroacetate use is impractical.

Strychnine is inserted into baits by making a small, deep slit into the meat, and inserting the powder, crystals or tablet within the cavity. This is done to mask the bitter taste, to maximise the chance of foxes consuming the bait (Lugton 1990). No dose is specified; only general guidelines (~30 mg or approximately the equivalent volume of a match head of strychnine powder) are given to regulate the amount of strychnine to add to bait. This appears to be a large dose for fox control given that the minimum lethal oral dose for dogs is reported to be 1.3 mg/kg (Best et al. 1974) Bait size is restricted to 250 g throughout the state.

Efficacy is reported to be high (Lugton 1990) but there is significant risk to non-target species. Strychnine is more environmentally persistent than fluoroacetate (Parker 1998; Twigg and Socha 2001) and is not prone to leaching from bait material. Consequently strychnine baits are likely to remain toxic as long as the bait matrix remains intact, which may be months.

Sodium or potassium cyanide

Cyanide is a rapid-acting, non-selective mammalian toxin. Historically, cyanide has been used illegally to poison foxes, particularly for the collection of carcasses for the fur trade, but it is not publicly available due to potential for misuse, and health and safety concerns. It is not a registered control technique but may be used for experimental use under authority from the Australian Pesticides and Veterinary Medicines Authority (APVMA).

The most popular presentation method of presenting cyanide is to encapsulate a small amount of finely ground powder into paraffin/wax matrix to form a moisture-impervious, 'brittlised' capsule (Lugton 1990). Capsules are added to small amounts of meat, which are dropped intermittently along a scent trail. An animal chewing on the bait will rupture the capsule, resulting in the production of hydrogen cyanide from a reaction between moisture (saliva) and the sodium or potassium cyanide. The animal will die quickly, usually within minutes.

Baits should be laid in the late afternoon or evening and retrieved the following morning to reduce access by non-target species. Preparation of the cyanide capsule also involves considerable effort and is potentially dangerous. It is not a registered control technique but may be used for research (under trial permit) since it can be used to generate, abundance indices in addition to carcass collection (Algar and Kinnear 1992).

Research into the application of cyanide for fox control is continuing. Given that cyanide is toxic to all mammals, a target-specific delivery mechanism would be beneficial.

The ejector is one such means; it delivers the toxin to the mouth of an animal following the pulling of a lure. Few animals apart from canids have the required pulling power, ensuring target specificity (Marks and Wilson 2005). The ejector may potentially incorporate cyanide, fluoroacetate or para-aminopropiophenone (PAPP) as the toxin fox and canid control (Marks et al. 2003; Marks et al. 2004; Van Polanen Petel et al. 2004).

Restrictions on baiting programs

Baiting may only be undertaken under the conditions of a permit issued by the APVMA under Commonwealth legislation *Agricultural and Veterinary Chemicals Code Act* 1994. Queensland has additional policies and guidelines for baiting.

Baiting operations are restricted by the factors such as the size of the property, the distance from infrastructure, impregnation techniques, dose rates and bait size. On holdings between five and 40 hectares (ha), fluoroacetate and strychnine baits may only be used at the discretion of the LPO. Areas over 40 ha may be baited where certain conditions are met. (for example distance restrictions to fenced boundaries, public roads and habitation).

Appendix 3 provides a summary of the distance, bait size and toxin restrictions in Queensland.

Fox baiting in Queensland—distribution, intensity and trends

NRW records indicate that fox baits were purchased for use in a total of 44 local government areas in 2003. These areas roughly coincide with the distribution of foxes in Queensland (see Figures 1 and 2), but the intensity of campaigns undertaken does not appear to be correlated with expected fox density. The number of landholders undertaking fox baiting each year (Foxoff® and fresh meat combined) in Queensland is generally increasing. The number of landholders participating in fox baiting has risen from 1429 in 1998 to over 4000 in 2002, but declined slightly to 3215 in 2003 (see Figure 10).

This data is perhaps misleading and probably overstates the control effort directed for fox control in Queensland. Fox management and wild dog/dingo management with poison baits may overlap. Both species may be targeted using 1080 baits; where both species are present, dog-strength baits (6 or 10 mg fluoroacetate) are recommended. This underestimates the fox control effort. However, contrary to NRW recommendations, some landholders may use fox-strength baits for dog control.

Figure 10 Landholders undertaking fox baiting each month in Queensland from January 1998 and December 2003

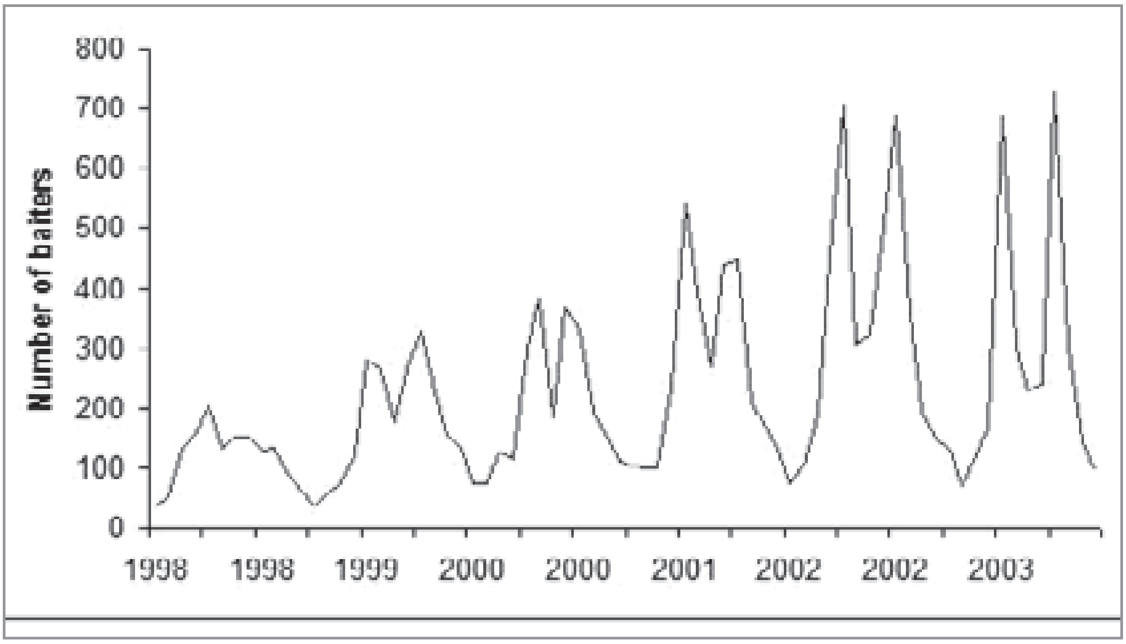


Figure 11 Landholders undertaking fox baiting in each region of Queensland between 1998 and 2003

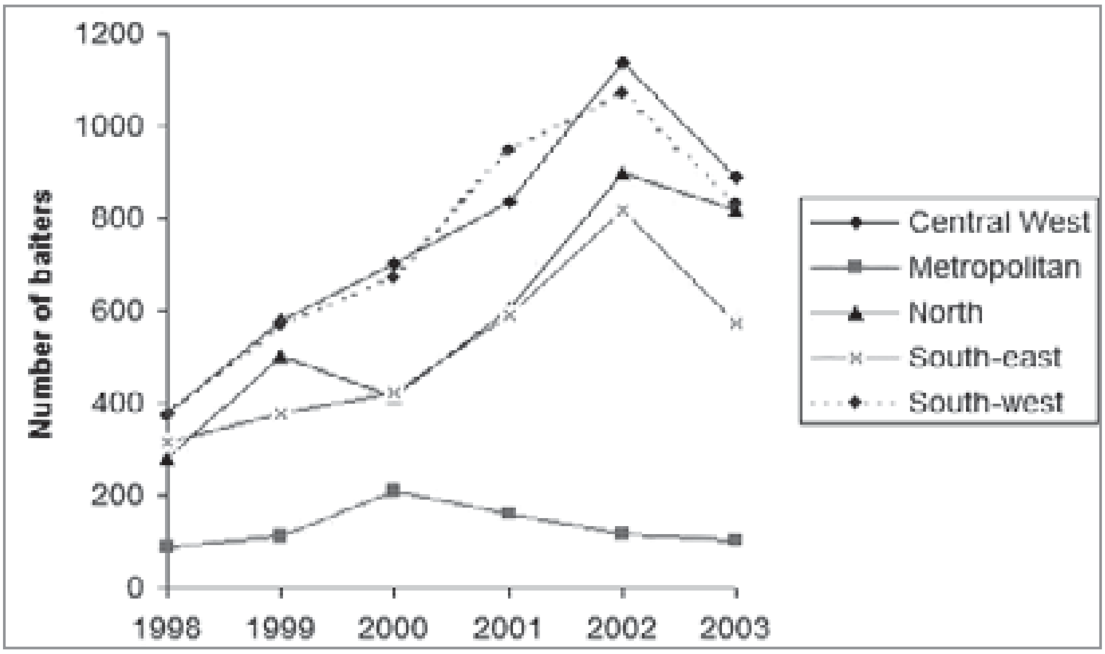
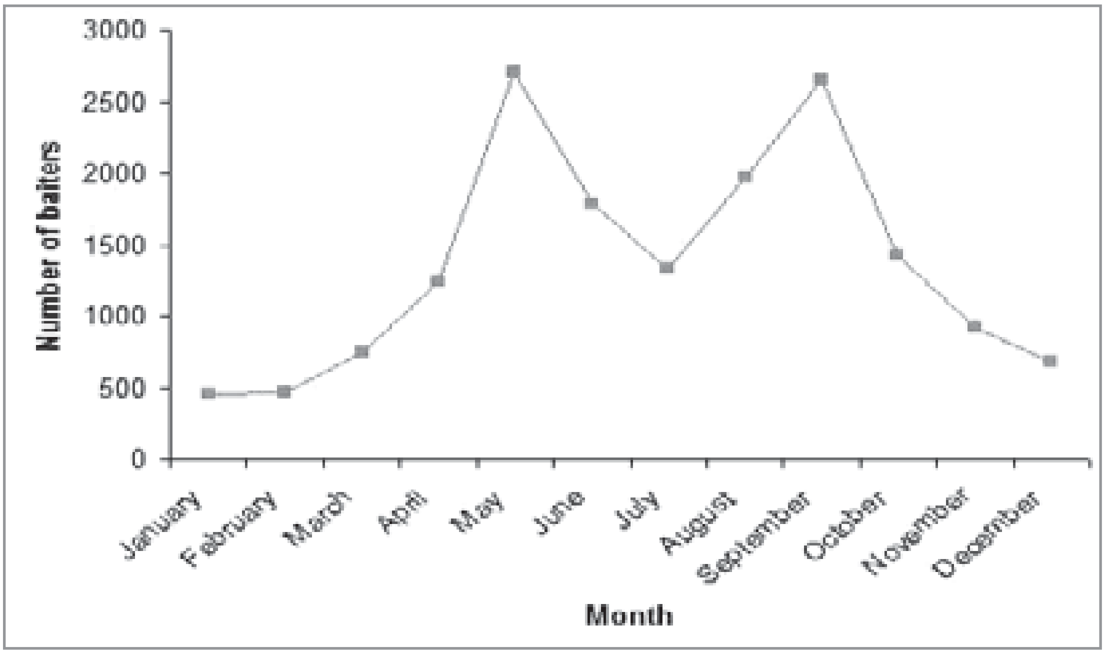


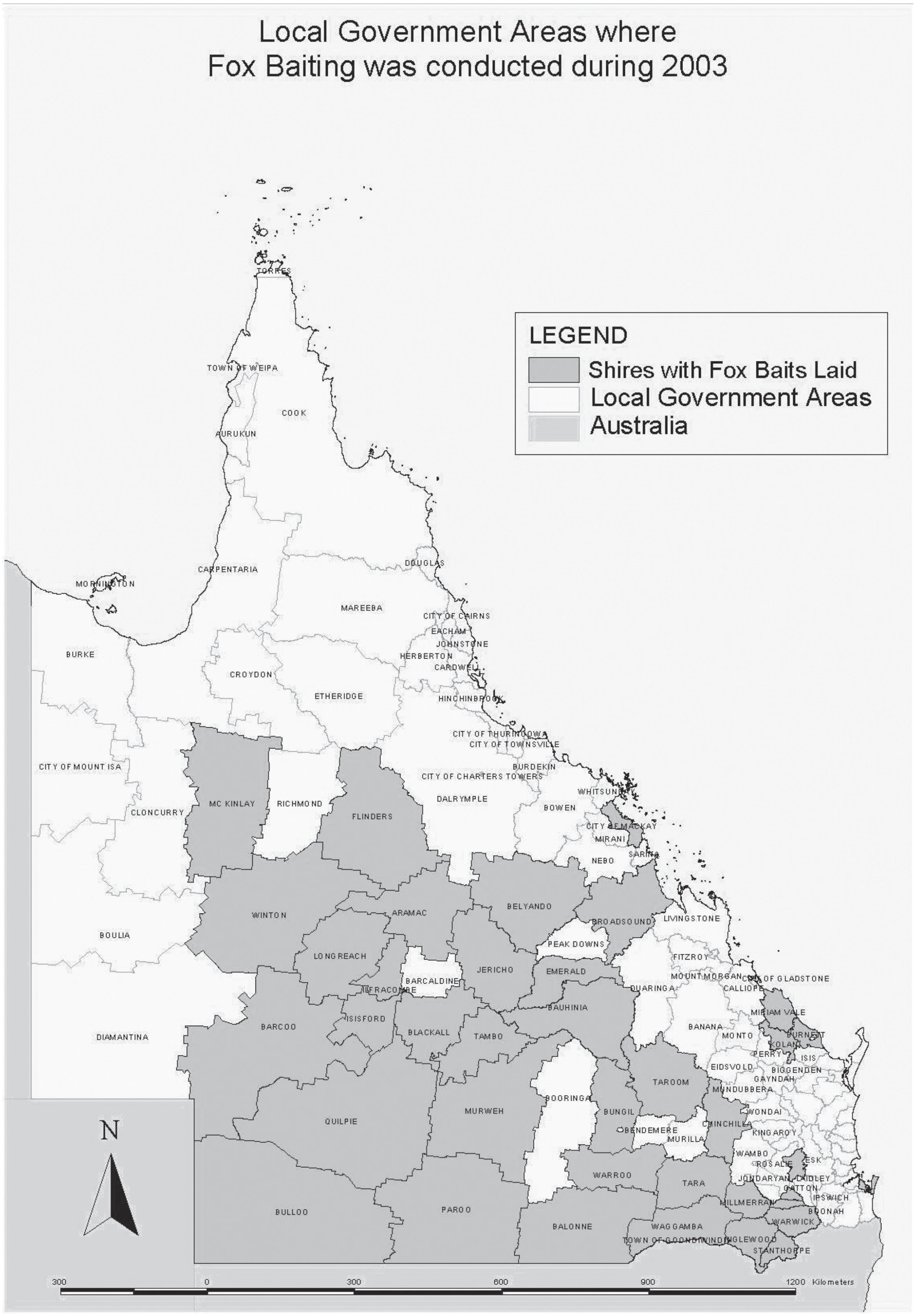
Figure 12 Landholders undertaking fox baiting each month for the years 1998–2003



The number of landholders undertaking baiting in different regions of Queensland appears to be increasing at a similar rate for all areas apart from the metropolitan areas. This is consistent with the results of a landholder survey by Oliver and Walton (2004) that found that foxes are perceived as a pest throughout Queensland, especially in the non-urban areas. Furthermore, it shows that more landholders are undertaking fox management, possibly in greater recognition of the status of the fox as a pest animal.

The timing of baiting programs appears to peak in autumn and spring (see Figures 10 and 12). Conventional sheep joining usually occurs during March–April and December–January resulting in lambs being born in winter, spring or autumn respectively (Lloyd Davies and Devauld 1988; Balogh et al. 2001). Lambs are most susceptible to predation during their first few weeks, and landholders appear to concentrate baiting efforts before and during these periods. However, primary producers from all categories surveyed (including beef cattle, horticultural, cropping and dairy) recognised foxes as a significant pest animal (Oliver and Walton 2004), suggesting that foxes are perceived as pests to enterprises other than sheep production. This is supported by the distribution of landholders that are undertaking fox baiting; fox baiting is being conducted in many local government areas that are not recognised as major sheep or goat producing areas (see Figure 13). Landholders may bait to simply cooperate with neighbouring sheep producers, or reduce impacts on native wildlife. Many landholders are aware of the environmental damage caused by pest animals (Oliver and Walton 2004) and wildlife conservation may be an important driver for increasing involvement of non-sheep producers in fox baiting campaigns. A greater understanding of what motivates non-sheep producers to undertake fox baiting may lead to improved strategies to increase participation in fox baiting programs.

Figure 13 Queensland local government areas where fox baits were conducted during 2003



7.2 Trapping

Trapping of foxes is not suitable for undertaking large-scale control of foxes, and generally lags behind baiting and shooting in popularity. However, trapping is often the only means of removing foxes in closely settled or populated areas where other techniques are unable to be used. Soft-jawed (such as Victor Soft-Catch®, Woodstream Corporation, Lititz, Pennsylvannia, USA), cage-style, treadle snare (Glenburn Motors, Yea, Victoria, Australia) or collarum traps are the most commonly used. The use of steel-jawed ('gin') traps is illegal in most states in Australia, but, at time of writing, it is still permitted in Queensland. It is recommended that steel-jawed traps are used in conjunction with strychnine.

Soft-jawed traps have off-set jaws with rubber-like inserts on each jaw to cushion their impact on the animals limb (Fleming et al. 1998). The treadle snare is shaped like a banjo and has a circular pan. A wire cable snare placed around the circular pan is springs up and around an animal's limb when the treadle is triggered (Fleming et al. 1998). Cage traps are usually wire mesh constructed 'box' style traps that are triggered to close once the animal is inside.

Trapping efficiency and likelihood of injury varies according to the trap design. Soft-catch traps are as efficient at capturing canids as steel-jawed traps, but cause significantly fewer injuries. Treadle snares are generally less efficient than jawed traps, but also cause fewer injuries than steel-jawed traps (Fleming et al. 1998). Cage traps can be effective in urban or other areas where animals are used to human presence, but these are usually less efficient at catching wild canids than snare or jaw-type traps. Because wild canids are highly suspicious and neophobic, cage trapping is highly inefficient.

Relatively new trapping devices, such as the Collarum® and Ecotrap® (see Figure 14 and 15 respectively) have shown some success. Collarum® (Wildlife Control Supplies LLC, Simsbury, Connecticut, USA) is reportedly canid-specific since the trigger requires a pull action, similar in principle to the mechanical ejector. When triggered, Collarum® throws a loop over the animal's head, effectively snaring it. The Ecotrap® (Ecotrap®, Rowville, Victoria, Australia) comprises a flexible metal frame and netting and/or bag which collapses over the animal when triggered, entangling it within a soft net. The soft net and structure of Ecotrap® reportedly reduces injuries to the trapped animal.

Trapping foxes is a labour intensive and highly skilled task. Success is greater when the traps are located where foxes are likely to visit, such as outside dens, adjacent to paths, and tracks and holes in fences. In one study, Kay et al. (2000) reported trap success in rural New South Wales as greatest when located adjacent to carcasses. Despite this, trap success was still very low with approximately 150 trap nights required to capture one individual. The labour involved in a trapping program usually makes it inefficient for large-scale fox control. However, trapping may be very effective for localised problems where small numbers of foxes are responsible or in situations where other techniques are not suitable.

Figure 14. Collarum

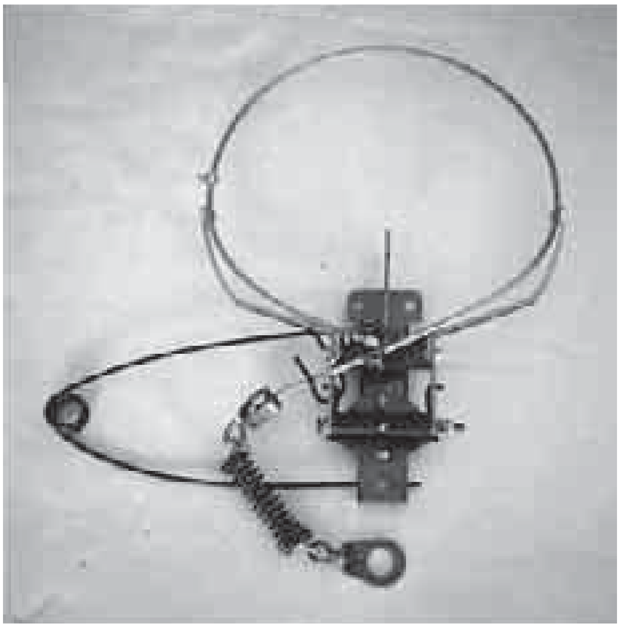


Photo courtesy of Wildlife Control Supplies LLC, Simsbury, Connecticut, USA. </www.collarum.com/>

Figure 15. Ecotrap Urban.

Photo courtesy Ecotrap, Rowville, Victoria Australia ‹www.ecotrap.com.au/mainindex.html›

NRW supports the use of leghold traps and certified snares by proficient operators where 1080 baiting or other control methods are not feasible. Cage traps are recommended over the leghold traps and snares; where leghold traps are used they should be rubber-jawed and used in conjunction with strychnine-impregnated material. All capture devices must be used in a manner that minimises pain, suffering and capture of non-target species.

7.3 Fencing

Fences may be designed to be totally exclusive or simply designed to reduce the visitation by foxes. Exclusion fences are only required where eradication of the pest species within the given area is undertaken and needs to be maintained to stop re-invasion (Long and Robley 2004).

Foxes are agile, capable climbers and strong diggers, and most fence designs involve barriers to restrict such activities (see Appendix 5). Other designs, such as simple electrified fences rely on avoidance learning rather than direct exclusion; individuals associate electric shock with the proximity to the fence and subsequently avoid contact with, and crossing of, the fence. There are three basic groups of fence designs used in Australia:

- plain wires with some/all electrified
- combination of wire netting and electrified plain wire
- standard chain-mesh.

The design of each fence will change with the species to be protected, and local conditions such as topography. Despite the availability of a variety of fence designs, there are few assessments of the effectiveness of fencing to reduce fox impact (Saunders et al. 1995).

Rudimentary electric fences (for example, three strands of electrified plain steel wire placed at 15 cm intervals from the ground) have been shown to be an effective deterrent in the short term, reducing both crossings by foxes and fox activity inside the protected area (Patterson 1977). However, fences should be at least 1.5 m high to prevent foxes from jumping over them (Coman and McCutchan 1994).

In the United Kingdom, exclusion fences are popular in managing fox predation on birds. Fences are generally used where birds are nesting at high densities in relatively small areas (such as tern colonies and rookeries), although more extensive areas may also be fenced (N. Ratcliffe [Royal Society for the Protection of Birds] pers. comm. 2004). Fences are usually electrified but a variety of designs are used including physical barriers with electric strands top and bottom, six strand tensioned electric fences and Flexinet® fencing. Flexinet® (Horizont Pty Ltd, Gloucester, United Kingdom) is sheep or poultry netting with horizontal, electroplastic twines and inert vertical wire. Some bird conservation programs in the United Kingdom construct temporary Flexinet® fences around nesting areas after the initial birds begin nesting, but some permanent enclosures have also been made (B. Yates Rye Harbour Nature Reserve, Sussex pers comm. 2004). In one assessment, clutch survival rates were greater in areas protected by Flexinet® than unprotected areas, or areas protected by ordinary electrified wire fences (Yates 1999). However, it is doubtful that this technique would remain effective for long periods. Once an individual learns how to successfully breach the fence then the fence no longer remains an effective deterrent against that individual (Patterson 1977).

Coman and McCutchan (1994) found that most fences provided an incomplete barrier to foxes. Constant fence maintenance, monitoring and quick action to remove any foxes that breach the barrier are essential to ensure that fences remain effective. Consideration must be given to integrating control with exclusion (Coman and McCutchan 1994) to ensure that fences are effective. For intensive agricultural enterprises, or small-scale enterprises, exclusion fencing may be the only viable option to prevent fox damage. In many cases, breaches of exclusion fences by even one individual can result in significant damage.

Exclusion fences are expensive to construct and maintain. Coman and McCutchan (1994) provide examples where fox exclusion fences have cost between

$18 000 and $50 000 per kilometre to construct. A recent review of fences in Australia indicates that an average of 0.9 hours of labour per kilometre of fence are required to maintain fences each week (Long and Robley 2004). The considerable construction and maintenance costs suggest that exclusion fencing is usually restricted to protecting rare or threatened species, situations where prey are confined to a small area, and/or commercial applications where economic benefits exceed costs.

7.4 Den fumigation and destruction

Fumigation and destruction of breeding dens or earths can be very effective techniques to reduce fox numbers. In most cases these techniques are used to target cubs, but adults may also be killed. Dens are fumigated during the whelping period, generally during August/September (Saunders et al. 1995). Dens are only used during early spring to summer.

Constructing a den may require significant energy; as a result many dens are reused in consecutive breeding seasons. Fumigation of dens without subsequent destruction will allow these dens to be re-colonised during the following breeding season. If dens can be reached by machinery then deep ripping may be used to destroy the den. Dens may also be collapsed by explosives, or rendered unusable by filling with soil or obstructing holes with rocks or wire mesh.

Historically, chloropicrin and other substances including phosphine were used to fumigate fox dens; however, only carbon-monoxide (Den-co-Fume®, Animal Control Technologies) is registered for use as a fumigant in Queensland.

Figure 16 Shooting is one alternative to offer a short-term, localised reduction in fox numbers

Photo: Wayne Carter

7.5 Shooting

Shooting of foxes is commonly employed to reduce numbers at a local level. This is most often done at night with the aid of a spotlight (usually 100 watt), but foxes may be taken opportunistically at any time. Spotlight shooting is favoured since foxes have very bright, characteristic eyeshine that allows them to be easily seen, often at distances of up to several hundred metres. Fox drives, or battues, may be undertaken where foxes are known to reside. These usually involve a line of people who flush foxes out of areas into the path of waiting shooters. Battues are more popular in New South Wales and Victoria than in Queensland.

Shooting is a humane method of destruction when properly carried out (Sub-Commitee on Animal Welfare, Animal Health Committee 1996). Foxes may be shot with low-power, rimfire rifles (.22 and .22 magnum) at short distances, but high velocity centrefire rifles (.222 or greater) are recommended for most field situations to ensure a swift and humane kill. Head shots are preferred, but foxes shot in the heart/lung region from a high velocity centrefire will typically be dispatched quickly and humanely. However, there are considerable welfare concerns as a result of foxes being wounded from shotguns (see Section 8).

Broadscale reductions of foxes through shooting are generally a time-consuming and labour intensive process. Considerable effort is required to target foxes within an area, especially as fox density decreases. There is also considerable evidence to suggest that shooting selectively targets juvenile foxes, with older, more wary animals escaping. Shooting can often reduce the problem without the need for widespread control. For example, a single resident fox may be responsible for poultry losses. Removal of that one fox may result in a total cessation of impacts, albeit in the short-term. No thorough evaluation of damage reduction due to shooting as a control technique has been completed, but it is unlikely to be effective for broad scale, and/or long-term reduction.

7.6 Bounties

A bounty is a sum of money paid to encourage the destruction of a specified introduced pest animal (Tomlinson 1957). Therefore, bounties are not an actual control method but a motivational tool used to encourage the use of specific control methods. The bounty is usually only paid on presentation of a nominated body part, effectively limiting the control methods to those that allow for retrieval of carcasses such as trapping or shooting (Tisdell 1982; Hassall & Associates Pty Ltd). Bounties usually receive strong support and give the public a strong perception of government action in managing pest species. Bounties have been introduced in the absence of adequate assessments of alternative solutions to a perceived pest problem and as a response to political pressure (Hassall & Associates Pty Ltd).

Bounty schemes have been shown to be an ineffective and inefficient means of managing a pest population. Whitehouse 1976 reports that bounties have shown little success and have not effectively controlled any predator population. More recent evaluations of bounties (Smith 1990; Hassall & Associates Pty Ltd) found several inherent problems associated with the bounty system. The main conclusions from these studies found that bounties are:

- inefficient since they
    - fail to specifically target the individuals causing damage
    - provide incentive to control animals in areas where they are abundant, not areas where they are causing the most damage
- counter-productive to more efficient forms of control since they provide a financial incentive not to use more efficient techniques or participate in more effective programs
- subject to fraud, misinterpretation, and exploitation e.g. 'farming' pests, animals are collected outside the bounty area, or false animal 'scalps' are presented
- ineffective at reducing pest animal density sufficiently to prevent compensatory responses either through increased survivorship or immigration into controlled areas.

An economic evaluation of the bounty system found that bounty payments may be effective in some circumstances. Bioeconomic modelling and successful experience with the coypu (an introduced rodent) in southern England suggests that bounties may be cost-effective and applicable where there are small, established pest populations (Gosling 1989). However, for widespread, established species such as the fox, bounties are inefficient. Even 'smart' bounty options, that are restricted in their application (e.g. time or area limited bounties) still remain an inefficient method of control for widespread established species (Hassall & Associates Pty Ltd 1998).

Both the National Vertebrate Pests Committee (1975) and the Committee of Inquiry into Animal and Vertebrate Pests, Queensland (1976) recommended that the bounty systems be abolished since they were ineffective and uneconomical. As a result, NRW does not directly pay or support the use of bounties for pest animal management. However, local governments have the authority to support and pay bonuses within their jurisdiction.

Victoria recently completed a 12-month trial assessing the bounty as part of the Enhanced Fox Management Scheme (2002–2003). A case study of this scheme demonstrates the issues and failures of the bounty scheme strategy.

Case study

Victoria's Enhance Fox Management Program

(Based on an assessment by C. Marks, Department of Natural Resources and Environment, Victoria)

A trial was undertaken across Victoria between July 2002 and July 2003 to determine the effectiveness of a fox bounty as a means of reducing fox predation on lambs during late winter and early spring. A total of 150 822 fox tails were handed in over the 12-month period at a cost of over $1.5 million. These figures appear impressive, but with a population of greater than one million foxes within Victoria at any one time, the removal of only 150 000 foxes would have minimal effect. An estimated population reduction of >65 per cent is needed to reduce fox population growth to below the critical level required to maintain populations (Hone 1999). Assuming many agricultural areas in Victoria have four foxes per km^2 (Coman et al. 1991), it would be necessary to remove more than 2.6 foxes per km^2 to have some effect on fox populations. Analyses of returns indicate that only 4 per cent of 10 km^2 grid cells across Victoria experienced this level of reduction. Additionally, these areas were spatially isolated, effectively representing islands where the potential for immigration and recolonisation from the surrounding fox populations would be large.

Several problems identified with former bounty schemes were again highlighted as potential problems in the 2002–2003 Victorian trial. Bounty systems appear to result in similar outcomes to harvesting, where animals are removed from high density and easily accessible areas where less effort is required while the remaining areas are more or less neglected. Similarly, shooting is biased towards the younger, inexperienced animals. Since foxes suffer from high juvenile mortality (Saunders et al. 2002b), removal of younger animals may only act to remove the 'surplus', and take animals likely to die anyway. Older animals generally contribute more to breeding and population growth. Bounties may be subject to issues such as fraud, where animals from outside the bounty area are bought and sold within that area, or payment is made on animals not necessarily killed by shooting (such as road kills). Similarly, the overall lack of focus on reducing damage and not simply reducing fox numbers means that no adequate measure of success can be made. Since pest animal impacts are not always directly related to pest density (for example Choquenot et al. 1996), simply removing a few animals may not necessarily decrease damage.

Although it is unlikely that the bounty program had any effect on long-term fox density in Victoria, a reduction in lamb predation may have been achieved in some areas. A short-term reduction of fox numbers when lambs are susceptible to predation (<6 weeks) may be all that is required to reduce predation to acceptable levels.

7.7 Guard animals

Livestock guard dogs have been used for thousands of years to protect stock from predators (de la Cruz 2003). Only dogs that have strong protective instincts, as opposed to herding instincts, are used as guards. There are many breeds of guard dogs originating from over 27 countries (Rigg 2001), but currently there are three breeds available in Australia: Anatolian mastiffs (Karabash), Great Pyrenees, and Maremmas (Jenkins 2003).

Other animals apart from dogs can be used to guard against livestock predation. Alpacas, llamas and donkeys are aggressive against canids and are used to protect stock in Australia from predation by canids. Alpacas are the most popular, especially to protect against fox predation. They are tall and have good eyesight, but their woolly faces may partially obscure their vision, reducing their ability to detect canids advancing on a flock (Jenkins 2003). Similarly, their ability to chase may be hampered by their heavy fleece. The Australian Alpaca Association strongly recommends that only fully grown, castrated males are used. Guard alpacas normally cost up to $550, and are relatively maintenance free. Producers recommend that they are drenched at similar intervals to sheep, and that their nails and teeth are periodically clipped. Alpacas will consume a range of native and introduced plants and therefore do not require any specialist feeding.

Llamas have more weight, height and speed than alpacas, which may make them more useful against wild dogs. Donkeys have similar advantages to alpacas and llamas, but are generally cheaper to purchase.

The basic strategy for the use of guard animals is to allow the guard animal time to bond with the species that they are protecting. Once they are bonded, the animal will discourage canids, and other species seen as a threat, from approaching their flock. The use of guard dogs generally requires a much greater investment in initial training and ongoing maintenance than that for alpacas, llamas and donkeys. Guard dogs generally require more supervision than donkeys, alpacas and llamas, and must be supplied with food that is different from that eaten by the animals under their protection. Additionally, to prevent dogs from wandering, especially to mark out their territory, secure fences or other measures are necessary. (Jenkins 2003).

Overseas studies have reported that livestock guard animals substantially reduce predation on sheep or goats by a range of predators including foxes. All species of guard animal appear to be highly variable in their effectiveness (Jenkins 2003). The level of effectiveness will depend on a number of flock management and environmental factors, such as:

- prey species and response to predation
- the density of guard animals to prey
- the protective response of the guard animals
- the size, habitat and topography of the paddock where prey are located
- the number and density of the prey
- predator density

Factors that reduce the ability of a guard animal to observe or defend the flock will ultimately reduce the effectiveness of the guard animal. The ratio of guard animals to prey is critically important to ensure the success of reducing predation; the ability of a guard animal to detect and deter predators will increase with a low ratio. A ratio of greater than one guard per 100 prey is usually recommended. However, ratios up to one alpaca per 270 ewes have reported to be effective at reducing predation in central-west Queensland (A. Martin, 'Toolmaree' pers comm. 2004).

Guards are more effective at protecting prey that group or herd together when confronted by predators (Jenkins 2003). This often alerts the guard animal to the presence of a predator and allows it to concentrate efforts on a contained group rather than on scattered animals. Foxes may not initiate this response since stock such as sheep and goats are usually unconcerned by the presence of a fox. Additionally, sheep and goats typically give birth in secluded areas away from the main flock; these areas would be less protected by guard animals and ultimately more susceptible to fox predation.

Results are less effective in habitats or situations that offer the predator shelter from observation by the guard animal. For example, woodland habitats or undulating terrain would offer more physical barriers to observation than open, relatively flat paddocks. Similarly, if individual guards have to cover large areas, then the ability of the guard animal to adequately 'patrol' the flocks would decrease, leaving greater opportunities for predators to attack unopposed. Recommendations for use usually incorporate an area in addition to flock size. For example, Jenkins (2003) suggests that one alpaca can protect 100 sheep in a 20 hectare paddock.

With all species of guard animals, there will always be individuals that show either insufficient aggression towards predators, or too much aggression towards stock. These animals do not make good guards and should be replaced. Intact male donkeys, alpacas and llamas are especially aggressive and may cause fibre contamination, or stress and injure stock while attempting to mate with them.

Many anecdotes from Australia have provided encouraging signs of the effectiveness of guard animals, but replicated studies need undertaken to assess their effectiveness under Australian conditions (Jenkins 2003).

7.8 Fertility control

Limiting recruitment rather than reducing adult mortality may be a humane alternative to lethal control for reducing long-term fox impact. Fertility control has been presented in recent years as an alternative to other forms of lethal control. It may be undertaken through use of a chemical abortifacient to induce miscarriage or abortion or immunocontraception, using the animals own immune system to block reproduction.

Chemical abortifacients

Attempts have been made to control fertility in free-ranging vixens using chemicals such as diethylstilbestrol but have been largely unsuccessful (Kirkpatrick and Turner 1985). The chemical abortifacient cabergoline has shown some success, a single 100 mg can cause abortions and/or post natal mortality of cubs from day 21 of pregnancy (Marks 2001). Cabergoline-impregnated bait was distributed around natal dens in August and September in an attempt to target pregnant vixens. Treated dens showed a significant reduction in cub activity compared to untreated dens (Marks et al. 1996). The disadvantage of cabergoline and other 'one-off' abortifacients is that the vixens would have to be re-treated each year for the remainder of her fertile life to reduce recruitment (Marks et al. 1996). This would be less cost-efficient compared to lethal baiting programs. Additionally, there may be some risk to native species from consuming abortifacient-treated bait. This risk is considered to be low since their period of pregnancy does not generally overlap with the recommended baiting period (Marks 2001); this risk may be increased if cabergoline remains viable in baits for extended periods. However, the technique may still be suitable for targeting foxes in urban areas where lethal control techniques may not be recommended.

Immunocontraception

Another approach to fertility control is immunocontraception. This is essentially where an individual's immune system attacks its own eggs or sperm and prevents it from reproducing. Immunocontraception would ideally maintain normal endocrine function and reproductive behaviour, but prevent pregnancy (Tyndale-Biscoe 1994). Although initial work has been undertaken to manufacture a self-disseminating virus to induce immunocontraception, its final form is likely to be a bait-delivered vaccine (Bradley et al. 1997). Generally, modelling indicates that immunocontraception will be effective in reducing the rate of increase of fox populations (Hone 1992; Pech et al. 1997). No effective fox immunocontraceptives are currently available.

8.0 Animal welfare considerations

Lethal and non-lethal fox damage control techniques should be undertaken in a humane and ethical manner. The welfare of non-target animals in addition to foxes must be considered in choosing an appropriate control technique to use in each situation. Assessing the humaneness of control techniques is difficult and often relies on subjective measures of pain, suffering or distress.

Section 42 of the *Animal Care and Protection Act 1991* applies to control of pest animals, including foxes. It is not an offence to control pest animals such as the fox if the control is done in a manner that causes the animal as little pain as is reasonable. There are steps that can be taken to reduce the potential for distress and suffering to the animal. For animal welfare purposes, techniques that act quickly to kill or leave an animal unconscious are better than those that take a considerable time to act. In the following section, the humaneness of commonly used control techniques will be examined, and considerations to improve welfare presented.

8.1 Poisoning

Fluoroacetate

Rammell and Fleming (1978) report the effects of fluoroacetate poisoning on dogs:

> The effects of 1080 poisoning in the dog are heralded, 4 to 5 hours after ingestion, by continual barking and howling for a few minutes. The dog becomes over-active, and behaves as if terrified, but appears to be unaware of its surroundings. There are tonic convulsions (sustained muscle contractions) followed by running movements. Vomiting is common in field poisoning cases. All clinical signs may disappear completely and the dog appears normal until it finally succumbs to the toxic effect on the central nervous system. Death is typically the result of respiratory paralysis. Death is never primarily cardiac in origin; the heart generally slows during the convulsive seizures but often continues beating for some time after respiration fails.

Viewing the above symptoms may lead to subjective assessments as to the humaneness of the fluoroacetate mode of action. However, it is particularly difficult to assess whether fluoroacetate poisoning is humane since it primarily affects the central nervous system of canids, making it difficult to assess whether individuals are able to suffer from pain (RSPCA 2003). Fluoroacetate poisoning is characterised by a long latent period (usually between 30 minutes and four hours) proceeded by initial signs of poisoning (Marks et al. 2000). Death normally occurs approximately two hours after initial appearance of signs. Symptoms of fluoroacetate poisoning in foxes usually include vomiting, anxiety, vocalisations (such as yelping and howling), hyperactivity (such as manic running), followed by collapse, muscle spasms and tetanic fits (Marks et al. 2000). Initial signs of poisoning such as vocalisations, running, and vomiting occur when the animal is conscious and capable of suffering (Sharp and Saunders 2004). Such symptoms may not be painful but may still be distressing to the individual (for example, Rammell and Fleming 1978; RSPCA 2003). Given the period between initial symptoms and death (mean 1.57 hours), this distress may be significant (Marks et al. 2000). There is much conjecture about whether fluoroacetate poisoned animals can feel pain while convulsing; some studies suggest that animals may be conscious during or after convulsions (for example, Foss 1948) but most studies suggest that they are unlikely to feel pain since they are probably unconscious during this period (Gregory 1996).

Comments by the APVMA on the humanness of 1080 also suggest there is little evidence of pain when viewed from the perspective of human poisoning cases (APVMA 2005):

> Although the measurement of pain in animals must always be a subjective exercise, some insight into the degree of suffering experienced by 1080 poisoned animals can be obtained from humans that have been poisoned in this way. Symptoms in humans involve central nervous system stimulation with clinical signs of anxiety, agitation, nausea and generalised tonic-clonic convulsions, but pain is usually not reported. In one example, a man poisoned during mixing of 1080 powder reported tingling sensations around the mouth and nasal passages, extending to the arms and legs. However, there was no recollection of pain during the spasmodic contractions of voluntary muscles that occurred in the 2.5 hours before unconsciousness intervened.

The RSPCA (2003) has raised concerns that animals surviving consumption of sub-lethal doses fluoroacetate may suffer from injuries sustained during convulsions. However, the probability of this occurring is low, given the high sensitivity of foxes to fluoroacetate and the relatively large nominal dose (3 mg) presented in bait (McIlroy and King 1990). Additionally, non-target deaths and suffering are unlikely since measures including bait placement and presentation are designed to minimise exposure to toxic baits.

Strychnine

Strychnine affects the nerve fibres, increasing the reflex irritability of the spinal cord, resulting in violent tetanic convulsions, and asphyxiation through diaphragmatic spasms. Symptoms usually appear within 10–30 minutes of ingestion; convulsions may subside for brief periods but may recur at noise, touch or other stimuli. Death normally occurs within an hour of the onset of clinical signs (Seawright 1989). Strychnine is less humane than fluoroacetate since the affected animal remains conscious during prolonged and severe tetanic convulsions, allowing it to suffer from anxiety and pain from onset of clinical signs through to death (Sharp and Saunders 2004).

There is a significant primary and secondary poisoning risk to non-target species from strychnine poisoning. Strychnine is less discriminating than fluoroacetate; the amount of strychnine inserted into bait material (~50 mg) means that many non-target animals may be susceptible from consuming strychnine baits. The approximate LD_{50} for dogs is 1.3 mg/kg. Vomiting from strychnine poisoning is not common, therefore bait material is likely to remain in the stomach of carcasses, providing a significant secondary poisoning risk. Poisoning hazards may persist for long periods since strychnine is more resistant to decomposition than fluoroacetate.

There appears to be some human hazard from intentional or accidental misuse of strychnine. There were at least five hospital admissions due to strychnine ingestion in 1998. Three people intentionally swallowed the poison; the other two were accidentally poisoned. There was one strychnine-related death in 1998 (Queensland Health 2001) but it is not known whether the poison was intentionally or accidentally ingested.

As a result of animal welfare concerns, the use of strychnine in Queensland is discouraged. The National Consultative Committee on Animal Welfare has recommended that strychnine should be no longer sold or used in Australia.

8.2 Trapping

All traps have the potential to cause some injury or distress to the target and non-target animal, although the risk varies significantly with each trap type. Steel-jawed gin traps without padding between the jaws are more likely to cause significant injury to the muscle or bone tissue than softjaw or treadle traps, and are not recommended (Meek et al. 1995; Fleming et al.1998). However, all trap types may incur some injury to the animal through entanglement, lacerations, bruises, or fractures. Cage traps are usually preferred in urban areas since non-target animals can be released easily and foxes can be removed and euthanased in the appropriate manner.

NRW recommends rubber-jawed traps but does not condone the use of steel-jawed traps. If they must be used, then they should be used in conjunction with strychnine-impregnated material (Department of Natural Resources and Mines 2005).

Traps should be checked at least daily to ensure that animals caught are not distressed for longer than necessary. Efforts should be made to ensure that animals caught in traps are not exposed to adverse conditions such as cold or hot weather, or direct predation or harassment from other animals such as domestic dogs.

Traps should be located in areas where the risk of catching non-target animals is minimised. For example, setting traps on animal pads or roads is non-selective and may result in a significant non-target catch.

8.3 Fencing

Fencing is generally regarded as a humane technique to control foxes or associated damage, since it relies upon exclusion rather than lethal measures to reduce damage. Fences may have some detrimental effects on non-target populations through restricting movements of other species, interfering with social and population dynamics. Fences may also cause direct harm to individuals through collision and entanglement injuries, where animals may become injured as a result of colliding with, or attempting to cross the fence (Long and Robley 2004). For example, echidnas commonly become entangled in low slung electric wires and are electrocuted (Coman and McCutchan 1994). Before fences are constructed, consideration should be given to the potential effects of their design and placement on non-target and target species. (Long and Robley 2004). Overall though, the benefit of excluding feral predators like the fox is considered to outweigh the impact of exclusion fencing on native fauna (see (Long and Robley 2004 for review).

8.4 Den fumigation and destruction

Carbon-monoxide (CO) is a colourless, odourless gas that rapidly dissipates in open-air conditions. CO binds preferentially to haemoglobin reducing the availability of oxygen in the blood and body tissues (hypoxia), resulting in unconsciousness, eventually resulting in death through asphyxiation. Death from carbon-monoxide induced hypoxia appears to be humane since animals become unconscious without pain or distress (Sharp and Saunders 2004) when sufficiently high concentrations are produced (e.g. human exposure to concentrations greater than 1 per cent results in loss of sensibility before any convulsions (Stewart 1975). Obviously, the appropriate safety requirements and protective clothing must be used to ensure operator safety.

There are some concerns with the humaneness of the den fumigation technique. Dispersal of the fumigant through the den may not be consistent, leaving air pockets where animals may survive for considerable periods (Ross et al. 1998). The Den-co-Fume® dispenser, which emits carbon-monoxide, operates at a high temperature and may burn animals located close to where the cartridge is placed (Hart et al. 1996). Young animals are more resistant to hypoxia; physiological mechanisms protect the animal from cerebral damage when oxygen is limited in the uterus and during birth. Fumigation of dens containing neonatal cubs is less effective and is considered to be inhumane (Sharp and Saunders 2004).

Most of these concerns can be overcome with thought and consideration. Effort should be made to ensure that individuals are not located near the entrance where the cartridge is placed to avoid scorching individuals. Several Den-co-Fume® cartridges should be used for large dens to ensure that CO concentrations are high enough to provide a swift kill. Fumigation should only be undertaken when cubs are fully susceptible to CO effects (>4 weeks old).

Another important issue is to ensure that the 'den' targeted is indeed a fox den. Some native animals (for example, wombats) will construct burrows that may closely resemble fox dens. Additionally, many dens are used only intermittently during the breeding season and other animals may temporarily reside in them. Dens should be checked for evidence of occupation by foxes (such as footprints, scats, distinct scent) before fumigation. A good method is to place sand or sifted soil plots at the entrance to a den, and check for fox and cub footprints.

The destruction of dens through mechanical or explosive means should only be done following fumigation. Ripping or using explosives to collapse dens, or blocking the entrances with soil or other means to prevent escape from or restrict access to the den may cause unnecessary stress or suffering. Death from den collapse is usually a result of crush injuries from collapsed tunnels, leading to asphyxiation. However, if some tunnels or chambers remain intact, or entrances are simply blocked, animals can remain trapped in the den for considerable periods before death. Efforts should be made to ensure that animals are dead by fumigating with CO before dens are destroyed. This should entail monitoring entrances for signs of activity post-fumigation to ensure that dens are inactive before destroying.

8.5 Shooting

Shooting is recognised as the most humane of the lethal control methods, provided that it is carried out correctly (Tapper 1992). However, there are many factors that can reduce the ability to humanely dispatch an animal through shooting. When shots are misplaced, or an inappropriate projectile or calibre is used, shooting can be injurious rather than fatal and cause significant suffering (Sub-Committee on Animal Welfare, Animal Health Committee 1996). In recognition of these problems the Model Code of Practice for the Destruction or Capture, Handling and Marketing of Feral Livestock Animals recommends that to reduce the likelihood of wounding, shooting only be undertaken:

- by well-supervised, experienced and conscientious shooters
- using a firearm capable of killing the target animal with a single round
- when the animal can be clearly seen and is within range.

A large-scale study was recently undertaken in the United Kingdom to investigate the welfare aspects of shooting foxes (Fox et al. 2003). Almost 200 individual shooters fired 2168 shots at targets and fox carcasses to investigate the accuracy, spread of shot, penetration and subsequent likelihood of wounding and death. The results were highly variable depending on the range, shooter skill, size of the ammunition, and whether the firearm was supported. Rifles (.22 LR and various centrefire calibres) were more likely to dispatch an animal (43 per cent killed) than shotguns (26 per cent killed), but shotguns were more likely to wound or seriously wound (59 per cent) compared to rifles (48 per cent). Generally skill level is positively correlated to kill rates, but in shotgun shooting, paradoxically, skilled shooters hit the target more, killed more, but also wounded more than unskilled shooters. Undertaking shooting at moving targets with a shotgun (common practice when foxes are 'flushed' during battues) has recently been identified as a particular source for non-lethal injuries and suffering in foxes (Fox et al. 2003). Both rifles and shotguns are capable of killing efficiently when used by skilled shooters but 'all forms of shooting inevitably entail some level of wounding' (Fox et al. 2003).

Where possible, wounded foxes should be located and humanely dispatched as soon as practicable. Sharp and Saunders (2004) suggest that, if lactating vixens are shot, efforts should be made to find dependent cubs and kill them humanly and quickly, to avoid suffering and ultimate death through starvation. Given that dens are difficult to locate, this may be practicable only where vixens are killed in close proximity to the den.

8.6 Guard animals

Guard animals are seen as a humane alternative to other forms of control. The use of guard animals attempts to directly prevent predation of vulnerable prey (usually domestic stock such as sheep and goats) through repelling predators, or alerting land managers to the presence of predators (Jenkins 2003). It can also reduce the use of other more inhumane techniques.

The welfare of the guard animal must be considered. Animals must be supplied with adequate levels of food, water and shelter. Welfare issues are potentially greater with guard dogs since they generally require more maintenance than the herbivorous guards (donkeys, alpacas and llamas) who generally require the same food requirements as the species they protect.

8.7 Fertility control

Fertility control has been raised as a humane alternative to lethal forms of control. The basis for this claim is that preventing the birth of young will reduce the need to use less humane forms of control. Chemical abortifacients such as cabergoline may function through preventing embryo implantation or inducing miscarriages, but may also impede lactation. Termination of lactation would result in unweaned young dying from starvation and this would be a significant welfare issue. However, undertaking lethal control techniques when cubs are dependent will have the same result, therefore it is difficult to condemn chemical abortifacients on animal welfare grounds.

9.0 Management and control practices

9.1 Legislative status of foxes: Commonwealth

Predation by the fox is listed as a key threatening process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under this Act, the Australian Government in consultation with the states and territories has developed the Threat Abatement Plan for Predation by the European Red Fox (Biodiversity Group, Environment Australia 1999).

The threat abatement plan aims to reduce the impact of fox predation by:

- implementing fox control programs in specific areas of high conservation priority
- encouraging the development and use of innovative and humane control methods for managing foxes
- educating land managers to improve their knowledge of fox impacts, and to ensure skilled and effective participation in control activities
- collecting and disseminating information to improve our understanding foxes in Australia, their ecology, impacts and methods to control them.

The threat abatement plan provides a framework that enables the best use of the available resources for fox management. This plan is largely the basis for guiding the federal Department of the Environment and Heritage expenditure on control-technique research, such as the fox immunofertility investigation and for on-ground management in high conservation areas (Hart 2005). Therefore the Australian Government works with the states and territories to deal with this national problem (Biodiversity Group, Environment Australia 1999).

9.1 Legislative status of foxes: Queensland

The fox is a declared Class 2 pest under section 38 (2)b of the *Land Protection (Pest and Stock Route) Act 2002* and the Land Protection (Pest and Stock Route) Regulation 2003. A Class 2 pest is one that is established in Queensland and is causing, or has the potential to cause, an adverse economic, environmental or social impact.

It is illegal to keep, release, feed or introduce foxes in Queensland (see Table 4). Additionally, this legislation requires that landowners (not occupiers or managers) must take reasonable steps to keep their land free from foxes. Those who fail to do so are committing an offence, and a pest control notice may be issued to enforce this obligation. If the landholder fails to comply with the notice then the issuer can authorise a pest controller to undertake the work at the landowner's expense. State government agencies are under similar obligations to control declared pests as any landowner, but they cannot be issued a notice under a pest control order.

Table 4 Offences and penalties applicable to foxes under state legislation

Offence	Penalty (penalty units)	Section of Act
Introduce declared pest without permit	400	39 b
Feeding declared pest	40	40 (1)b
Keeping declared pest without permit	400	41 b
Releasing declared pest without permit	400	42 (1)b
Supply declared pest without permit	400	44 b

Appropriate authorities, including government agencies, tertiary institutions and registered zoos or wildlife parks, can apply for a permit to keep foxes. There are no provisions under the Act that enable foxes to be kept as pets.

A permit is not required to hunt foxes in Queensland, although other licences (such as weapons licences) may be required. The statutory framework for fox management is given in Appendix 4.

9.2 Responsibilities of the Department of Natural Resources and Water (Qld)

NRW aims to minimise the environmental, economic and social impact of foxes in Queensland by promoting regional or community-based control programs, developed and coordinated in areas of significant impact.

A memorandum of understanding (MOU) has been developed between NRW and local government. It identifies the roles, responsibilities and priority actions of state and local government for pest management and stock route management throughout Queensland. The MOU identifies that an integrated approach between NRW and local government, and participation by the community, industry and private sector are required to successfully manage all pests, including foxes, across Queensland.

NRW is responsible for overseeing the supply and use of fluoroacetate within Queensland. Information on fox impacts, distribution and control is made available through extension materials and the NRW website at ‹www.nrm.qld.gov.au/pests›. Land Protection officers provide training to local governments, and pest control agencies in handling, storage, and use of poisons in a coordinated manner, as well as other fox control techniques. Opportunities for future research on fox ecology, new or improved control techniques and island eradication programs will be considered by NRW. The current range of control techniques, combined with the obligation of landowners to take reasonable steps to keep their land free of foxes provides a basis for fox management in Queensland at this time. Improvements from research will be incorporated into best practice as they become available.

9.3 Local government responsibilities

Under the *Land Protection (Pest and Stock Route Management) Act 2002*, local governments are responsible for undertaking pest management planning for all land within their local government area, regardless of tenure. These local government area pest management plans (LGAPMPs) include assessments of the priority of control for each pest species, and the measures that are to be undertaken. They assist local government in assessing the most destructive pests in their area, and developing priorities for their management. Once developed, the plans also assist NRW in identifying areas where foxes are perceived to be causing significant damage.

9.4 Management strategies in Queensland

Agricultural and pastoral areas

The main strategy used to reduce fox damage on these lands is baiting using fluoroacetate baits. This strategy is popular since it is the most efficient and effective means to control foxes over large areas. Strychnine baits are also used in areas close to human habitation or where property sizes do not permit laying of fluoroacetate baits (‹40 ha). On smaller properties, or where damage is localised, removal of individual 'problem' animals may be all that is required, and therefore techniques including shooting, trapping, and the use of guard animals can be effective.

Conservation lands

Baiting using fluoroacetate baits is the main strategy for reducing fox damage on conservation lands. Where endangered fauna are re-introduced, any predation by foxes, regardless of what level, can be disastrous. In these circumstances, other measures such as exclusion fencing are often used. Such techniques are only cost-effective for small areas, or where 'high-value' prey is to be protected.

Urban areas

The vicinity of urban foxes to human habitation means there are limited techniques available to control foxes and associated damage. Many lethal techniques are not suitable for use close to urban habitation because of health and safety concerns, non-target issues and negative public perceptions. Shooting is not permitted in urban areas unless regulated by the Queensland Police Service, and is not recommended or undertaken because of the potential for public harm or panic. Poisoning is generally not recommended because non-target uptake and distance restrictions limit the areas where baits may be laid (see Section 7.1.4).

Trapping is a suitable technique. Foxes are usually cautious of cage-type traps, but those habituated to human presence will be more easily caught. Alternatively, the use of other trap types (such as leghold traps) usually requires specialised training and may require a significant effort to capture even one individual. If a fox is captured, it must be humanely destroyed and not relocated.

Removal of foxes is usually only a short-term solution as others will quickly immigrate into a vacant territory. The Department for Environment, Food and Rural Affairs (DEFRA), United Kingdom has provided a guide to solutions available to restrict fox damage and nuisance activity in urban areas (Rural Development Service 2005). DEFRA recognises that there is no simple solution to eliminate fox-associated problems in urban areas, but sensible measures may help to minimise such impacts. DEFRA suggests the following recommendations to reduce fox damage in urban environments:

- The most effective deterrent is a suitable perimeter fence (electric or barrier), but fox-proof fences are expensive to install and maintain, and may be unsightly.
- Restrict access to food from domestic pets or animals. Ensure that bird-feeders are high enough to restrict access by foxes (at least 1.5 m). Clean-up any spilled food where pets are fed. Clean-up wind-fallen fruit. Do not intentionally or unintentionally feed foxes.
- Store rubbish (such as food waste and compost) in fox-proof containers and secure lids of rubbish bins.
- Provide secure, fox-proof accommodation for vulnerable animals, especially at night. Foxes are capable climbers and can climb into un-roofed pens. Weld-mesh provides more protection than ordinary chicken wire and cannot be bitten through.
- Human interference will often encourage foxes to leave a site. Filling in excavations as soon as possible after they appear can prevent foxes from moving in where they are not wanted.
- Remove and dispose of all fox (and dog/cat) droppings. Do not handle droppings with bare hands.
- Wash all home-grown fruit and vegetables before consuming them.
- Ensure that dogs and cats are regularly wormed and vaccinated to reduce the potential of parasites and diseases infecting domestic pest.
- Approved chemical repellents may be used to make a particular area unattractive to foxes. They are usually applied directly via spray or brush to affected areas or perimeters of affected areas. Most usually have an unpleasant odour. Examples of repellents that may be suitable for foxes and are available in Australia include the Multicrop range ‘Keep off®’, ‘Scat®’ and ‘Skedaddle®’.

9.4 Regional and local-level management strategies

The Bureau of Resource Sciences (Braysher 1993; Saunders et al. 1995) has outlined four stages of a strategic management program at both the regional and local level.

Problem definition

The problem, if it is real or perceived, needs to be defined. This process will compare the dollar or conservation value of the damage caused by foxes with the benefits received from controlling them. The estimation of environmental costs and benefits is difficult and requires the costing of intangible factors.

An example of the difference between perceived and real problems is noted by Marks (2004), who reports that many people are surprised by the lack of an active eradication campaign for urban foxes in Melbourne. Many people in these areas perceive foxes as a serious pest, but Marks (2004) argues that, apart from some specific situations to conserve wildlife such as the little penguin (*Eudyptula minor*), there would be little benefit from wide-spread control of foxes in Melbourne.

Developing a management plan

The main components of developing a management plan are to establish:

- a set of objectives (interim and long-term goals)
- a timeframe in which to achieve goals
- indicators for measuring performance.

There are several options for the level of control, ranging from local eradication, strategic management, commercial management, crisis management or no management, depending on the situation. Strategic management offers the most flexible option, as it allows for changes in economic, environmental and pest circumstances. Control techniques need to be included in this plan.

Implementing the plan

In order to implement the plan effectively, it is essential to gain broad support for it. Stakeholders should be identified and their involvement and ownership of the plan should be encouraged.

Monitoring and evaluating progress

Monitoring of both the operational (cost effectiveness) and performance (effectiveness of the management plan) components of the plan is essential if changes are to be made, and mistakes rectified.

This approach will allow for the preparation of a dynamic plan that can be adapted for a variety of situations and changing circumstances.

9.5 Property management strategies

Participation in coordinated baiting campaigns for wild dogs and foxes is the most common strategy for the management of foxes at the property level. In situations where this is not appropriate, other suitable control techniques can be available.

These fox control techniques can feed into property management plans, which are generally prepared by landowners for their private use. Therefore as an individual management tool, the level of detail depends on the outcomes to be achieved. The preparation of a property pest management plan is voluntary; however, it can be a requirement of a pest control notice issued under the *Land Protection (Pest and Stock Route Management) Act 2002*.

OnePlan is a state government initiative designed to make it easier for landholders to prepare property management plans. It has been designed primarily for use by individual property owners across a range of industries, but can also be used by natural resource management regional bodies and other community groups.

OnePlan has statutory planning modules, but it also includes voluntary modules such as property pest management plans. The property pest management module can be used to:

- develop a plan for the management of a specific pest (e.g. foxes)
- develop a comprehensive plan for the management of all pests (e.g. weeds and pest animals including foxes and plague pests).

While this module is designed for landholders to develop their own Property Pest Management Plan, consideration should be given to consulting with neighbours and other local people or groups. This will increase the effectiveness of any control methods used and also reduce the risk of new pests emerging and existing pests, such as foxes, spreading.

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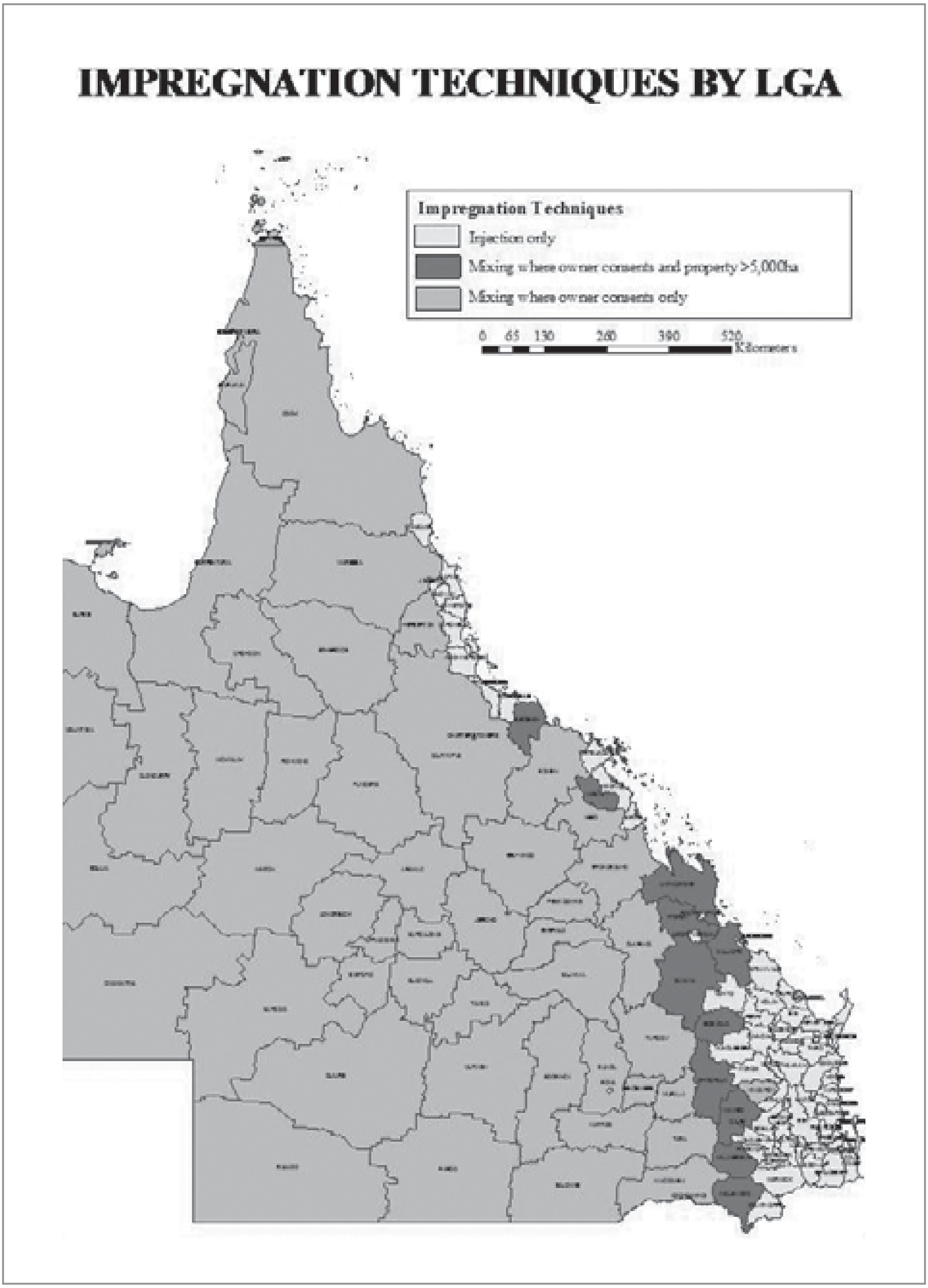
Appendix 1


IMPREGNATION TECHNIQUES BY LGA
Impregnation Techniques
Injection only
Mixing where owner consents and property >5,000ha
Mixing where owner consents only
0 65 130 260 390 520
Kilometers

Appendix 2

Per cent weight and per cent occurrences of all food items recorded in fox stomachs collected in south-western Queensland (Palmer 1995). Unidentified species (unident.)

Food item	Species/order	%Wt	%Occ
Mammal		**63.9**	**79.7**
Dunnart	*Sminthopsis* spp.	<0.1	1.4
Grey kangaroo	*Macropus giganteus*	10.2	16.2
Red kangaroo	*Macropus rufus*	13.5	14.9
Kangaroo unidentified	*Macropus* spp.	3.1	2.7
House mouse	*Mus musculus*	0.9	2.7
Rabbit	*Oryctolagus cuniculus*	10.4	9.5
Fox	*Vulpes vulpes*	<0.1	1.4
Feral pig	*Sus scrofa*	0.6	1.4
Cattle	*Bos taurus*	0.1	1.4
Sheep	*Ovis aries*	25.1	47.3
Bird		**2.1**	**28.4**
Pacific black duck	*Anas superiliosa*	0.2	1.4
Grey teal	*Anas gracilis*	0.8	2.7
Pink-eared duck	*Malacorhynchus membranaceus*	0.3	2.7
Brown goshawk	*Accipiter fasciatus*	0.2	1.4
Australian pratincole	*Stiltia isabella*	<0.1	1.4
Australian kestrel	*Falco cenchroides*	<0.1	1.4
Galah	*Cacatuaa roseicapilla*	0.4	4.1
Mulga parrot	*Psephotus varius*	<0.1	1.4
Barn owl	*Tyto alba*	<0.1	1.4
Richard's pipit	*Anthus novaeseelandiae*	<0.1	1.4
Rufous whistler	*Pachycephala rufivetris*	<0.1	1.4
Double-barred finch	*Poephila bichenovii*	0.1	1.4
Bird unidentified		<0.1	8.1
Cold-blooded vertebrate		**6.2**	**44.6**
Frog		2.1	8.1
Long-thumbed frog	*Limnodynastes fletcheri*	2.0	6.8
Ornate burrowing frog	*Limnodynastes ornatus*	0.1	1.4
Reptile	*Diplodactylus tessellates*	3.6	36.5
Tessellated gecko	*Gehyra varigata*	0.3	13.5
Tree dtella	*Gekkonidae unident*	0.1	5.4
		<0.1	1.4
Central bearded dragon	*Pogona vitticeps*	1.2	4.1
	Pogona spp.	0.1	5.4
	Agamidae unident	0.2	5.4
	Lerista spp.	<0.1	5.4
	Morethia boulengeri	<0.1	1.4
	Ctenotus spp.	<0.1	1.4

Food item	Species/order	%Wt	%Occ
Cold-blooded vertebrate (contd)			
	Elapidae unident	<0.1	1.4
Mulga snake	*Pseudechis australis*	1.6	1.4
Fish		**0.6**	**5.4**
Spangled grunter	*Leiopotherapon unicolour*	<0.1	1.4
Mosquito fish	*Gambusia affinis*	0.4	4.1
Goldfish	*Carissius auratus*	0.2	1.4
Insect		**16.1**	**90.5**
Dragonfly	*Odonata*	<0.1	1.4
Earwig	*Dermaptera*	<0.1	1.4
Grasshopper	*Acrididae*	5.5	73.0
King cricket	*Gryllacrididae*	0.4	16.2
Cricket	*Gryllidae*	7.2	24.3
Shield bug	*Pentatomidae*	<0.1	
Beetle	*Coleoptera*	1.5	50.0
Mantid	*Manidae*	0.1	6.8
Blowfly	*Calliphoride*	0.1	21.6
		<0.1	1.4
Moth and butterfly	*Lepidoptera*	1.2	12.2
Stick insect	*Phasmida*	0.1	4.1
Ant	*Formicidae*	<0.1	10.8
Other Invertebrates		**9.7**	**51.4**
Centipede	*Scolopendromorpha*	2.3	41.9
Wolfspider	*Lycosa* spp.	0.1	17.6
Red-back spider	*Latrodectus mactans*	<0.1	1.4
Scorpion	*Arachnida*	<0.1	8.1
Freshwater crayfish	*Cherax destructor*	7.2	13.5
Slater	*Isopoda*	<0.1	1.4
Plant		**2.0**	**78.4**
Wild tomato	*Solanum* spp.	0.6	17.6
Date palm	*Phoenix dactylifera*	0.2	1.4
Vegetative matter		1.2	71.6
Miscellaneous		**0.1**	**12.2**
Parasites		<0.1	5.4
Sheep faeces		0.1	5.4
Aluminium foil		<0.1	1.4

Appendix 3

Restrictions of baiting campaigns

<table>
<tr><th>Property size</th><th>Permitted forms of baiting</th><th>Distances to infrastructure</th><th>Bait size</th></tr>
<tr><td><5 ha</td><td>No poisons recommended.
No fluoroacetate or strychnine service provided without approval of regional manager</td><td rowspan="3">No baits are to be laid within:
• 5 m of a fenced boundary
• 50 m of the centre line of a declared road
• 2 km of any habitation (including any dwelling other than the owner's, without permission of the owner) or public facility
• 5 km of a town area without LPO approval</td><td rowspan="3">In isolated areas, meat baits should weigh approximately 125 g

In areas of high human population, or where there is a risk of baits being carried away by animals the minimum size should be 250 g

Foxoff® (30 g or 60 g) and De-fox® (24g) may be used in any area</td></tr>
<tr><td>5–40 ha</td><td>Fluoroacetate or strychnine baits can be used at the discretion of the LPO/approved LGO</td></tr>
<tr><td>>40 ha</td><td>Baits impregnated with fluoroacetate as decided by LPO/ approved LGO</td></tr>
</table>

LPO = land protection officer

LGO = local government officer

Other restrictions

- Only landholders or their agents will attend the baiting centre.
- Landholders must give at least 72 hours notice to all landholders whose property boundary is within 2 km of the bait site.
- Landholders must not supply baits to others.
- Landholders must bring a copy of their shire rates notice, showing an accurate property description.
- Landholders must erect warning signs at all entrances to a property being baited. These must be kept for a minimum of one month after baiting

Appendix 4

Species listed on Schedule 1 of the *Endangered Species Protection Act 1992* for which foxes are a known or perceived threat. Species currently known to be in Queensland are highlighted with an asterisk (*). Species with a historic range in Queensland are highlighted with a #.

Known threat		
Scientific name	**Common name**	**Reference**
Birds		
Leipoa ocellate	Malleefowl	Benshemesh (1998)
*Sterna albifrons**	Little tern	Lane et al. (1998)
Mammals		
Dasyurus geoffroii#	Western quoll	Orell and Morris (1994)
Lagorchestes hirsutus	Rufous hare-wallaby	Lundie-Jenkins and Moore (1996)
*Macrotis lagotis**	Greater bilby	Southgate (1997)
Myrmecobius fasciatus	Numbat	Friend (1994)
Perameles gunnii	Eastern barred bandicoot	Driessen and Hocking (1991)
*Petrogale lateralis**	Black-footed rock-wallaby	Hall, GP and Kinnear J (1991)
Potorous longipes	Long-footed potoroo	Nunan et al. (1998)
Reptiles		
*Caretta caretta**	Loggerhead turtle	Biodiversity Group, Environment Australia (1998)
*Chelonia mydas**	Green turtle	Biodiversity Group, Environment Australia (1998)
Perceived threat		
Amphibians		
Philoria frosti	Baw baw frog	Hollis (1997)
Birds		
Geopsittacus occidentalis	Night parrot	Blyth (1996)
Neophema chrysogaster	Orange-bellied parrot	Orange-bellied Parrot Recovery Team (1998)
Pezoporus wallicus flaviventris	Western ground parrot	Burbidge et al. (1996)
*Stipiturus malachurus intermedius**	Mount Lofty southern emu-wren	Littely and Cutten (1994)
*Turnix melanogaster**	Black-breasted button-quail	Smyth (1995)
Mammals		
Pseudomys fieldi	Djoongari	Morris et al. (1997)
Bettongia lesueur	Burrowing bettong	Short and Turner (1993)
*Sminthopsis douglasi**	Julia Creek dunnart	Woolley (1998)
*Bettongia tropica**	Northern bettong	Dennis (1998)
Burramys parvus	Mountain pygmy-possum	Broome (1996)
*Dasycercus cristicauda**	Mulgara	Masters and Baker (1996)
*Dasyuroides byrnei**	Kowari	Lim (1992)
Leporillus conditor	Greater stick-nest rat	Copley (1994)
*Onychogalea fraenata**	Bridled nailtail wallaby	Clancy (1994)
Parantechinus apicalis	Dibbler	Start (1996)
*Petrogale penicillata**	Brush-tailed rock-wallaby	Hill (1991)
Potorous tridactylus gilberti	Gilbert's potoroo	Courtenay et al. (1998)

Known threat		
Scientific name	**Common name**	**Reference**
*Pseudomys oralis**	Hastings river mouse	Smith (1997)
Zyzomys pedunculatus	Central rock-rat	Burbidge et al. (1996)
Reptiles		
Delma impar	Striped legless lizard	Smith and Robertson (1997)
*Dermochelys coriacea**	Leathery turtle	Biodiversity Group, Environment Australia (1998)
Pseudemydura umbrina	Western swamp tortoise	Burbidge and Kuchling (1997)

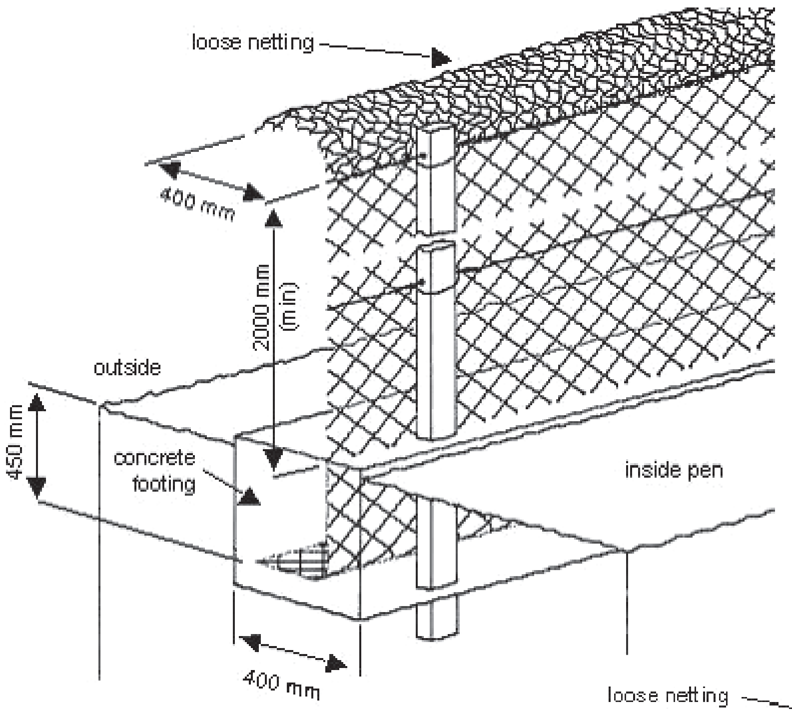
Source: Biodiversity Group, Environment Australia (1999)

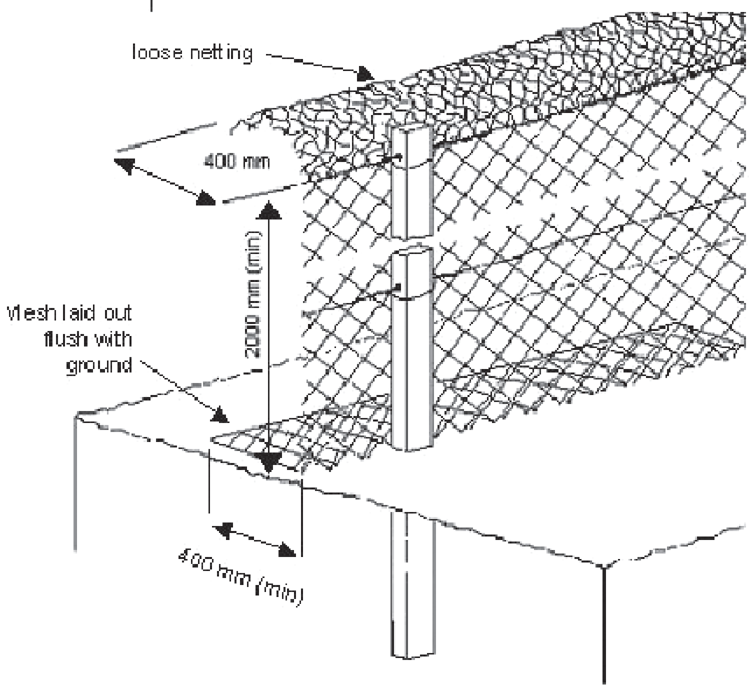
Appendix 5

Exclusion fences—examples of design

Exclusion fences should not use ordinary light- gauge chicken wire, as foxes can bite through this. Stronger gauge netting such as chainwire/chainlink or weldmesh (mesh size not exceeding 80 mm) provides greater protection. The netting should be buried at least 450 mm to prevent foxes from digging underneath. Alternatively, concrete footings, timber sleepers/logs or a skirt of netting can be placed along the surface facing outside the fence. Foxes are capable climbers and barriers such as wire overhangs (loose or tight netting), closely-spaced plain or barbed wire, or outrigged electrified wires should be added to prevent climbing. Smooth barriers such as iron sheeting or plywood hung vertically at the top of the fence can also prevent climbing. Where possible, enclosures should be roofed with strong gauge netting. Fences should be at least 2.0 m high.

Figures 17 and 18 Examples of exclusion fences with skirt netting either buried (Figure 17) or on the surface (Figure 18) suitable for protecting poultry.





Source: S. O'Keeffe, NRW.

Appendix 6

Queensland legislation in addition to the *Land Protection (Pest and Stock Route Management) Act 2002* that may be relevant in fox management practices

Legislation	Relevance
Animal Care and Protection Act 2001	Provisions for welfare of animals including humane dispatch of animals
Animal Care and Protection Regulation 2002	
Weapons Act 1990	Weapons licensing for firearms and other use of weapons
Weapons Regulations 1996	
Stock Act 1915	Disease control
Exotic Diseases in Animals Act 1981	
Stock Regulation 1988	
Dividing Fences Act 1953	Construction and repair of exclusion fencing
Nature Conservation Act 1992	Pest animal control in protected areas
Nature Conservation Regulation 1994	Use of vertebrate pesticide in protected area
Health Act 1937	Administration of the manufacture, sale and use of drugs and poisons
Health (Drugs and Poisons) Regulations 1996	
Workplace Health and Safety Act 1995	Health and safety obligations when undertaking control operations
Workplace Health and Safety Regulation 1997	
Criminal Code Act 1899	Transport of weapons