Approved - NSW THREAT ABATEMENT PLAN

Predation by the red fox *(Vulpes vulpes)*

NSW
NATIONAL
PARKS AND
WILDLIFE
SERVICE

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Cover photos: red fox (*Vulpes vulpes*), malleefowl (*Leipoa ocellata*), rufous bettong (*Aepyprymnus rufescens*), little tern (*Sterna albifrons*) with nest and yellow-footed rock wallaby (*Petrogale xanthopus*).

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EXECUTIVE SUMMARY

Predation by the red fox (*Vulpes vulpes*) was listed as a key threatening process under the New South Wales *Threatened Species Conservation Act 1995* in March 1998. Under the Act, the National Parks and Wildlife Service must produce a threat abatement plan which proposes actions to reduce the impacts of fox predation on threatened species and to help conserve biodiversity more generally. This document constitutes the NSW threat abatement plan for predation by the red fox.

Since their introduction into Australia in the 1870s, foxes have contributed to significant declines in the distribution and abundance of a suite of native fauna, particularly among medium-sized ground-dwelling and semi-arboreal mammals, ground-nesting birds and chelid tortoises. Recent experimental studies have also shown that predation by foxes continues to suppress remnant populations of several such species. However, fox predation may have little or no impact on some populations of native prey, including some small mammal populations in dense microhabitats. Given limited resources, fox control for the conservation of native fauna must be prioritised to focus on those species for which the population-level impacts are likely to be greatest. Resources can then be directed to ensure that the resultant fox control programmes are effective in reducing these impacts.

This plan provides a strategy for fox control for the conservation of native fauna in New South Wales. In particular, it identifies those threatened species which are most likely to be impacted by fox predation and the sites at which fox control for these species is most critical. Establishing collaborative fox control programmes across all land tenures at these priority sites is the core action of the plan.

In addition, the plan identifies best-practice methods for fox control which aim to maximise the effectiveness of control programmes while minimising their impacts on non-target species. Research actions to refine these methods are identified.

Finally, the plan outlines experiments to measure the response of threatened species to fox control. The main objective of these experiments is to test critically whether populations of threatened species targeted for fox control in this plan are limited by fox predation. These experiments are necessary to justify ongoing fox control targeting these species. Where impacts are established, subsequent experiments can be used to measure the effectiveness of specific management strategies. Experiments will be established by monitoring threatened species and fox populations in parallel with fox control at priority sites. Where possible, selected priority sites will be left unmanipulated as experimental controls. Additional experiments to measure interactions between logging and fox predation on native fauna will be undertaken to refine the prioritisation of predator control in State Forests.

The selection of priority sites is determined by particular threatened species, however, many common species will also benefit from the fox control programmes outlined in the plan. In particular, the increased frequency and scale of fox control highlighted in the best-practice guidelines is likely to result in more effective fox control for all native fauna at risk from fox predation. Where possible, selected common fauna will be monitored as a measure of the additional benefits of fox control at priority sites.

This threat abatement plan will be implemented over a five-year period. Subsequent analysis of data from the monitoring programmes will allow both the priorities for fox control to be reviewed and the methods employed in fox control to be refined. Actions identified in the plan will be undertaken by the New South Wales National Parks and Wildlife Service, State Forests of New South Wales, and the New South Wales Department of Lands and Water Conservation.

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1 INTRODUCTION

At least 54 species of vertebrates have gone extinct in Australia since European settlement, while many others have suffered marked reductions in their distribution and abundance. Predation by the red fox has been proposed as an important mechanism which has contributed to these declines (Burbidge and McKenzie 1989, Morton 1990, Dickman *et al*. 1993, Smith and Quin 1996).

The impacts of fox predation on native fauna appear to have been greatest on medium-sized (450-5000g) ground-dwelling and semi-arboreal mammals, ground-nesting birds and chelid tortoises (Dickman 1996a). The most apparent evidence of these impacts is where local and regional extinctions of native fauna coincided with the arrival of foxes. Thus, the spread of foxes across southern Australia was associated with declines in the distribution of a suite of medium-sized ground-dwelling mammals, including the brush-tailed bettong, burrowing bettong, rufous bettong, Tasmanian bettong, greater bilby, numbat, bridled nailtail wallaby and the quokka (Christensen 1980, Schlager 1981, Friend 1990, Southgate 1990, Fisher 1998, Short 1998). Many of these species now persist only on islands or areas of the mainland where foxes are rare or absent. Local declines in semi-arboreal species, particularly brush-tailed and western ringtail possums, occurred with the establishment of foxes in forest areas in south-west Western Australia (Christensen 1980). In addition, predator-removal experiments have demonstrated that foxes continue to suppress extant populations of several species of rock-wallabies, eastern grey kangaroos, brush-tailed bettongs, numbats and Murray river tortoises (Saunders *et al*. 1995, Friend 1996, Kinnear *et al*. 1998, Banks *et al*. 2000, Sharp 2000, Spencer 2000). Observations of high mortality due to fox predation on eggs in ground-nesting birds provide evidence of significant impacts on these species (Frith 1959, NPWS 2000).

In contrast, fox predation may have no significant impacts on some prey populations. For example, in a predator-removal experiment conducted in subalpine Australian Capital Territory, the abundance and survival rates of bush rats did not increase with fox removal despite the regular occurrence of rats in the diet of foxes (Banks 1999). Fox predation on rats may have been compensatory, in that it was a proximate source of mortality only and had no net effect on populations (Errington 1946). Additionally, predation may have been a minor source of mortality compared to other factors. Nevertheless, the impacts of fox predation on most native species remain unknown.

At present, fox control for the conservation of native fauna is undertaken in many areas of NSW, on both public and private lands. However, many of these programmes do not clearly identify the prey species that are expected to benefit from fox control. Where target prey species are identified, an objective basis for proposing that fox predation is a limiting factor for populations of these species has not always been provided. In particular, the observation of a species in the diet of foxes (e.g. via faecal analysis) does not imply that mortality due to fox predation is high, or that a significant population-level effect exists.

Furthermore, the effectiveness of many existing fox control programmes in reducing the impacts of foxes is unclear. Fox control rarely results in the removal of all individuals, while new foxes may immigrate rapidly into target areas. Many control programmes are undertaken infrequently (e.g. 1-2 per year) and are localised to small areas where target prey species occur. The effectiveness of such programmes is likely to be compromised by the rapid immigration of foxes into control areas (e.g. Priddel and Wheeler 1997).

The New South Wales Threat Abatement Plan for Predation by the Red Fox (*Vulpes vulpes*) (NSW Fox TAP) recognises that there are insufficient resources to control foxes effectively in all areas where they coexist with native fauna. Thus the plan aims to direct fox control to areas where impacts on threatened species are likely to be greatest and to ensure that the resultant programmes are effective in reducing such impacts. Fox removal experiments will be used to measure the impact of fox predation on threatened species; thus providing feedback on the species targeted by control programmes. Where impact has been established, removal experiments can then be used to measure the effectiveness of ongoing fox management strategies.

Following an outline of the legislation relevant to the plan in Section 2, the biology of the red fox is summarised in Section 3. Section 4 provides a brief discussion of the impacts of foxes on native and introduced prey populations in Australia. In Section 5, the specific objectives of the plan are developed and actions necessary to achieve these objectives are proposed. Section 6 discusses the social and economic impacts of the plan, while Section 7 discusses alternative management actions to those proposed in the plan. Section 8 provides a summary of actions proposed in the plan, identifies the agencies involved in their implementation and provides an estimate of costs.

2 RELEVANT LEGISLATION, PROGRAMMES AND STRATEGIES

The control of foxes in NSW is subject to a range of Commonwealth and State legislation governing both how and why fox control is undertaken. These Acts and related strategies are outlined below.

2.1 NSW legislation and strategies

2.1.1 Threatened Species Conservation Act 1995

The main objective of the *Threatened Species Conservation Act 1995* (TSC Act) is to conserve biological diversity and, in particular, to recover threatened species, populations and ecological communities so that their long-term survival in nature can be assured. This involves eliminating or managing ecological processes that threaten the survival or evolutionary development of such species.

One of the key mechanisms provided in the TSC Act to achieve this goal is the listing of *key threatening processes*. A threatening process is eligible to be listed as a key threatening process if, in the opinion of the Scientific Committee, it:

a) adversely affects two or more threatened species, populations or ecological communities, or
b) could causes species, populations or ecological communities that are not threatened to become threatened.

Under the TSC Act, the NSW National Parks and Wildlife Service (NPWS) is required to prepare a threat abatement plan to manage the threatening process so as to abate, ameliorate or eliminate the adverse impacts of the process on threatened species, populations or ecological communities.

Once a threat abatement plan has been approved, the TSC Act requires Ministers and public authorities to take any appropriate action available to them to implement the measures included in the plan for which they are responsible. Furthermore, they must not make decisions that are inconsistent with the provisions of the plan. A public authority identified in a plan as responsible for the implementation of particular measures must report to Parliament on actions taken by it to implement those measures.

Predation by the European red fox was the first process to be listed as a key threatening process under the TSC Act.

2.1.2 National Parks and Wildlife Act 1974

The *National Parks and Wildlife Act 1974* (NPW Act) establishes the NSW National Parks and Wildlife Service and provides for the establishment and management of conservation reserves, including national parks and nature reserves, and the protection of certain fauna, native plants and Aboriginal relics.

The NPW Act requires the NPWS to arrange for the carrying out of works considered necessary for the management or maintenance of every national park, historic site, state recreation area, regional park, nature reserve, karst conservation reserve and Aboriginal area. Pest management activities, including fox control, are included in such works.

The NPW Act also requires the preparation of a plan of management (POM) for each reserve managed by the NPWS. The conservation of wildlife, including the conservation of threatened species, populations and ecological communities and their habitats is a goal of each POM. Thus, a POM provides a process for examining the occurrence and distribution of various pest species, investigating management strategies and setting priorities for pest control programmes.

2.1.3 The Forestry and National Park Estate Act 1998

The *Forestry and National Park Estate Act 1998* (FNPE Act) requires the preparation of Integrated Forestry Operation Approvals (IFOAs) for all State Forests and other Crown-timber lands in New South Wales. These IFOAs allow for State Forests to conduct specified forestry activities, e.g. harvesting and on-going forest management operations, that give effect to the principles of ecologically sustainable forest management. Each IFOA contains three Licenses, one of which is the Terms of License under the TSC Act 1995 which sets out habitat protection measures to be implemented across the State Forests of NSW (SFNSW) Estate. Under Condition 8, Schedule 7, SFNSW is required to prepare a Draft Feral and Introduced Predator Plan for the Estate that will give rise to a series of local area plans aimed at mitigating the threat to native species by fox predation.

2.1.4 Environmental Planning and Assessment Act 1979

Land use within New South Wales is primarily regulated by the *Environmental Planning and Assessment Act 1979* (EP&A Act). The EP&A Act seeks to encourage ecologically sustainable development by managing the development process and the effects of development on the environment.

It is the requirement of the NPWS that all activities (including pest control) proposed on NPWS land are assessed under Part 5 of the EP&A Act. This involves an assessment of whether the activity is likely to significantly affect the environment, including threatened species, populations and ecological communities, and their habitats. The mechanism to carry out this assessment is generally regarded as a *review of environmental factors*. Where a significant effect is likely, the EP&A Act requires the preparation of an *environmental impact statement* and in the case of a significant effect on threatened species, populations or ecological communities, a *species impact statement*.

2.1.5 Local Government Act 1993

The *Local Government Act 1993* (LG Act) defines the powers, duties and functions of all local councils in New South Wales. The Act provides a framework for the use and management of council-managed public land, known as *community land*. The LG Act requires councils to use and manage community land in accordance with a plan of management, prepared by the council. Where a threat abatement plan requires a council to implement certain measures on or in respect to the land, the plan of management must:

- state that the land, or relevant part, is affected by a threat abatement plan; and
- identify objectives and performance targets that take account of the council's obligations under the threat abatement plan.

2.1.6 Pesticides Act 1999

The *Pesticides Act 1999* regulates and controls the use of pesticides within NSW. Under the Act, it is illegal to possess, prepare for use or use a pesticide in NSW unless it is registered by the National Registration Authority (NRA) or covered by an NRA permit issued under the Commonwealth *Agricultural and Veterinary Chemical Code Act 1994*. The Pesticides Act requires strict adherence to label instructions when using a registered pesticide.

The Pesticides Act also makes it an offence to use a pesticide in a way that harms any non-target animal or plant. A defence against prosecution is provided where a person takes all reasonable precautions and exercises all due diligence when using the pesticide and the offence was due to causes beyond the person's control.

The use of sodium monofluoroacetate, commonly referred to as 1080, in fox baits is regulated by the *Pesticides Act 1999*. Fox baiting can be carried out only under the conditions specified in the current Off-label Permits for possession, preparation, supply and use of 1080 products issued under the *Agricultural and Veterinary Chemical Code Act 1994*.

2.1.7 Rural Lands Protection Act 1998

The *Rural Lands Protection Act 1998* (RLP Act) provides for the protection of rural lands. The RLP Act repeals the *Rural Lands Protection Act 1989*. Under the RLP Act, occupiers of land have a duty to fully and continuously suppress and destroy by any lawful method (or other specified method) all animals on their land which have been declared as pests in a Pest Control Order. Pest Control Orders are made by the Minister for Agriculture and may declare any animal within the animal kingdom (except humans) as a pest and describe any land to which the order applies. The fox has not been declared a pest by the Minister for Agriculture under the RLP Act but it is possible that, in the future, a Pest Control Order could be prepared to declare the fox a pest animal in a local area.

2.1.8 NSW Biodiversity Strategy

The NSW Biodiversity Strategy was released in 1999. The goal of the Strategy is to protect the native biological diversity of NSW and maintain ecological processes and systems. The Strategy provides a policy framework for ensuring that the objects of the TSC Act are achieved.

The Strategy calls for the effective management of pest animals. Actions in the Strategy include:

- increase and improve coordination of research on methods to control pest animal populations (including foxes);
- continue enhancement of cooperative pest animal control programmes targeting areas with threatened species, conducted with the closest practical involvement of relevant community groups; and

- review current practices and monitor the success of pest animal control programmes to ensure the cost effective use of resources.

2.1.9 *NSW Pest Animal Council Policy on the Management of Foxes*

The NSW Pest Animal Council provides advice to the Minister for Agriculture on all issues relating to the management of vertebrate pests, including foxes. The goal of the Council is: *To promote humane, environmentally, economically and socially acceptable pest control through the adoption of well coordinated best practice programmes*. The Pest Animal Council will shortly be preparing a policy for the statewide management of foxes. This policy will address the management of foxes to abate the threats they pose to agricultural and natural ecosystems. The Pest Animal Council provided advice during the preparation of the NSW Fox TAP. It is envisaged that the Council policy on foxes will embrace the conservation objectives of the NSW Fox TAP.

2.2 National legislation and programmes

2.2.1 *Environment Protection and Biodiversity Conservation Act 1999*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) commenced on 16 July 2000. The EPBC Act repeals the *Environment Protection (Impact of Proposals) Act 1974*, the *Endangered Species Protection Act 1992*, the *National Parks and Wildlife Conservation Act 1975*, the *World Heritage Properties Conservation Act 1983*, and the *Whale Protection Act 1980*. The EPBC Act provides a framework for the environmental assessment and approval of actions that are likely to have a significant impact on a matter of *national environmental significance*. Matters of *national environmental significance* are world heritage properties, Ramsar wetlands of international importance, nationally threatened animal and plant species and ecological communities, internationally protected migratory species, Commonwealth marine areas, and nuclear actions.

Consequently, fox control activities that are likely to have a significant impact on a matter of national environmental significance may require approval from the Commonwealth Minister for the Environment and Heritage. The EPBC Act does not over-ride State assessment processes. Both State and Commonwealth legislation must be complied with prior to carrying out an action that may require both State and Commonwealth approval.

The EPBC Act provides for the listing of threatened species and ecological communities, and key threatening processes.

2.2.2 *National threat abatement plan for predation by the European Red Fox*

Predation by the European red fox was listed as a key threatening process under Schedule 3 of the recently repealed *Endangered Species Protection Act 1992* (ESP Act). The ESP Act required the preparation and implementation of a threat abatement plan to coordinate nationally the management of the impact of fox predation on native wildlife (Commonwealth Fox TAP).

The Commonwealth Fox TAP provides a strategy to reduce the impact of fox predation on native wildlife. The plan seeks the cooperation of the States and Territories in the implementation of the plan and describes in broad terms the scope for national action and the allocation of Commonwealth resources.

The NSW Fox TAP addresses all of the relevant objectives listed in the Commonwealth Fox TAP:

Objective 1. Promote the recovery of species and ecological communities that are endangered or vulnerable as a result of fox predation.

Objective 3. Improve the effectiveness and humaneness of fox control methods.

Objective 4. Improve knowledge and understanding of fox impacts and interactions with other species.

Objective 6. Effectively coordinate fox control activities.

2.2.3 *National Feral Animal Control Programme*

The National Feral Animal Control Programme is an initiative funded by the Natural Heritage Trust. The goal of the programme is to ensure the effective management of the impact of feral animals on the natural environment and on primary production. The programme's national goal is to develop strategic approaches to the management of the impacts of nationally significant feral animals. The programme seeks to achieve this goal by:

- the production and implementation of threat abatement plans for key threatening processes caused by feral animals;
- the development of new techniques and technologies that will allow land managers to control feral animals;

- setting priorities for future work based on improved knowledge of feral animal management; and
- the strategic assessment of the status, nature and scale of the impact of feral animals leading to best practice management.

2.2.4 Endangered Species Programme

The Endangered Species Programme is funded by the Natural Heritage Trust. The national goal of the programme is to conserve Australia's native species and ecological communities in the wild. National outcomes of the programme include the abatement of nationally listed key threatening processes, by coordinating and integrating with the National Feral Animal Control Programme.

2.2.5 Agricultural and Veterinary Chemicals Code Act 1994

All pesticide products, including the vertebrate pesticide 1080, have to be registered under the *Agricultural and Veterinary Chemicals Code Act 1994* by the National Registration Authority (NRA). Before registering any product, the NRA is required to conduct a rigorous assessment of potential impacts of the pesticide on the environment, human health and trade, and of the likely effectiveness of the pesticide for its proposed uses. Baiting can be carried out only under the conditions specified in the current Off-label Permits for possession, preparation and supply and use of 1080 products for fox control.

3 THE BIOLOGY OF THE RED FOX

3.1 Description

The red fox (*Vulpes vulpes*) is a medium-sized (4000-8300 g) canid, most closely related in Australia to the dingo and the domestic dog (Coman 1995). Like most other canids, it has an elongated muzzle, long erect ears and non-retractable claws on its feet. It is reddish-brown with black above and white chest and belly (Coman 1995). It is distributed widely across Eurasia, Africa, Australia and North America, but it is absent from much of the tropics (Jarman 1986).

3.2 Introduction and distribution in Australia

Foxes were probably first introduced successfully into Victoria in 1871, although several earlier releases in Australia have been reported (Rolls 1969). Once established, they spread rapidly across the continent following the spread of the European rabbit (Rolls 1969). By the 1880s they occurred over much of Victoria and parts of South Australia. They had invaded NSW by 1893, reaching southern Queensland by 1907 and Western Australia by 1911 (Rolls 1969, Lever 1985, Jarman 1986). Foxes are now distributed widely across the Australian mainland, being absent only in the far north of the continent, Tasmania and most other offshore islands (Saunders *et al*. 1995).

Foxes are found in most habitats in Australia, including alpine areas (Green and Osborne 1981, Bubela 1995), deserts (Marlow 1992, Mahon 1999), forests (Catling and Burt 1995), coastal heathlands (Phillips and Catling 1991, Dexter and Meek 1998) and urban environments (Wallis *et al*. 1996, Marks and Bloomfield 1999). However, they are probably most abundant in agricultural areas with patches of uncleared vegetation, because these areas provide abundant food, cover and denning sites (Saunders *et al*. 1995). In contrast, foxes appear to be rare in closed forest distant from cleared land (Jarman 1986, Catling and Burt 1995). Whether high numbers of dingoes and wild dogs in these habitats play a role in reducing fox activity is not known (Catling and Burt 1995).

3.3 Reproduction, social organisation and movement patterns

Foxes show considerable flexibility in their reproductive, grouping and ranging behaviour reflecting variation in the density and dispersion of resources (e.g. Englund 1970, Voigt and Macdonald 1984, von Schantz 1984, Zimen 1984, Lindström 1988, Zabel and Taggart 1989, Saunders *et al*. 1993). They may live as individuals, breeding pairs or extended social groups, often occupying non-overlapping contiguous areas (Sargeant 1972, Voigt and Macdonald 1984, Reynolds and Tapper 1995). However, the link between home ranges and defended territories is unclear (Newsome 1995). Females are monoestrous, with breeding occurring in winter and early spring. Litter sizes of 1-12 have been recorded, but 3-6 is typical (McIntosh 1963, Englund 1970, Storm *et al*. 1976). Both sexes reach sexual maturity in the first year (McIntosh 1963, Ryan 1976), with dispersal common in late autumn (Phillips *et al*. 1972, Storm *et al*. 1976, Voigt and Macdonald 1984, Zimen 1984). Starvation, disease, predation by other canids and birds of prey, and human persecution are important proximate causes of mortality (Phillips *et al*. 1972, Storm *et al*. 1976, Lindström 1992, Reynolds and Trapper 1995). However, abundance is limited generally by the density and dispersion of resources, mediated through their effects on reproductive and spacing behaviour (Lindström 1989, Newsome *et al*. 1997).

In resource-rich habitats such as urban and rural areas, foxes often live in groups consisting of a dominant breeding pair and several subordinate, related females (e.g. Macdonald 1979, 1980, von Schantz 1981, Adkins and Scott 1998). Home ranges are small, typically 0.25-3 km^2 (e.g. Doncaster and Macdonald 1991, Saunders *et al*. 1993, Meia and Weber 1995). Subordinate females rarely breed successfully (e.g. von Schantz 1981), but may help to raise the cubs of the dominant female (Macdonald 1979, 1980). When resources are super-abundant, polygamy may occur (Zabel and Taggart 1989). Dispersal is high among subadult males, but females often remain in their natal ranges (Storm *et al*. 1976, von Schantz 1981, Voigt and Macdonald 1984).

In contrast, in habitats where resources are less abundant, breeding pairs and individual animals predominate (Sargeant *et al*. 1987, Phillips and Catling 1991). Home ranges of resident animals are larger (often > 10 km^2; Jones and Theberge 1982, Major and Sherburne 1987, Sargeant *et al*. 1987) and there is a greater proportion of transient animals in the population (Zimen 1984, Newsome 1995). Dispersal is common among both male and female subadults, with few vixens remaining in natal areas (Zimen 1984).

In habitats where resources fluctuate temporally, reproductive and grouping behaviour vary accordingly (Englund 1970, Lindström 1980, von Schantz 1984). For example, in northern Fennoscandia, multiannual fluctuations in rodent populations result in dramatic changes in food availability for their predators between years (Stenseth and Ims 1993, Korpimäki and Krebs 1996). In foxes, the proportion of adult females breeding and mean litter size fluctuate with prey abundance (Englund 1970, Lindström 1988; but see Newsome 1995). Dispersal among subadult females also varies, with more subadult females remaining within their natal range when prey are abundant (Lindström 1980, von Schantz 1984). However, ranging behaviour appears to be governed by the density of resources during periods of scarcity, such that home range size of resident animals does not vary between years (Lindström *et al*. 1982, von Schantz 1984). Similar effects on reproduction, grouping and ranging behaviour have been observed in habitats where annual resource shortages occur over winter (Jones and Theberge 1982, Voigt and Macdonald 1984, Meia and Weber 1995).

In Australia, foxes breed from July to October, with a peak in breeding activity in August (McIntosh 1963, Ryan 1976). The average litter is approximately four, although up to 10 young have been recorded (McIntosh 1963, Ryan 1976). Estimates of home range sizes vary from 0.6 km^2 in urban areas (Coman *et al*. 1991) to > 24 km^2 in arid areas (Mahon 1999). Group living has been recorded in one study in a resource-rich alpine area (Bubela 1995), but other studies suggest that breeding pairs and individuals predominate (Coman *et al*. 1991, Phillips and Catling 1991, Marlow 1992, Banks 1997, Meek 1997). It is unclear how the reproductive, grouping and ranging behaviour in Australian foxes respond to fluctuations in food resources but it is likely that the flexibility observed in Northern Hemisphere populations also occurs in Australia (Marlow 1992, Newsome *et al*. 1997, Mahon 1999).

3.4 Diet

Foxes are omnivorous. They take a wide range of vertebrate and invertebrate prey, carrion, plant material such as fruits and human refuse (see Newsome *et al*. 1997 for a review). However, across much of Europe and North America, lagomorphs (rabbits and hares) and rodents dominate the diet (Halpin and Bissonette 1988, Theberge and Wedeles 1989, Weber and Aubry 1993, Lindström 1994, Reynolds and Tapper 1995), and several studies have found that foxes prey selectively on these taxa (Doncaster *et al*. 1990, Jedrzejewski and Jedrzejewska 1992).

Similarly, in Australia, rabbits dominate the diet of foxes where the two species coexist (Coman 1973, Croft and Hone 1978, Catling 1988), and both the local and continental distribution of foxes is linked to the presence of rabbits (Saunders *et al*. 1995). House mice and *Rattus* species are major dietary items when they are abundant (Coman 1973, Mahon 1999). Sheep are an important dietary component for foxes in agricultural areas (Coman 1973, Croft and Hone 1978, Lugton 1993).

Although native fauna typically constitute only a minor part of the diet of foxes where rabbits are available (Newsome *et al*. 1997), impact on these species may be significant (Pech *et al*. 1995; Section 4). Among native taxa, ground-dwelling mammals, particularly macropods, *Rattus* and *Antechinus* species, occur frequently in the diet (Green and Osborne 1981, Triggs *et al*. 1984, Lunney *et al*. 1990). Foxes are capable of taking these prey up to the size of juvenile eastern grey kangaroos (Banks *et al*. 2000). Semi-arboreal species, such as ringtail and brushtail possums, may be common in the diet in forest environments (Triggs *et al*. 1984, Meek and Triggs 1998). Birds and reptiles are typically supplementary prey; they occur infrequently in the diet in most areas (Newsome *et al*. 1997). However, predation on the eggs of turtles and ground-nesting birds can be substantial (Frith 1959, Thompson 1983). Invertebrates may dominate the diet sometimes (Green and Osborne 1981, Mahon 1999).

3.5 Disease

Foxes may carry a number of important parasites and diseases including mange, hydatids and rabies. In northern Europe, widespread declines in fox populations due to the mange mite *Sarcoptes scabiei* have been observed (Lindström 1992), resulting in population increases in a range of prey species (Lindström *et al*. 1994). In Australia, mange has been associated with high juvenile mortality in foxes in one study (Bubela *et al*. 1998), but there is little other evidence that it limits fox populations generally. Foxes may assist in the transmission of mange to other animals including dogs and wombats.

Foxes are a major vector for rabies in the Northern Hemisphere (Lloyd 1980), and several studies have assessed the potential to control the spread of the disease by foxes in Australia if it were introduced (Fleming 1997, Marks and Bloomfield 1999). However, the probability of rabies being introduced to Australia at present is low (Saunders *et al*. 1995).

The occurrence of hydatids in foxes in rural Australia is low and thus it is unlikely that foxes play a significant role in the cycling of the disease in these areas (Saunders *et al*. 1995).

3.6 Interactions with other canids

There has been considerable speculation about the role of dingoes and wild dogs in excluding foxes from some areas of Australia, and the consequent benefits this may have had for native fauna. However, there is no direct evidence that dingoes exclude foxes, other than the observation that foxes do not persist in some areas where dingoes are abundant (Catling and Burt 1995). In North America, several studies have shown that habitat use in foxes is restricted by coyotes, with fox activity being concentrated on the boundary of coyote ranges (Major and Sherburne 1987, Sargeant *et al*. 1987, Harrison *et al*. 1989). In particular, coyotes may dominate access to preferred prey when food is scarce (Theberge and Wedeles 1989). While coyotes may thus limit fox densities (Major and Sherburne 1987, Sargeant *et al*. 1987), foxes are able to persist due to considerable flexibility in their diet and habitat requirements (Harrison *et al*. 1989, Theberge and Wedeles 1989). It is probable that dingoes similarly limit but do not exclude foxes from some areas of Australia.

4 THE IMPACT OF FOX PREDATION ON NATIVE AND INTRODUCED SPECIES IN AUSTRALIA

At least 54 species of vertebrates have gone extinct in Australia since European settlement, while many others have suffered marked reductions in distribution and abundance (EPBC Act 1999 Schedules, as amended 27 April 2001). Declines have been most severe among small to medium-sized (35-5500 g) ground-dwelling mammals (Burbidge and McKenzie 1989, Morton 1990, Dickman *et al*. 1993), although significant declines in amphibians and birds have also been reported (Smith *et al*. 1994, Campbell 1999). Clearing of native vegetation, competition and habitat degradation from introduced herbivores, changed fire regimes, the introduction of exotic diseases and predation by exotic carnivores have been proposed as factors contributing to the demise of native fauna (Burbidge and McKenzie 1989, Morton 1990, Dickman *et al*. 1993, Smith *et al*. 1994, Dickman 1996a, Smith and Quin 1996).

The role of foxes in the decline of native fauna is most apparent where local and regional extinctions coincided with the establishment of foxes. Thus the spread of foxes across southern Australia coincided with declines in the distribution of a suite of medium-sized ground-dwelling mammals, including the greater bilby, brush-tailed bettong, burrowing bettong, rufous bettong, Tasmanian bettong, numbat, bridled nailtail wallaby and the quokka (Christensen 1980, Schlager 1981, Friend 1990, Southgate 1990, Fisher 1998, Short 1998). Many of these species now persist only on islands or areas of the mainland where foxes are rare or absent. Local declines in semi-arboreal species, particularly brushtail and western ringtail possums, occurred with the establishment of foxes in forest areas in south-west Western Australia (Christensen 1980). Further declines in brush-tailed bettongs, numbats and other ground mammals occurred in this area in the 1970s, coinciding with increased fox numbers following the cessation of 1080 baiting for rabbits. Losses were greatest in woodland areas with minimal understorey (Christensen 1980).

Attempts to reintroduce native species into areas of their former range provide further evidence of the role of foxes in the decline of native fauna. In a review of reintroduction programmes for macropods, Short *et al*. (1992) concluded that the failure of many programmes was attributable to the presence of exotic predators, especially foxes. On islands without exotic predators, 82 % (9 from 11) of reintroductions reviewed were successful, compared to only 8 % (1 from 13) at mainland or island sites where these predators were present (Short *et al*. 1992). Recent attempts to re-establish species at mainland sites have proved more successful with effective predator control. Thus, the control or exclusion of exotic carnivores has seen successful reintroductions of brush-tailed bettongs, burrowing bettongs, numbats, golden bandicoots and bridled nailtail wallabies at mainland sites (Christensen and Burrows 1994, Friend and Thomas 1994, Short *et al*. 1994, Fisher 1998, CRC 1999). In particular, experiments have demonstrated that survival in translocated brush-tailed bettongs is increased by frequent fox control (CRC 1999). The success of reintroduction programmes may be enhanced further if animals are introduced into habitat with high structural complexity which provides refuge against predation (Short *et al*. 1992, Dickman 1996a).

In areas where native fauna coexist with foxes, the impacts of fox predation have been demonstrated using fox-removal experiments. In the Western Australian wheatbelt, replicated removal experiments showed that foxes were suppressing remnant populations of black-footed rock wallabies, thereby increasing the likelihood of local extinction (Kinnear *et al*. 1988, 1998). Populations of rock wallabies increased to 6.4 and 5.0 times their initial densities after eight years of fox control at each of two sites. At sites without fox control, populations either increased marginally, decreased or declined to extinction (Kinnear *et al*. 1998). In sub-alpine ACT, replicated removal experiments showed that fox predation limited survival in juvenile grey kangaroos, resulting in reduced population growth (Banks *et al*. 2000). In the absence of fox control, the proportion of females with young declined by 50% during the period when young were emerging from the pouch. At sites where fox numbers had been reduced, no such decline was evident (Banks *et al*. 2000).

In other, unreplicated experiments, counts of yellow-footed rock wallabies increased six-fold over 4 years of fox control at one site in western New South Wales, but showed no increase at another site where foxes were not baited (Sharp 2000). In Dryandra woodland in south-west Western Australia, sightings of numbats increased in an area where foxes were baited relative to an adjacent unbaited site (Friend 1990). Increases occurred throughout both areas when baiting was extended over the entire reserve (Friend 1996). Substantial increases in capture rates of brush-tailed bettongs were also observed following baiting of the Dryandra site (Kinnear *unpublished*, Christensen *unpublished* in Friend 1996). On Dolphin Island off north-west Western Australia, sightings of Rothschild's rock wallabies increased nearly 30-fold from low levels following fox control. On the adjacent fox-free island of Enderby, the abundance of wallabies was high and unvarying over the same period (Kinnear *unpublished* in Saunders *et al*. 1995). In uncontrolled comparisons, increased numbers of brush-tailed bettongs, tammar wallabies, brush wallabies and brushtail possums were observed following fox control at Tutanning and Boyagin forest reserves in south-west Western Australia (Kinnear 1990). On the Beecroft Peninsula in coastal New South Wales, sightings of ringtail possums more than doubled following fox control; long-nosed bandicoots and bush rats, which had not been observed previously in the area, became abundant (Dexter *et al*. 2001).

For other native mammals, the evidence for population-level impacts of fox predation is largely circumstantial. In an historical analysis of the decline of brush-tailed rock wallabies in New South Wales, Lunney *et al*. (1995) concluded that the initial widespread decline of the species was caused primarily by hunting, with predation by foxes increasing the rate of decline in some regions. In particular, declines in rock wallabies preceded the arrival of foxes in some areas. However, with the cessation of legalised hunting, the recovery of rock wallabies was prevented by a range of factors including fox predation; the impact of these factors was enhanced by fragmentation of habitat (Lunney *et al*. 1995). Similarly, in reviewing their current distribution, Short and Milkovits (1990) noted that rock wallabies were most abundant in areas where the impacts of foxes were probably minimal. On a local scale, rock wallabies show a preference for sites which provide refuge from terrestrial predators (Short 1982). However, preliminary data from fox-removal experiments to measure the impacts of fox predation on populations of brush-tailed rock wallabies are inconclusive (Rummery *et al*. 2000).

The impact of foxes on some mammalian prey has been surmised through indirect measures of predation mortality. For example, Mahon (1999) presented data on the functional and numerical response of foxes to a rain-induced eruption of a population of long-haired rats in the northern Simpson Desert. Following the eruption, per capita mortality due to fox predation increased as rodent numbers declined. Thus it was proposed that fox predation may have accelerated the decline of rodent numbers following eruption, resulting in localised extinctions in refuge habitat (Mahon 1999). In studies in alpine New South Wales, Green and Osborne (1981) and Bubela *et al*. (1998) observed that foxes preyed preferentially on broad-toothed rats over other, more-abundant rodent species. Where alternative abundant prey maintain high fox densities, the impacts of predation on preferred rare prey species may be severe (Dickman 1996a).

The impacts of fox predation on non-mammalian prey are less apparent. Smith *et al*. (1994) listed predation by feral cats and foxes as the likely cause for the decline of several species of birds in western New South Wales, particularly among ground-nesting species. However, few studies have assessed the impacts of introduced predators on these species directly. At Pulletop Nature Reserve in central New South Wales, Frith (1959) reported 33 of 71 malleefowl nests observed (46 %) were subjected to fox predation, resulting in 377 of 1094 of eggs laid (34 %) being eaten. In contrast, Brickhill (1987) reported only 27 of 530 malleefowl eggs laid (5 %) taken by foxes across a range of sites in New South Wales, while Booth (1987) reported no predation by foxes on malleefowl eggs at a site in South Australia. Given the high fecundity observed in this species, all studies reported sufficient recruitment such that nest predation was unlikely to be the major factor limiting population growth (Brickhill 1987).

Predation by foxes may limit adult and juvenile survival in the malleefowl. Priddel and Wheeler (1994) identified fox predation as the major cause for the failure of an attempted reintroduction of malleefowl into remnant habitat in central New South Wales. Predation was the proximate cause of death for 94 % of birds released (29 of 31), with foxes accounting for up to 65 % of birds released (20 of 31). In subsequent experimental releases of malleefowl into areas with and without fox control, Priddel and Wheeler (1997) reported higher survival among birds released into areas under fox control. However, predation by foxes remained the primary source of mortality regardless of treatment. Rapid immigration of foxes into small baited areas appeared to limit the effectiveness of fox control (Priddel and Wheeler 1997; see Section 5.4.2).

By comparison, predation by foxes on eggs and unfledged birds may severely limit recruitment in shore-nesting birds. Foxes have been recorded as the major source of egg loss for little terns in some seasons, with the nesting failure of entire colonies being attributed to foxes (NPWS 2000). Similarly, fox predation has been identified as a major source of egg loss in nesting pied oystercatchers at key breeding sites in northern New South Wales (Wellman *et al*. 2000). Low fecundity and exposed nesting sites leave these species particularly susceptible to predation impacts on populations.

The nesting success of Murray River turtles at several sites along the Murray River in South Australia was evaluated by Thompson (1983). Nesting success was low with fox predation accounting for 93 % of eggs laid. Comparisons of the age structure between the Murray River populations and a population in Coopers Creek, south-west Queensland where there were few foxes, revealed that the Murray River populations had few juvenile and young adult animals (Thompson 1983). Subsequent fox-removal experiments conducted on the Murray River near Albury, showed that fox predation significantly reduced recruitment of juveniles into the breeding population, and thus threatened the long-term viability of the population (Spencer 2000).

In addition to direct mortality, foxes have the potential to affect the population dynamics of native fauna through the behavioural responses of prey to predation risk. In the presence of predators, prey animals may alter foraging and other behaviours which may reduce individual fitness (Lima and Dill 1990). In turn, this has the potential to reduce fecundity and survival in prey populations (Hik 1995). In Australia, fox-removal experiments have shown that some native fauna modify foraging behaviour in response to the risk of fox predation. In experiments conducted at Burrendong Dam in central New South Wales, Gresser (1996) found that brushtail possums reduced the time spent foraging and foraged closer to cover at sites where foxes were present compared to sites where fox numbers had been reduced. Similarly, Banks (2001) found that eastern grey kangaroos grazed closer to cover and in smaller groups at sites where fox numbers were unmanipulated compared to sites where their numbers had been reduced. Whether reduced foraging in the presence of predators leads to population-level impacts in these prey species is unknown.

The impact of predation on prey populations may vary in time and space as the result of interactions with other extrinsic factors. For example, the impacts on prey populations may increase with declines in the availability of food or cover for prey (McNamara and Houston 1987, Krebs *et al*. 1995), or with declines in the availability of preferred prey for predators (e.g. Angelstam *et al*. 1984). One interaction that is likely to be important for threatened prey species in forest and woodland habitats in New South Wales is that between predation and habitat fragmentation (Dickman 1996a). Where forests are fragmented, the close proximity of cleared areas may lead to increased fox densities within remnant patches of habitat (Catling and Burt 1995, Saunders *et al*. 1995). The loss of cover may also lead to severe predation on animals dispersing between remnant patches. Hence, predation may be a minor source of mortality in continuous habitat, but a major source of mortality where habitat is fragmented (Dickman 1996a). In addition, the presence of predators may reduce access to food resources in cleared areas through the behavioural responses of prey to predation risk (as above). Thus, both the direct and indirect effects of predation are likely to increase as a result of habitat fragmentation. Increased impacts from introduced predators as a result of habitat fragmentation have been proposed for several threatened species, including the brush-tailed rock-wallaby (Lunney *et al*. 1995), rufous bettong (Schlager 1981) and malleefowl (Priddel and Wheeler 1994).

As a generalist predator, the fox has the potential to prey on most native terrestrial fauna. However, predation does not necessarily have a significant or measurable effect upon all prey populations. Predation may be compensatory, in that it is a proximate source of mortality only and has no net effect on populations (Errington 1946, Banks 1999). Alternatively, predation may simply be a minor source of mortality in a population relative to other factors. Hence, the observation of a species in the diet of foxes (e.g. via faecal analysis) does not imply that mortality due to fox predation is high, or that a significant population-level effect exists. Thus fox control will not necessarily benefit all prey species.

For example, Banks (1999) concluded that predation by foxes on native bush rats in subalpine ACT did not limit populations of the rodent. In a replicated fox-removal experiment, the abundance of bush rats, individual persistence (survival) and other demographic parameters did not vary between treatments (Banks 1999). Similarly, Mahon (1999) concluded that predation by foxes on sandy inland mice and lesser hairy-footed dunnarts in the northern Simpson Desert had little effect on the abundance of these prey. Although captures of sandy inland mice increased in experimental areas where the numbers of cats and foxes were reduced, other data suggested that cats were the dominant source of predation mortality. Populations of lesser hairy-footed dunnarts did not respond to predator control (Mahon 1999). At Heirisson Prong in semi-arid Western Australia, Risbey *et al*. (2000) also reported increased captures of sandy inland mice and ash-grey mice at a site where foxes and cats were reduced relative to an unmanipulated site. However, where only foxes were removed, captures of small mammals declined by 80 %. Risbey *et al*. (2000) concluded that increases in small mammals reflected reductions in the impacts of cats. Further, the impact of cats on small mammals was intensified in the absence of foxes through meso-predator release (Palomares *et al*. 1995; see below).

Other studies also suggest that fox predation is unlikely to have a significant effect on some populations of potential prey. For example, Whitaker (2000) used data from telemetry studies to estimate mortality in eastern brown and red-bellied black snakes in an agricultural area in southern New South Wales. In the study, 56 animals were monitored for up to three years. Despite high densities of foxes, no deaths due to fox predation were observed (Whitaker 2000). Similarly, Christy (2000) used mark-recapture and telemetry data to assess mortality in green and golden bell frogs in remnant habitat in urban Sydney. Mortality due to fox predation was trivial relative to predation on tadpoles by mosquito fish and the loss of all life stages from fungal disease (Christy 2000). Extensive long-term (up to 3 years) telemetry studies of koalas have also been conducted at a range of sites across New South Wales including Port Stephens, Yamba, the Pilliga and Coffs Harbour. Mortality due to fox predation was positively identified on only one occasion, although the impacts of dogs may have been significant in some areas (D. Lunney *pers comm*, R. Kavanagh *pers comm*, S. Townley *pers comm*).

In many of the above studies, the species examined probably formed only a minor component of the diet of foxes. However, the impact of foxes on prey which occur frequently in the diet may also be negligible. For example, voles are the primary prey of a range of avian and terrestrial predators including foxes in many areas of northern Europe. Following a widespread reduction in fox populations with an outbreak of sarcoptic mange in Sweden, increases in a range of secondary prey species including hares, roe deer and ground-nesting birds were observed (Lindstrom *et al*. 1994). However, the dynamics of vole populations were unaffected by reduced fox numbers. Similarly, populations of arctic hares and ground-nesting birds increased in response to experimental reductions in fox and marten densities on Bergon and Ranon Islands in the northern Baltic (Marcstrom *et al*. 1988, 1989) Again, vole dynamics appeared unaffected by predator control. In Finland, selective removal of specialist avian predators failed to prevent summer declines in vole numbers (Norrdahl and Korpimaki 1995). In these examples, compensatory increases in mortality due to other predators may have negated the effects of selective predator control (Korpimaki and Krebs 1996, Korpimaki and Norrdahl 1998).

Finally, foxes may have positive effects on native fauna through the suppression of other pest species. Foxes prey primarily on rabbits across much of their range (Section 3.4) and several studies have shown that foxes may limit rabbit populations. For example, in subalpine ACT, rabbit populations increased to 6.5 and 12.0 times their initial densities at two sites following 18 months of fox control, while populations increased only marginally at two untreated sites (Banks *et al*. 1998). In semi-arid NSW, rabbit populations increased rapidly following drought at one site where foxes and cats were reduced by shooting; rabbit numbers remained low at an adjacent untreated site (Newsome *et al*. 1989). Further experiments showed that predation by foxes and cats may regulate rabbit populations at low densities following drought (Pech *et al*. 1992). Given that rabbits may have negative impacts on a range on native flora and fauna, increases in the abundance of rabbits can be a substantial environmental cost of fox control (Banks *et al*. 1998).

Foxes may also play a role in reducing the impacts of predation by cats on small mammal populations (Dickman 1996b, Risbey *et al*. 2000; cf. meso-predator release). In a predator-removal experiment conducted at Heirisson Prong in Western Australia, Risbey *et al*. (2000) observed an increase in the abundance of small mammals at a site where foxes and cats were controlled relative to a site where their numbers were not manipulated. However, numbers of small mammals declined significantly at a third site where only foxes were removed. A three-fold increase in the activity of cats was also recorded at this site. Given that dietary studies indicated that cats preyed more frequently on these species than foxes (Risbey *et al*. 1999), it was concluded that cats had a greater direct impact on small mammal populations (Risbey *et al*. 2000). Furthermore, foxes may have had a facilitatory effect on small mammal populations by suppressing the abundance of cats (Risbey *et al*. 2000). Several studies have described significant dietary overlap between these predators, particular for rabbits (Newsome *et al*. 1997) and larger rodent species (Mahon 1999). There is also some evidence of direct predation on cats by foxes (Molsher 1999). One experimental study in central New South Wales found that cats may shift their diet and habitat use in the presence of foxes (Molsher 1999).

In summary, four conclusions can be made about the impact of fox predation on native and pest species in Australia. Firstly, the impact of fox predation on the abundance of the majority of native fauna is not known. However, evidence of impacts is greatest for medium-sized ground-dwelling and semi-arboreal mammals, ground-nesting birds and chelid tortoises. These impacts may be intensified in areas of minimal understorey. Secondly, foxes do not have a significant impact on all prey populations. For example, predator-removal experiments have found no evidence for impacts on some small mammal species. Thirdly, where impacts do occur, they can be modified by interactions with other extrinsic factors. In forest areas of New South Wales, habitat fragmentation may be important in increasing the impact of foxes on native species. Finally, increased densities of rabbits and cats may be a substantial environmental cost of fox control.

5 A STRATEGY TO MINIMISE THE IMPACT OF FOXES ON NATIVE FAUNA IN NEW SOUTH WALES

5.1 Introduction

As a result of experimental and circumstantial evidence implying that foxes were contributing to the decline of native fauna in south-west Western Australia (Christensen 1980, Kinnear *et al*. 1988, Friend 1990), aerial and ground baiting of foxes across large areas of the region was initiated in 1994 (Armstrong 1998). This was possible because many of the fauna native to the area have a high tolerance to sodium monofluoroacetate (1080), the toxin used in fox control (King *et al*. 1978). This increased tolerance probably reflects the occurrence of 1080 in plants of the genus *Gastrolobium* which occur in the area. The effectiveness of the programme has been demonstrated by the successful reintroduction of several native species into the area (Friend and Thomas 1994, de Tores *et al*. 1998, CRC 1999).

By comparison, many fauna native to eastern Australia have a low tolerance to 1080 (McIlroy 1986). As a result, labour-intensive baiting techniques which reduce the exposure of these taxa are employed in many areas (see Section 5.4.3). Thus, fox control on the scale undertaken in Western Australia cannot be achieved in many areas of New South Wales. Rather, fox control is often restricted to localised programmes targeting reserves and other sites where rare and threatened species persist. The success of these programmes may be limited by the rapid reinvasion of foxes into treatment areas (Priddel and Wheeler 1997, Rummery *et al*. 2000).

There are insufficient resources to control foxes effectively in all areas where they coexist with native fauna. However, fox predation does not necessarily have a significant impact on all prey populations (Section 4). Thus, control programmes need to focus on those prey species for which the population-level impacts of fox predation are likely to be greatest. Resources can then be allocated to increase the effectiveness of fox control at key sites for these species and more rigorous measures can be established to determine the success of these programmes. Without substantial increases in resources, this may come at the expense of some existing control programmes. However, being more critical about where fox control is undertaken will prevent resources being used where they may have little conservation value.

The overall objective of this plan is to focus fox control on areas where the impacts of fox predation on threatened fauna are greatest and to ensure that the resultant control programmes are effective in reducing these impacts. In particular, the plan identifies those threatened species which are most likely to be impacted by fox predation and the sites at which fox control for these species is most critical. Establishing collaborative fox control programmes across all land tenures at these priority sites is the core action of the plan. In addition, the plan identifies best-practice methods for fox control which aim to maximise the effectiveness of the resultant control programmes while minimising their impacts on non-target species. Research actions to refine these methods are identified.

The plan also outlines experiments to measure the response of threatened species to fox control. The main objective of these experiments is to test critically whether populations of threatened species targeted for fox control in this plan are limited by fox predation. These experiments are necessary to justify ongoing fox control targeting these species. Where impacts are established, subsequent experiments can then be used to measure the effectiveness of specific management strategies.

5.2 Objectives of the plan

The plan has four specific objectives.

Objective 1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation.

Objective 2. Ensure that fox control programmes are effective in minimising the impacts of fox predation on targeted threatened species.

Objective 3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes.

Objective 4. Provide support for the implementation of the plan.

The strategy to address each of these objectives is described in the following sections.

5.3 Priority fox control programmes

Objective 1. Ensure that fox control programmes undertaken for conservation purposes in New South Wales focus on those threatened species which are most likely to be impacted by fox predation.

5.3.1 Fox control to reduce impacts on threatened species

There have been few direct measurements of the impact of foxes on populations of native fauna, such that the impact of foxes on most prey species remains unknown (Section 4). Where impacts do occur, they are often complex, varying in space and time as a consequence of interactions with other factors. Thus, no absolute measure of the impact of foxes on threatened fauna currently exists which may be used as a basis for prioritising fox control. Hence, for this plan, an objective method for comparing the likelihood of impact between species was derived. This acts as a starting point for prioritising fox control for the conservation of threatened species. Priorities will be reviewed pending the results of experiments to measure impact (Objective 3).

Following several previous studies (e.g. Dickman 1996b, Newsome *et al*. 1997), the likelihood of impact on threatened fauna (including threatened populations and subspecies) was modelled by comparing factors related to the susceptibility of species to fox predation (Appendix 1). These factors were derived by establishing attributes common to species for which there exists at least circumstantial evidence of impact (Section 4). The factors included in the model were body mass, habitat use, spacing and anti-predator behaviour, mobility and fecundity. These attributes were compared across all threatened fauna enabling species to be ranked by the likelihood of impact (Appendix 1).

Ranked species were partitioned into three broad categories to facilitate the planning of control programmes (Table 5.1, Appendix 1). For high priority species, fox control will be considered at all sites where significant populations persist (see below), unless the site is designated as an unbaited area in experiments to measure impact (Section 5.5.2). For medium priority species, fox control will be conducted if the distribution of the species is restricted to one or two locations only. Fox control at sites where only low priority species are present is not a priority in this plan.

Sites where significant populations of high priority species persist were identified from the NPWS Atlas and other species records and by consulting relevant recovery plans (Appendix 2). Each site was rated as high, medium or low priority for fox control based on an assessment of the likelihood of fox impact at a site (fox density and habitat fragmentation), the ability to achieve effective fox control at a site (size of area and land tenure) and the importance of the population to the species overall (higher priority for large and/or outlying populations). Sites were listed as requiring further assessment where there was insufficient information on fox activity. Thus fox activity at 2 of 13 brush-tailed rock-wallaby sites, 13 of 14 rufous bettong sites and all 4 Albert's lyrebird sites will be assessed prior to their inclusion as priority sites for fox control. In total, 81 sites were identified as high or medium priority areas for fox control or as areas requiring further assessment (Table 5.2; Appendix 2).

Many of the sites identified are already subject to fox control undertaken by NPWS or other agencies. Their inclusion in this plan shows how they fit into the statewide strategy, thus providing a justification for the ongoing resourcing of these programmes.

The large majority of priority sites are on public lands managed by NPWS, State Forests of NSW (SFNSW) or the Department of Land and Water Conservation (DLWC). Thus, the establishment and/or continuation of fox control programmes at priority sites will be co-ordinated by these agencies. Where priority sites include private lands, voluntary agreements will be sought to include these lands in control programmes. Fox control will not be undertaken at priority sites designated as unbaited areas in experiments to measure impact (Section 5.5.2). NPWS and SFNSW will coordinate the assessment of fox activity at sites where further assessment is required.

5.3.2 Fox control for non-threatened species

Limited fox control already occurs at many of the sites listed in Table 5.2. However, a substantial increase in resources is necessary for fox control to be effective in protecting populations of threatened species at these sites. Thus, with the exception of programmes aimed at threatened populations or subspecies of otherwise unlisted fauna (Section 5.3.1.), fox control specifically targeting non-threatened species is not a priority in this plan.

Nevertheless, many non-threatened species are likely to benefit from fox control programmes at the sites listed to protect threatened species. For example, 36 priority sites for fox control have been identified in forest or woodland areas of eastern NSW to protect populations of the brush-tailed rock-wallaby, rufous bettong, southern brown bandicoot, long-footed potoroo or Albert's lyrebird. Fox control at these sites may also result in increases in other medium-sized ground-dwelling and semi-arboreal species, including eastern grey kangaroos, several species of wallaby, brushtail and ringtail possums and long-nosed bandicoots. Furthermore, given that these programmes will involve frequent baiting over extended areas (Section 5.4), they are likely to be more effective than many existing programmes in reducing the impacts of fox predation on all native fauna.

5.3.3 Actions and performance criteria

Action 1.1. NPWS, SFNSW and the DLWC to coordinate fox control programmes at priority sites on public lands (Table 5.2). Agreements will be sought with private landholders where priority sites include private lands. Fox control will not be undertaken at sites designated as unbaited areas in experiments to measure impact (Section 5.5.2).

Performance criteria. Fox control programmes to be established at 75 % of high priority sites within two years of the date of publication of this plan.

Action 1.2. NPWS and SFNSW to coordinate the measurement of fox activity at priority sites identified as requiring further assessment (Table 5.2).

Performance criteria. Fox activity to be assessed at these sites and new control programmes established as required within two years of the date of publication of this plan.

Table 5.1 Priority threatened species for fox control (from Appendix 1).

Species are listed in order of decreasing likelihood of impact within taxonomic classes as predicted by the model. High and medium priority species differ in the management actions proposed (see text). Also shown are species abbreviations (codes) used in Table 5.2.

Species	Common Name	Code
Mammals		
High priority		
Aepyprymnus rufescens	Rufous Bettong	RB
Petrogale penicillata	Brush-tailed Rock-wallaby	BTRW
Petrogale xanthopus	Yellow-footed Rock-wallaby	YFRW
Macropus dorsalis (Narrabri populations)	Black-striped Wallaby	BSW
Mastacomys fuscus	Broad-toothed Rat	BTR
Potorous longipes	Long-footed Potoroo	LFP
Isoodon obesulus	Southern Brown Bandicoot	SBB
Perameles nasuta (North Head population)	Long-nosed Bandicoot	LNB
Rattus villosissimus	Long-haired Rat	LHR
Medium priority		
Burramys parvus	Mountain Pygmy Possum	MPP
Dasyurus maculatus	Spotted-tailed Quoll	STQ
Phascogale tapoatafa	Brush-tailed Phascogale	BTP
Pseudomys fumeus	Smoky Mouse	SM
Pseudomys gracilicaudatus	Eastern Chestnut Mouse	ECM
Birds		
High priority		
Menura alberti	Albert's Lyrebird	AL
Burhinus grallarius	Bush Stone-curlew	BuSC
Cinclosoma castanotus	Chestnut Quail-thrush	CQT
Esacus neglectus	Beach Stone-curlew	BeSC
Haematopus longirostris	Pied Oystercatcher	POC
Phaps histrionica	Flock Bronzewing	FB
Ardeotis australis	Australian Bustard	B
Drymodes brunneopygia	Southern Scrub-robin	SSR
Geophaps scripta	Squatter Pigeon	SP
Leipoa ocellata	Malleefowl	M
Sterna albifrons	Little Tern	LT
Botaurus poiciloptilus	Australasian Bittern	AB
Grus rubicunda	Brolga	Br
Pedionomus torquatus	Plains-wanderer	PW
Thinornis rubricollis	Hooded Plover	HP
Medium priority		
Amytornis barbatus	Grey Grasswren	GGW
Reptiles		
High priority		
Elseya Belli	Bell’s Elsya	EB
Emydura macquarii (Bellinger River subspecies)	Bellinger River Emydura	EM
Tiliqua multifasciata	Centralian Blue-tongued Lizard	CB
Aspidites ramsayi	Woma	W
Demansia torquata	Collared Whip-snake	CW
Liasis stimsoni	Stimson's Python	SPy
Simoselaps fasciolatus	Narrow-banded Snake	NBS
Tiliqua occipitalis	Western Blue-tongued Lizard	WB
Medium priority		
Aprasia inaurita	Mallee Worm Lizard	MWL
Amphibians	*No species*	

Table 5.2 Priority sites for fox control (from Appendix 2).

Sites are partitioned by NPWS Regions. The target threatened species are given for each site. The priority status of each site is given as high (H), medium (M) or further assessment required (A).

NPWS Region	Site	Target species	Priority
Northern Rivers	South Ballina Beach	POC	H
	Broadwater Beach	POC	M
	Bombing Range Beach	POC	M
	Koorelah	RB	A
	Tooloom	RB	A
	Yabbra	RB	A
	Richmond Range	RB	A
	Bungawalbin	RB, BuSC	A
	Myrtle	RB, BuSC	A
	Border Ranges East	AL	A
	Mt Jerusalem	AL	A
	Mt Warning	AL	A
	Nightcap	AL	A
Nth Tablelands	Girard	RB	A
	Timbarra/ Ewingar	RB	A
	Attunga	BTRW	H
North Coast	Clarence River Entrance	Br, POC, BeSC	H
	Yuraygir Mid	BeSC, POC	H
	Yuraygir Sth	BeSC, LT, POC	H
	Sawtell/ Bongil Bongil	LT	H
	Nambucca Heads	LT, BeSC	H
	Upper Bellinger River	EM	H
	Ramornie-Jackadgey edge	RB	A
	Chaelundi-Kangaroo River edge	RB	A
	Grange	RB	A
	Glenugie	RB	A
Mid North Coast	Kumbantine-Bellangry edge	RB	H
	Manning R Harrington/Farquhar	LT, BeSC	H
Hunter	Barrington Tops	BTR	H
	Barnard River	BTRW	A
Central Coast Hunter	Broke	BTRW	H
	North Wollemi Martindale	BTRW	H
	Watagans	BTRW	H
	Mount Royal	RB	A
Blue Mtns Wollemi	Nth Wollemi Widden Valley	BTRW	H
	Wolgan River	BTRW	H
	Jenolan Caves	BTRW	H
	St Albans	BTRW	M
	Lower Colo	BTRW	A
Sydney North	Ku-ring-gai Chase	SBB	H
	Garigal	SBB	H
Sydney	North Head	LNB	H
Sydney South	Towra Pt	LT, POC	H

NPWS Region	Site	Target species	Priority
South Coast	Kangaroo Valley	BTRW	H
	Taralga	BTRW	H
	Coomonderry Swamp	AB	H
	Coomerang Island	POC	H
	Lake Wollumboola	LT	H
	Conjola	HP, POC	H
	Murramarang	HP, POC	H
Far South Coast	Tuross/ Lake Brou	POC, LT	H
	Mimosa Rocks	HP, POC	H
	Moruya Estuary	HP, POC	H
	Wallagoot Lake	HP	H
	Ben Boyd	SBB, HP	H
	South East Forests (Sth)	LFP, SBB	H
	South East Forests (Nullica)	SM	H
	Narooma/ Mystery Bay	HP	M
	Tilba & Wallaga Lakes	POC, LT	M
	Tathra Beach	LT	M
	Nadgee	SBB, HP	M
Snowy Mountains	Snowy Mountains Main Range	BTR, MPP	H
South West Slopes	Kosciuszko North	BTR	H
Northern Plains	Warrumbungles	BTRW	H
	Brigalow Park (Narrabri)	BSW	H
	Macquarie Marshes	Br, AB	H
	Narren Lakes	Br	M
Central West	Goonoo	M	H
Riverina	Nombinnie/ Round Hill	CQT, M, SSR	H
	North Canargo	PW	H
	Wanganella	PW	M
Upper Darling	Yathong	CQT, M, SSR	H
	Nocoleche	Br	H
Far West	Sturt NP	LHR, B, FB, SP, CB, CW, NBS, Spy	H
	Mutawinji NP	YFRW, B, NBS, Spy	H
	Coturaundee NR	YFRW	H
	Tarawi	CQT, M, SSR, WB	H
	Mallee Cliffs	CQT, M, SSR	H
	Abbotts Tank	CQT, M, SSR	H
	Mungo	CQT, SSR, WBT	H
	Peery Lake	Br	M

5.4 Effective fox control programmes

Objective 2. Ensure that fox control programmes are effective in minimising the impacts of fox predation.

5.4.1 Effective fox control

The objective of fox control programmes proposed in this plan is not to reduce fox populations *per se*, but to reduce the impacts of foxes on threatened species. Thus, the effectiveness of control programmes must be measured by the response of populations of threatened species to fox control (Objective 3; Section 5.5). However, given that programmes target species that are limited by fox predation (Section 5.3), and given that they are directed where and when impacts on these species are significant, then the effectiveness of control programmes will be determined by whether fox densities can be reduced sufficiently to allow prey populations to increase. The reduction in fox numbers required to achieve prey increases will depend on individual predator-prey relationships (Rosenzweig and Macarthur 1963).

Broadscale baiting using the toxin 1080 is the most effective and target-specific method of fox control currently available and thus it is used widely throughout Australia (Saunders *et al*. 1995). However, the ability of baiting programmes to reduce fox populations will be limited by many factors, including immigration and reproduction, the proportion of the population exposed to baits, the proportion of bait-shy individuals in the population and the potential for compensatory increases in survival among unexposed and bait-shy foxes. Most of these factors are influenced in turn by the methods employed in baiting programmes.

5.4.2 Immigration

In a study of the impact of fox baiting on the survival of translocated brush-tailed bettongs in Western Australia, survival of bettongs was compared between areas baited 0, 2, 4 and 6 times per year (CRC 1999). In the core of treatment areas (> 5 km from the edge), survival of bettongs was greater than in the unbaited site where baiting occurred four or six times per year, but not where baiting occurred twice per year. On the periphery of treatment areas (< 5 km from the edge), survival of bettongs was greater than in the unbaited site only where baiting occurred six times per year. The lack of response of bettongs to low-frequency baiting was attributed to rapid immigration of foxes into treatment areas (CRC 1999). Given that more frequent baiting was necessary to increase bettong survival on the periphery of treatment areas, immigration appeared to be greater in areas adjacent to unbaited lands. An inverse relationship between the size of the area baited and the frequency of baiting required to reduce immigration of foxes into treatment areas is intuitive (Thomson *et al*. 1998).

The success of fox control programmes for threatened species in eastern Australia may be limited similarly by the rapid reinvasion of foxes into treatment areas (e.g. Priddel and Wheeler 1997). Many existing programmes involve less frequent baiting (< 4 times/year) and cover smaller areas than the Western Australian study (areas under fox control in the WA study were 900-2200 km^2; de Tores *et al.*1998). However, given that mobility of foxes is related to resource density (Section 3.3), the rate of reinvasion will also vary with habitat and the prevailing environmental conditions. Furthermore, the reduction in fox numbers necessary to allow prey increases will depend on individual predator-prey relationships. Thus the frequency of baiting and size of the baited area necessary to achieve prey increases will vary between programmes.

Where land tenure is fragmented, establishing buffer zones (baited areas extending beyond the distribution of the target prey species at a site) will require collaboration with managers of adjacent lands (Saunders *et al*. 1995). This may reduce fox immigration into core areas and also expand the area over which prey species can increase if the habitat is suitable. Establishing buffer zones may be critical if predation on animals dispersing between patches of habitat is significant (Section 5.5.3). Where priority sites adjoin agricultural lands, collaborative agreements with private landholders to increase the area over which foxes are controlled simultaneously can benefit both conservation and agricultural objectives (Section 6).

In undertaking fox control at priority sites, NPWS, SFNSW and DLWC will seek to establish collaborative programmes with managers of adjacent lands to create buffer zones. In particular, these agreements will seek to extend the area under fox control beyond the local distribution of the target prey species. Pending subsequent experiments to measure the effectiveness of specific levels of fox control, the frequency of fox control will be maximised given available resources (see Section 5.5.1).

5.4.3 Exposure

The proportion of a fox population killed by baiting programmes is often high, regardless of differences in techniques and habitats. Thomson *et al*. (1998) observed 100 % mortality among radiocollared foxes (45 of 45) and estimated an overall reduction of > 95 % in fox numbers following aerial baiting at 5 baits/km^2 in the Western Australian rangelands. Similarly, Algar and Kinnear (1992) observed the death of 10 from 11 radiocollared foxes (91 %) and estimated a decline of 86 % in fox density following aerial baiting at 6 baits/km^2 in the Western Australian wheatbelt. Thompson and Fleming (1994) estimated reductions of 66 and 73 % in fox densities following ground baiting at 12 baits/km^2 at two sites in rural north-east NSW. Fleming (1996) estimated a mean reduction of 90.8 % at two sites in forested areas of north-east NSW after ground baiting with replacement at 250 m intervals along roads and tracks. Finally, Dexter and Meek (1998) reported a decline of 97 % in bait take and the death of 6 from 6 radiocollared foxes following ground baiting at 300 m intervals along tracks in heath and forest habitat in coastal NSW. In non-lethal trials, Marks and Bloomfield (1999) observed bait uptake rates of 72.7 and 92 % among radiocollared foxes in urban Melbourne (small areas baited at 800 baits/km^2). Models of population growth by Hone (1999) suggest that a kill rate of 65 % is needed to stop growth in fox numbers.

Over the last ten years, there has been an increased emphasis on modifying baiting practices used in eastern Australia to reduce the risk of poisoning non-target species (Korn *et al*. 1992, Belcher 1998, Murray 1998). This follows the recognition that domestic dogs and some native fauna (especially spotted-tailed quolls) are at risk from 1080 baiting programmes (McIlroy 1986, 1999; Section 5.4.5). Using bait stations (area of sand under which a bait is buried) and free feeds (non-toxic baits), increasing the depth of burial and spacing of baits and reducing dosage rates have been proposed as methods to reduce the impact on non-target species (Allen *et al*. 1989, McIlroy and King 1990, Dexter and Meek 1998, Murray 1998, Saunders *et al*. 1999). However, whether such modifications reduce the effectiveness of baiting programmes is often unclear. In particular, where methods increase the time and costs involved in baiting, undertaking fox control at sufficient frequency and over sufficient area to counteract immigration may be precluded (Section 5.4.2).

Burying baits can reduce the uptake of baits by non-target species (Allen *et al*. 1989). When used in association with a bait station the identity of species taking baits may be surmised by assessing prints and other signs left in the sand. By preceding toxic baiting with a period of free feeding, the selectivity of baiting can be increased by avoiding stations where non-target species have been recorded and, more conservatively, using toxic baits where target species only have been identified (Dexter and Meek 1998). This is based on the assumption that the likelihood of future activity in target and non-target species at a bait station is greater if they have been observed there previously.

Several studies have quantified changes in bait uptake by foxes during periods of free feeding (e.g. Trewhella *et al*. 1991, Dexter and Meek 1998, Williams and Marshall 2000). These studies typically report a pattern of increasing bait uptake over a period of several days until a plateau is reached (Dexter and Meek 1998). While some increase in the number of foxes taking baits may occur, an increased uptake by individual foxes is expected as animals locate more stations within their daily ranges. When toxic baiting follows, uptake may fall precipitously (Thompson and Fleming 1994, Dexter and Meek 1998, Williams and Marshall 2000).

Uptake of baits by non-target species may also increase over extended periods of free feeding. Williams and Marshall (2000) measured greater activity at bait stations by spotted-tailed quolls during days 15-18 of baiting than during the preceding 14 days of free feeding (10 baits taken where quolls were active at bait stations over 764 baitnights during baiting on days 15-18 compared with 9 baits taken over 2674 baitnights during the previous 14 days). Poisoning of quolls was avoided as toxic baits were placed where fox activity only had been observed during the 14-day free feed period; quolls did not visit these stations (Williams and Marshall 2000). Similarly, Dexter and Meek (1998) observed peaks in bait take by birds and rats 9 days and 18 days into a baiting programme, respectively.

Although such methods have the potential to increase target-specificity, they increase the time and costs involved in baiting programmes considerably. In particular, daily monitoring of bait stations is necessary to obtain reliable information on the activity of both target and non-target species (Dexter and Meek 1998). If such procedures prohibit fox control being conducted at sufficient frequency and over sufficient area to counteract immigration, these programmes will be of no benefit to threatened prey species (cf. de Tores *et al*. 1998, CRC 1999). If so, minimising the impacts of baiting on non-target species would be best achieved by abandoning fox control altogether.

Furthermore, given that caching in foxes is related to resource availability (MacDonald 1976), then the discovery of multiple bait stations by individuals may lead to the caching of baits. Thus, long periods of free feeding may increase the probability that toxic baits are cached when they are eventually placed, thereby increasing the risk to non-target species (Saunders *et al*. 1999). Whether increased activity by non-target species at bait stations following long periods of free feeding increases the risk of poisoning will depend on whether animals learn to associate food with bait stations in general (Belcher 1998, Murray 1998).

Establishing methods that limit the access of non-target species to baits without reducing uptake by foxes significantly could make free feeding and daily monitoring of bait stations unnecessary. Murray (1998) proposed that burying baits at depths of 10 cm or more reduces the risk to spotted-tailed quolls significantly. This observation was based on the results of ten independent pen trials in which quolls were offered baits at a range of depths concurrently; each trial was conducted over several nights. Baits were excavated in only two trials from a depth of 10 cm, but were retrieved in all trials when buried just below the surface; baits were not retrieved when buried 15-20 cm below the surface (Murray 1998). Williams and Marshall (2000) also observed low uptake of baits buried at 10 cm by quolls in field experiments in an area of relatively high quoll density in north-eastern NSW (19 baits taken from stations where quoll signs were observed over 3438 baitnights; see above). However, given that the spotted-tailed quoll is already rare in some areas, a low level of bait-take has the potential to have significant effects on populations (but see 5.4.5).

Increasing the depth of burial beyond 10 cm may reduce the risk posed to this non-target species further. In pen trials, Belcher (1998) and Murray (1998) observed that baits were not taken by spotted-tailed quolls when buried at depths of 15-20 cm. However, while burying baits at 10 cm appears to be effective in removing a large proportion of foxes (Dexter and Meek 1998), no data are available on the effectiveness of baiting programmes where baits are buried at 15-20 cm.

Alternatively, uptake of baits by quolls may be reduced by changing the way bait stations are constructed. In the trials of Murray (1998) and Williams and Marshall (2000), baits were placed on or just below the surface of the ground with sand piled over the top of the bait to form a mound (baits were 10 cm below the surface of the mound). “Mound-baiting” is often used in fox and wild dog control on the assumption that it increases bait-take by these canids because of the visual and olfactory cues left by the mound and the ease with which the bait may be excavated. However, these factors presumably increase the uptake of baits by non-target species such as spotted-tailed quolls as well. For instance, Glen (2001) measured greater retrieval by quolls of baits buried 7 cm under mounds than when buried into the ground. Murray (1998) noted that where baits had been retrieved by quolls from mounds during pen trials, mounds had been “trampled flat” rather than “dug out”. It should be noted that there no data which demonstrate that mound-baiting increases the effectiveness of fox and wild dog control.

The availability of baits to non-target species can also be reduced by increasing the spacing between baits. In montane forest, Murray (1998) proposed a minimum distance of 1 km between baits in canid control programmes (many existing programmes space baits < 500 m apart). This was based on the observation that individual foxes and wild dogs often visit bait stations that are 1 km apart. However, Banks (1997) reported home ranges of 0.9-3.9 km^2 (100% minimum convex polygon MCP; Mohr 1947) for foxes in montane forest edges in

Namadgi NP, ACT. Phillips and Catling (1991) and Meek (1997) recorded home ranges of 0.6-5.2 km^2 (100% MCP) for foxes in coastal forest habitats in southern NSW. Excluding exploratory excursions, core areas of activity were much smaller (Banks 1997, Meek 1997). Among animals, small home ranges were associated with resource-rich patches (Bubela 1995, Banks 1997) or social status (Meek 1997). Thus, depending on how roads are positioned relative to home ranges, baiting at 1 km spacing will miss animals in some forest areas. While reducing the intensity of baiting will decrease exposure of non-target species and the caching of baits (as above), the efficacy of larger bait spacings in reducing fox numbers has not been assessed adequately (Saunders *et al*. 1999).

For priority sites identified in this plan, free feeding and daily monitoring of bait stations will be used only where a non-target risk is identified (i.e. where spotted-tailed quolls are likely to be present; Section 5.4.5). The NPWS and SFNSW will undertake further trials as part of these programmes to measure differences in bait uptake rates by foxes and non-target species as a function of bait station type (mound versus ground-buried; cf. Glen 2001). The objective of these trials will be to explore the trade-off between effective fox control and reducing non-target impacts as a result of bait station type.

5.4.4 Bait-shy individuals

In theory, some proportion of the fox population can be expected to avoid baits, either through surviving a sub-lethal dose of 1080, or through neophobia (Saunders *et al*. 1995). In Section 5.4.3, data presented on mortality in fox populations following baiting programmes suggest that these animals represent a small proportion of the population. However, some of these data were derived from changes in bait uptake rates (e.g. Thompson and Fleming 1994, Fleming 1996, Dexter and Meek 1998). Such measures do not detect foxes which are bait-shy.

Low densities of foxes may still pose a significant threat to prey populations. For example, in colonial shore-nesting birds such as the little tern, individual foxes may cause the nesting failure of entire colonies (NPWS 2000). Thus other methods of fox control may need to be employed alongside 1080 baiting to achieve further reductions in fox densities at these sites. Alternative methods may also be necessary at sites close to human habitation, where the use of 1080 is restricted by the conditions of the Off-label Permit (Section 2.1.6).

There are several alternative techniques which can be used in fox control, including trapping, shooting, exclusion fencing, controlling their food supply (e.g. pest control for rabbits) and den fumigation (Saunders *et al*. 1995). Exclusion fencing may be particularly useful to protect colonial shore-nesting birds such as little terns because nesting birds are restricted to small areas and human habitation is often close. Alternative techniques will be employed at priority sites as required.

5.4.5 The impact of baiting programmes on non-target species

Despite efforts to reduce the uptake of baits by non-target species (Section 5.4.3), there are few data on the population-level effects of 1080 baiting programmes on native fauna. Given a typical dose of 3 mg of 1080, there are many native animals which could be killed by consuming a single fox bait. Animals at risk include several species of dasyurids, murid rodents, potoroids and macropods, brushtail possums and several species of birds (McIlroy 1986). However, the frequency of poisoning of non-target animals depends on many factors, including the accessibility of the bait, the attractiveness and palatability of the bait, the size of the bait relative to the amount of food typically eaten by non-target animals per day, the availability of preferred food and the response of these animals to sublethal doses of 1080. Whether baiting has population-level impacts on these species will also depend on the spacing of baits relative to the density of animals and the rate at which baits are removed by other species or degraded due to rain.

In baiting campaigns for wild dogs, McIlroy (1986) predicted that carnivorous mammals including the larger dasyurids were the most at risk, with rats and scavenging birds at less risk. In subsequent field studies in southern NSW, McIlroy *et al*. (1986) found no evidence that 1080 baiting programmes for dogs affected the abundance of small mammals and birds (baits were laid on the surface at a spacing of 8.5-9.4 baits/km of trail, with dosage rates of 3-7 mg of 1080 per bait). However, Murray *et al*. (2000) found that a high proportion of spotted-tailed quolls can find and consume meat baits deployed during aerial baiting for dogs (62.5 % of a trapped sample of 16 quolls had consumed non-toxic baits impregnated with a biomaker. Baits were deployed at 40 baits/km of transect). Assuming that a high proportion of quolls would be killed by baits of this toxicity (McIlroy 1981), it is possible that aerial baiting programmes have a significant impact on quoll populations (Murray *et al*. 2000).

The risk posed to non-target species by fox baiting is presumably less than for dog baiting because of lower 1080 dose rates (fox baits nominally contain 3.0 mg of 1080 compared to 6.0 mg for dog baits) and because baits are usually buried (Allen *et al*. 1989, Murray 1998). For scavenging birds such as pied currawongs, 3.0 mg of 1080 is not sufficient to kill most adult birds (McIlroy 1986). Furthermore, if baits are buried well apart (e.g. 500 m; Section 5.4.6), then the likelihood of non-target animals consuming multiple baits in a short period of time is low. However, baits used in fox control are often small compared to those used in the control of wild dogs (e.g. FOXOFF® Econobaits are 35 g compared to the 250 g meat baits used in aerial baiting of dogs), such that rats and birds too small to consume whole dog baits may be at greater risk from fox baits. Nevertheless, uptake of baits by rats and birds is typically low where baits are buried, thus population-level impacts on these species are unlikely (Dexter and Meek 1998).

In New South Wales, carnivorous mammals at risk during baiting programmes for foxes include spotted-tailed quolls, brush-tailed phascogales, domestic and wild dogs, cats and foxes. Brush-tailed phascogales may rarely find buried baits because the species is predominately arboreal (cf. McIlroy 1999). However, an unexpectedly high bait-take was observed during one study in Victoria (D. Fairbridge *pers. comm.*) suggesting that further investigation is needed. Generally, the spotted-tailed quoll is the native species most at risk from 1080 baiting programmes for foxes.

As discussed in Section 5.4.3, restrictions are often placed on 1080 baiting programmes for foxes to reduce the risk of poisoning spotted-tailed quolls. These restrictions have the potential to limit the effectiveness of such programmes in reducing fox populations. Based on the estimates of McIlroy (1981), more than 50 % of juvenile quolls would die from consuming a single fox bait (most adults would not be killed). However, given the range of factors that may limit the frequency of poisoning during baiting programmes as described above, the impacts of 1080 baiting for foxes on this species remain unclear.

The NPWS will undertake field studies to assess mortality in spotted-tailed quolls during buried-baiting programmes for foxes. Pending the results of these studies and of the bait station trials described in Section 5.4.3, free feeding and daily monitoring of bait stations will be employed at priority sites where spotted-tailed quolls are likely to be present (see Section 5.4.6). These precautions are not necessary at other sites. However, additional site-specific measures to reduce the risk to domestic dogs and cats (typically increased signs and advertising) may be required at priority sites close to urban areas in accordance with the Off-label Permit (Section 2.1.6).

5.4.6 Interim conservation best-practice guidelines for fox control

Following the completion of the studies proposed above, NPWS and SFNSW will develop best-practice guidelines for fox control for the conservation of native fauna. The objective of the guidelines will be to maximise the effectiveness of control programmes in reducing and maintaining low fox numbers while minimising their impacts on non-target species. The guidelines will address issues related to bait delivery (e.g. free feeding, the use of bait stations, bait station type and bait spacing), the frequency and size of control programmes and the use of alternative control techniques. Pending their completion, preliminary recommendations are provided here. These recommendations are divided into three scenarios: quolls likely to be present; quolls likely to be absent; and aerial baiting in western New South Wales. These recommendations are in addition to the conditions specified in the current Off-label Permit for the Use of 1080 Baits for the Control of Foxes (Section 2.1.6).

1. Quolls likely to be present:

- Baits should be buried 10 cm below the ground. A pad of sand or fine dirt should be placed over the buried bait to detect prints and other signs of visiting animals (bait station).
- Bait stations should be spaced at approximately 500 m intervals along roads and tracks and located away from ground cover. In areas of exceptionally high or low fox densities, spacing should be altered accordingly (under the Off-label Permit for the Use of 1080 Baits for the Control of Foxes, baits cannot be placed less than 100 m apart).
- A short period of free feeding should be used (4-5 days), followed by a short period of toxic baiting (5-6 days). For programmes with frequent baiting, it is not necessary to continue baiting until uptake rates drop below some target threshold.
- Bait stations should be checked daily and toxic baits placed only where no non-target activity has been recorded.
- Bait type should be varied occasionally in expectation of individual foxes showing aversion to specific bait types. The Off-label Permit for the Use of 1080 Baits for the Control of Foxes lists the bait materials that may be used with 1080 poison.
- The frequency of fox control and area under fox control should be maximised given available resources. In particular, the area under fox control should extend beyond the local distribution of the target prey species.
- Additional site-specific measures to reduce the risk to domestic dogs and cats (such as increased signs and advertising) may be necessary at priority sites close to urban areas in accordance with the Off-label Permit for the Use of 1080 Baits for the Control of Foxes.

2. Quolls likely to be absent

• Baits should be buried 10 cm below the ground. However, well-defined bait stations are not necessary.

• Baits should be spaced at approximately 500 m intervals along roads and tracks and located away from ground cover. In areas of exceptionally high or low fox densities, spacing should be altered accordingly (under the Off-label Permit for the Use of 1080 Baits for the Control of Foxes, baits cannot be placed less than 100m apart).

• Only toxic baits should be employed.

• Daily checking of bait stations is unnecessary.

• Baits can be checked and replaced after several days (nominally 4-5) to increase the exposure of foxes to baits. Checking baits will also provide a coarse measure of fox activity (bait uptake rates). It does not quantify the number of foxes killed during a programme (more frequent checking is required on holdings of less than 100 hectares under the current permit).

• Bait type should be varied occasionally in expectation of individual foxes showing aversion to specific bait types. The Off-label Permit for the Use of 1080 Baits for Control of Foxes lists the bait materials that may be used with 1080 poison.

• The frequency of fox control and area under fox control should be maximised given available resources. In particular, the area under fox control should extend beyond the local distribution of the target prey species.

• Additional site-specific measures to reduce the risk to domestic dogs and cats (such as increased signs and advertising) may be necessary at priority sites close to urban areas in accordance with the Off-label Permit for the Use of 1080 Baits for Control of Foxes.

3. Aerial baiting in Western New South Wales.

Aerial delivery of dried meat baits is an efficient way to reduce fox populations over large areas, and thus it is currently used to protect native prey species at several sites in western NSW. However, aerial baiting poses additional risks to non-target species (see Section 5.4.3). Aerial baiting will be used only at sites where additional environmental impact assessment has been conducted. It will be undertaken using the registered pesticide “Yathong Fox Bait” in accordance with product label directions.

5.4.7 Actions and performance criteria

Action 2.1. NPWS, SFNSW and DLWC to seek agreements with private landholders adjoining priority sites to undertake collaborative fox control. These agreements aim to extend the area under fox control beyond the local distribution of the target prey species.

Performance criteria. Collaborative programmes to be established where possible within one year of the commencement of fox baiting at priority sites.

Action 2.2. NPWS and SFNSW to undertake field trials to measure bait uptake rates by foxes and non-target species as a function of bait station type (ground-buried versus mounds).

Performance criteria. Field trials to be completed and the results reported within two years of the date of this plan.

Action 2.3. NPWS to measure mortality in spotted-tailed quolls as the result of buried baiting programmes.

Performance criteria. Mortality to be measured and reported on within two years of the date of this plan.

Action 2.4. NPWS and SFNSW to develop conservation best-practice guidelines which aim to maximise the effectiveness of control programmes in reducing fox densities while minimising negative impacts on non-target species.

Performance criteria. Conservation best-practice guidelines for fox control to be completed within three years of the date of this plan and incorporated into ongoing control programmes.

5.5 Measuring the response of native fauna to fox control

Objective 3. Provide an experimental basis for validating the priority species for fox control and for measuring the effectiveness of control programmes.

5.5.1. Background

In section 5.3.1, priority sites for fox control were established by predicting which threatened fauna are most likely to be impacted by fox predation at the population level. These predictions were made by comparing species over a range of attributes related to susceptibility to impact. However, the impacts of fox predation on the majority of these species have not been measured critically. Thus, fox-removal experiments which quantify the impact of fox predation on prey populations are necessary to justify ongoing fox control targeting these species. In particular, fox-removal experiments can be used to test the hypothesis that fox predation is a limiting factor of these populations (see Section 4).

In theory, these experiments require the removal of all foxes from treatment areas. However, fox control rarely results in the removal of all individuals, while new foxes may immigrate rapidly into these areas following control (Section 5.4). Hence, fox-removal experiments which aim to measure the impact of fox predation on prey populations typically quantify the response of prey species to reducing fox numbers to the lowest levels achievable.

Where an impact on prey populations has been demonstrated, fox-removal experiments can then be used to measure the level of fox control necessary to achieve prey increases. These latter experiments provide a measure of effectiveness for specific management strategies. However, measuring the effectiveness of specific levels of fox control is meaningful only if it is first established that predation reduces prey densities. If prey show no response to a prescribed level of fox control, it will be unclear whether foxes were not reduced sufficiently, or whether predation simply does not limit prey abundance. This will be complicated further if fox densities have not been measured adequately.

In the present plan, fox-removal experiments will be used initially to measure the impact of fox predation on priority prey species. In practice, this means that the level of fox control to be undertaken at the priority sites will vary in response to measures of fox activity at each site. That is, every effort will be made to reduce fox numbers (defined here as *intensive* fox control). Subsequent or parallel experiments will then be used to measure the effectiveness of specific levels of fox control. Experiments will be established by incorporating monitoring for targeted prey and fox populations into fox control programmes at the priority sites. Monitoring will also occur at priority sites selected as non-treatment sites (i.e. sites without fox control). These experiments are described for individual species in Section 5.5.2.

Experiments which compare changes in prey populations at replicate sites with and without fox control before and after the commencement of treatment allow the effects of fox control to be differentiated from other sources of spatial and temporal variation in prey abundance (replicated Before-After-Control-Impact BACI; Krebs 1989, Winer *et al*. 1991, Underwood 1997). For some threatened fauna, however, there are too few sites to allow such rigorous experimental designs. Furthermore, many of the priority sites have already experienced some level of fox control. In these cases, asymmetrical and post-disturbance designs (Underwood 1992, 1993, 1994), comparing between a single treatment and non-treatment site and before-after comparisons at a single site still allow hypotheses related to the impact of predation to be tested (Dickman 1996c). The experimental designs employed in this plan will depend on the availability and history of priority sites for each species.

For some priority species, individuals may be too dispersed or too cryptic to derive reliable population measures. For example, the bush-stone curlew is sparsely distributed and observed too infrequently in NSW to assess populations reliably. Similarly, most of the lizard and snake species listed as threatened are too rare to establish population measures. Establishing experiments to measure the response of such species to fox control will not be attempted. Under the assumption that populations of these species are limited by fox predation, the effectiveness of programmes targeting these species will be measured by the response of fox populations to fox control.

Monitoring the responses of common species to fox control has been proposed as a surrogate for measuring the benefits of fox control for rare or cryptic species. However, more abundant fauna cannot be used as indicators in evaluating the responses of threatened species to fox control unless it is known that the dynamics of both populations are affected similarly by predation (Caro and O'Doherty 1999). This information is not available for the priority prey species identified in this plan. Thus, given that the objective of the fox control programmes proposed here is to recover threatened species, assessing the responses of common taxa does not provide a direct measure of their effectiveness. Monitoring common species at priority sites will be done only where it can be undertaken concurrently with monitoring for target threatened species and with few additional resources (Section 5.5.2). Such monitoring provides a measure of the additional benefits of these fox control programmes.

5.5.2 Specific experiments

- Brush-tailed Rock-wallaby

In Table 5.2, 13 priority sites for fox control were identified to protect populations of the brush-tailed rock-wallaby. A fox-removal experiment to measure the impact of fox predation on rock-wallaby populations commenced in 1997 and involves three of these sites (Watagans, Broke and St Albans; Rummery *et al*. 2000). Varying levels of fox control are ongoing at a further six sites (Attunga, North Wollemi Widden Valley, Wolgan River, Jenolan Caves, Kangaroo Valley and Warrumbungles). Monitoring of rock-wallaby populations occurs at four of these (Wolgan-Capertee, Jenolan Caves, Kangaroo Valley and Warrumbungles).

Given substantial between-site variation in wallaby dynamics (Rummery *et al*. 2000), a more powerful test of the impacts of fox predation on rock-wallaby populations than the existing experiment is warranted. In the present plan, the fox-removal experiment will be expanded to include up to nine of the thirteen priority sites identified for this species (Warrumbungles, Attunga, Jenolan Caves, and Taralga excluded). This will be achieved by using standardised monitoring of rock-wallaby and fox populations at these sites. Sites will be allocated to either intensive fox control or no fox control. The allocation of sites to treatments and the sampling designs used will be determined in consultation with the Brush-tailed Rock-wallaby Recovery Team. Surveys to assess the level of fox activity in the first year of the plan at two sites (Barnard River and Lower Colo) will refine the selection of sites involved in the experiment (Section 5.3.3; Action 1.2).

Monitoring of rock-wallaby populations and fox control will occur also at the four sites not included in the experiment. These sites are excluded from the experiment because wallaby numbers are too small to make valid comparisons to the other sites. Monitoring populations at these sites will be undertaken only to provide information on their persistence.

Brush-tailed rock wallabies also occur at six of the priority sites listed for rufous bettong. However, these populations were scored as low priority for fox control on the basis they are part of a large semi-contiguous population distributed throughout the escarpment of north-eastern NSW and as such they were of low importance to the conservation of the species overall (Appendix 2). Resources to monitor these rock-wallaby populations are not provided for in this plan.

- Yellow-footed Rock-wallaby

The yellow-footed rock-wallaby is now restricted in New South Wales to Coturaundee Range in Coturaundee NR and the adjacent Gap Range in Mutawinji NP. Monitoring of rock-wallaby colonies between 1980 and 1995 showed that populations were declining at these sites (Sharp 1999). Circumstantial evidence suggested that predation by foxes was contributing to these declines.

A fox-removal experiment to measure the impact of fox predation on rock-wallaby populations commenced in 1995 (Sharp 2000). At the Coturaundee Range site, fox numbers were reduced through intensive fox control. No fox control was undertaken at the Gap Range site. Populations of rock wallabies were indexed at both sites using aerial counts along standard transects. At Coturaundee Range, counts of rock wallabies increased to over 6 times the pre-control density between 1995 and 1999. There was no significant change in rock-wallaby counts at the Gap Range site over this time (Sharp 2000).

Given the marked response of wallabies to fox control at Coturaundee Range, fox control at the Gap Range site commenced in 1999. Under the plan, monitoring of rock-wallaby populations will continue at both sites to assess further changes in populations under the current intensive fox control. In particular, monitoring will determine whether similar increases are observed at the Gap Range site. Once no further increases are evident at either site, the response of rock-wallaby populations to reduced levels of baiting will be measured with the objective of reducing the long-term costs of the programme. The level of ongoing fox control will be determined in consultation with the Yellow-footed Rock-wallaby Recovery Team.

- Rufous Bettong (and the Spotted-tailed Quoll and Brush-tailed Phascogale)

Fourteen priority sites for fox control were identified to protect populations of rufous bettong in forest habitat in the north-east of the state (Table 5.2). Surveys to assess the level of fox activity at 13 of the sites in the first year of the plan will refine the selection of sites further (Section 5.3.3). An experiment to measure the impact of fox predation on rufous bettong populations will be established by dividing the remaining sites between intensive fox control and non-treatment areas. Rufous bettong and fox populations will be monitored at all sites.

Many of the sites identified for rufous bettong are also likely to contain populations of spotted-tailed quolls and brush-tailed phascogales, species identified as medium priority for fox control

(Table 5.1). The future preparation of recovery plans for these species may support monitoring of these species at bettong sites. Several non-listed species such as brush-tailed possums and red-necked and swamp wallabies may also respond to fox control at these sites. While the resources to monitor the responses of these species to fox control are not provided for in this plan, opportunities for collaborative research projects with other institutions (e.g. CSIRO, or universities) will be explored.

- Broad-toothed Rat (and Mountain Pygmy Possum).

Three priority sites for fox control were identified to protect populations of the broad-toothed rat. These were Snowy Mountains Main Range, Kosciuszko North and Barrington Tops. Fox control commenced at Charlottes Pass within the Snowy Mountains Main Range site in winter 1996 and was extended to cover most of the site in winter 1999. Monitoring of one broad-toothed rat population within this area has been ongoing since 1978, while monitoring of a second colony commenced in 1999. Within the Kosciuszko North site, monitoring of a single population commenced in 2000. Surveys for broad-tooted rats within the Barrington Tops site have been sporadic. Neither of the latter sites have ongoing fox control at present.

In the present plan, intensive fox control will be maintained throughout the Snowy Mountains Main Range site. The Kosciuszko North site will be a non-treatment area. Monitoring of broad-toothed rats will be expanded to include additional populations within both sites. Intensive fox control and regular monitoring of broad-toothed rat and fox populations will also be undertaken at the Barrington Tops site. However, the habitat at this site is too different from the other sites to make meaningful experimental comparisons.

The Snowy Mountains Main Range site also contains the only populations of mountain pygmy possums in New South Wales. This species was ranked as a medium priority for fox control (Table 5.1). Monitoring of populations of mountain pygmy possums will continue with fox control at this site.

- Southern Brown Bandicoot

Four priority sites for fox control were identified to protect populations of the southern brown bandicoot. These were Ku-ring-gai Chase, Garigal, Ben Boyd and Nadgee. Ku-ring-gai Chase and Garigal form a continuum of forest and heathland in the northern Sydney area. Similarly, Ben Boyd and Nadgee are two adjacent sites in the south-east of the state. Given the relative positions of the sites, two separate experiments measuring the response of this species to fox control were established in 1999. In the northern Sydney area, fox control is being undertaken at the Ku-ring-gai Chase site but not at the Garigal site. In the far south coast area, fox control is being conducted at the Ben Boyd site but not at the Nadgee site. Southern brown bandicoot and fox populations are being monitored in all sites. In addition, sand pads used to monitor fox activity in the two southern sites are also being used to measure changes in the total activity of medium-sized ground-dwelling mammals in response to fox control (following the methods of Newsome *et al*. 1983).

The Victorian Department of Natural Resources and the Environment have commenced an experiment to measure the impact of fox predation on populations of southern brown bandicoots and other ground-dwelling mammals in the coastal forests of north-eastern Victoria. In particular, this study involves intensive fox control at treatment sites to test the hypothesis that fox predation limits the abundances of these species. In contrast, the experiments in New South Wales seek to measure the effectiveness of fixed levels of fox control in promoting bandicoot numbers (4-6 baitings/year). Data from the New South Wales experiments will be assessed in light of data from the Victorian study.

- Long-nosed Bandicoot (North Head population)

An experimental study at Jervis Bay has been demonstrated that fox predation may reduce long-nosed bandicoot populations (Section 4). While foxes are not consistently present at the North Head site, they may rapidly invade this small headland peninsula from the adjoining urban area. Thus, baiting is undertaken at this site as a precaution. Monitoring of long-nosed bandicoots is ongoing, as identified in the recovery plan for this endangered population. However, these data do not provide a direct measure of the effectiveness of this precautionary programme.

- Black-striped Wallaby (Brigalow Park population)

In Appendix 1, the black-striped wallaby was rated as low priority for fox control on the premise that the species prefers forest areas with a dense understorey. However, these animals feed in adjacent patches of pasture at night where they are available (e.g. Jarman *et al*. 1991). For the Brigalow Park population near Narrabri, shelter is restricted to two remnant patches of brigalow separated by several hundred metres of open pasture. Animals are often observed feeding in and traversing this area. Given the special circumstances of this population, it was scored separately from the species in general and ranked as a high priority for fox control (Table 5.1).

The abundance of black-striped wallabies and foxes will be monitored with intensive fox control at this site. However, the lack of a non-treatment area and replicate sites will limit the rigour of these data as a measure of the impact of fox predation on the wallaby population.

- Smoky Mouse

The smoky mouse is restricted in New South Wales to several isolated colonies at one site in the Nullica section of the South East Forest National Park. In addition to being ranked as a medium priority for fox control (Table 5.1), predation by cats may be a limiting factor of these populations (cf. evidence for impacts by cats on other species of *Pseudomys*; Dickman 1996b, Mahon 1999, Riseby *et al*. 2000). The abundances of smoky mice, cats and foxes will be monitored with ongoing predator control at this site. The lack of a non-treatment area and replicate sites will limit the rigour of these data as a measure of the impact of fox and cat predation on the abundance of the smoky mouse.

- Shore-nesting birds: little tern, pied oystercatcher, beach stone-curlew and hooded plover

Fox predation has been frequently observed as a major cause of egg and chick loss in shore-nesting birds, particularly among little terns and pied oystercatchers (NPWS 2000, Wellman *et al*. 2000). Where fox control has been implemented, increased fledgling success in these birds has often been observed. While there is no experimental evidence that fox predation limits adult populations, for the purposes of this plan these observations provide sufficient evidence that fox predation limits recruitment in these species.

Twenty-three priority sites for fox control were identified to protect nesting sites of little terns, pied oystercatchers, beach-stone curlews and hooded plovers (Table 5.2). Fox control is already an integral part of the management of many of these sites (e.g. NPWS 2000). Given that the objective is to increase recruitment into the adult population, the effectiveness of these programmes is measured by fledgling success (i.e. the proportion of all eggs laid that result in fledged birds).

Fox control at these sites is typically intensive, responding to any evidence of fox activity. This is because individual foxes are capable of killing all eggs and unfledged birds at a site. Thus measuring the effectiveness of reduced levels of fox control is not proposed in this plan. Rather, fledgling success will continue to be used at all of the priority sites to measure the effectiveness of management actions (including fox control) on a site-by-site basis. At high priority sites (Table 5.2), monitoring will be intensive (typically ≥ 3 times per week) to increase the likelihood that the sources of any egg loss can be identified. Monitoring at medium priority sites may be limited to coincide with the baiting programme (often weekly).

- Malleefowl

Six priority sites for fox control were identified to protect populations of malleefowl. These were Goonoo, Yathong, Nombinnie/Round Hill, Mallee Cliffs, Abbotts Tank and Tarawi. At present, fox control is conducted at all sites except Abbotts Tank. The proportion of pre-marked mounds active is used to measure changes in adult populations of malleefowl with fox control at three of these sites (Yathong, Mallee Cliffs, and Tarawi). This indirect measure has been used instead of the density of active mounds using systematic survey due to insufficient resources.

While fox predation was found to reduce survival in translocated subadult birds in one study (Priddel and Wheeler 1997) and to cause high egg mortality in another (Frith 1959), there is no experimental evidence that fox predation limits adult populations of malleefowl. However, given low malleefowl densities, intensive fox control is proposed for all sites for the life of this plan. The density of active mounds will be used to measure changes in adult malleefowl populations at each site. The possibility of ceasing fox control at three sites to provide critical evidence of fox impacts on adult populations will be reviewed at the end of the term of this plan (given the very low densities, observable increases in the density of active mounds will take at least 5 years).

- Albert’s Lyrebird

Four priority sites for fox control were identified to protect populations of Albert’s lyrebird. These were Nightcap, Border Ranges East, Mt Warning and Mt Jerusalem. In particular, lower activity in lyrebirds has been observed on the edge of these sites than would be predicted from habitat quality alone (Gilmore *in prep*). Surveys to assess the level of fox activity in the first year of the plan will refine the selection of sites. An experiment to measure the impact of fox predation on populations of Albert’s lyrebird will be established by dividing the selected sites between intensive fox control and non-treatment. Albert’s lyrebird and fox populations will be monitored at all sites. If surveys reveal low levels of fox activity at all sites, no fox control will be conducted and the species will be removed from the high priority list.

- Plains-wanderer

Two priority sites for fox control have been identified to protect populations of plains-wanderers. These are North Canargo and Wanganella. An experiment to measure the impact of fox predation on populations of plains-wanderers will be established by undertaking intensive fox control at North Canargo and leaving Wanganella as a non-treatment area. Plains-wanderer and fox populations will be monitored at both sites. Given that both sites are mostly agricultural land, the experiment is dependent on the continued support of local landholders.

- Bellinger River Emydura

The Bellinger River Emydura is restricted to a single site on the upper Bellinger River. The abundance of turtles, juvenile recruitment and nesting success will be monitored with ongoing fox control at this site. The lack of a non-treatment area and replicate sites will limit the rigour of these data as a measure of the impact of fox predation on this species.

- Other high priority threatened species

No attempt will be made to monitor the response of other populations of high priority species to fox control. For some species, individuals may be too cryptic, dispersed or mobile to derive meaningful population indices. Thus, establishing population indices for the long-footed potoroo, bush stone-curlew, chestnut quail-thrush, southern scrub-robin, Australian bustard, centralian blue-tongued lizard, western blue-tongued lizard, Stimson’s python, narrow-banded snake, woma and collared whip-snake will not be attempted. The long-haired rat, flock bronzewing and squatter pigeon may become abundant after heavy rain; at other times these species are cryptic and may be absent from NSW. The Australasian bittern and the brolga are relatively conspicuous. However, the response of these species to fox control is likely to be small relative to fluctuations in factors related to habitat quality.

Under the assumption that populations of these species are limited by fox predation at certain times, the effectiveness of programmes targeting these species will be measured by the response of fox populations to fox control. In practice, this means that fox activity only will be measured at the following sites: Commenderry Swamp, South East Forests (South), Macquarie Marshes, Narren Lakes, Nocoleche, Sturt, Peery Lake and Mungo.

- Measuring changes in fox activity

Changes in fox activity will be measured at most sites. These data will provide a measure of effectiveness of fox control at sites where high priority species are not being monitored directly (as above). Furthermore, they will provide an interim measure of effectiveness at sites included in specific experiments for priority species, because the response of prey populations may take some time. The data will also provide a logical link between fox control and any increases in prey species observed.

For most of the specific experiments, changes in fox activity will be monitored using binary counts of footprints on sandpads placed across roads and tracks (Catling and Burt 1995). This method is likely to provide a reliable measure of changes in activity (Mahon *et al.* 1998). At other sites, bait uptake rates will be used as to measure of changes in fox activity. Although coarse, this measure can be derived from data collected during baiting programmes with little additional effort. The collection of bait uptake data will be standardised to allow comparisons between sites where relevant.

5.5.3 Interactions between predation and habitat fragmentation

In Appendix 2, priority sites for fox control for forest and woodland species were selected partly on the basis of an assessment of the degree of habitat fragmentation. This was done because habitat fragmentation is likely to increase the impacts of fox predation on these species (Section 4). However, the relationship between habitat fragmentation and fox predation has not been measured critically for any of the priority species identified in the plan. For the brush-tailed rock-wallaby, rufous bettong and Albert's lyrebird, the proposed fox-removal experiments could be used to measure the interaction between habitat fragmentation and fox predation if priority sites can be categorised further by the degree of fragmentation. In addition, telemetry studies could be used to determine the level of predation on animals dispersing between patches of habitat. These studies would provide more objective information on the importance of habitat fragmentation in accentuating the impacts of fox predation on these species.

Fox-removal experiments can also be used to test whether the presence of foxes limits the access of these species to resources in cleared or open areas (Section 4). If prey animals reduce foraging in response to the risk of predation, then changes in foraging activity could be used as a surrogate measure of the effectiveness of fox control. Such a measure is likely to respond more rapidly to a reduction in fox populations than prey abundance. More importantly, these data would result in a greater understanding of the impacts of foxes which in turn could effect how fox control is undertaken (Section 4).

Given potential interactions between habitat fragmentation and predation, increased impacts on native species by exotic carnivores (cats, foxes and dogs) as a result of logging and prescribed burning in forest areas has been proposed (May and Norton 1996, May 1997). Thus the *Feral and Introduced Management Plan for Eden Region* (prepared under the *Forestry and National Park Estate Act 1998*) proposes prelogging surveys of these predators in state forests to better target predator control. These efforts draw resources away from other areas where high-priority species persist. However, the underlying assumption that logging increases the activity of these predators and/or the vulnerability of prey has not been tested. This is particularly important for species associated with dense understorey including the black-striped wallaby, parma wallaby, long-nosed potoroo and red-legged pademelon because these species were rated as unlikely to be impacted by fox predation in Appendix 1.

SFNSW, in collaboration with NPWS, will seek additional funding to undertake experiments to measure the effects of logging and prescribed burning on the activity of exotic carnivores and predation rates on selected prey species. NPWS will likewise explore opportunities to undertake collaborative studies with other institutions to investigate interactions between predation and habitat fragmentation for priority species in forest or woodland environments. However, resources to undertake these studies are not provided in this plan.

5.5.4 Interactions between exotic pest species

In Section 4, the potential for fox control to have negative impacts on native fauna and flora through promoting increases in rabbits and cats was described. Thus, NPWS and SFNSW will monitor changes in cat populations at selected priority sites with and without fox control. In particular, these measurements will be incorporated into those experiments where sandpads will be used to monitor fox activity. Ongoing rabbit control programmes are an integral part of the management of many priority sites in western NSW.

5.5.5 Actions and performance criteria

Action 3.1. Undertake the fox-removal experiments described in Section 5.5.2 of the plan.

Performance criteria. Establish new experimental programmes within two years of the date of this plan. Report on the outcomes of all experiments within five years of the date of this plan.

Action 3.2. Measure the response of introduced carnivore populations and changes in predation on dense-understorey prey species as the result of logging and prescribed burning practices.

Performance criteria. Subject to the provision of additional funding, establish and report on experiments within five years of the date of this plan.

Action 3.3. Measure the response of cat populations to fox control at selected priority sites.

Performance criteria. Report on these data as part of the relevant experiments within 5 years of the date of this plan.

5.6 Plan coordination

Objective 4. Provide support for the implementation of the plan.

5.6.1 Plan coordination

Implementing this plan will require the establishment or continuation of fox control programmes at up to 81 sites throughout NSW across a range of land tenures. Furthermore, it will require the design, implementation and analysis of experiments to measure the response of threatened species to fox control at these sites. Given the scale of these actions, a position to coordinate the implementation of the plan will be established. The specific role of the position will be to:

1. coordinate the implementation of fox control at priority sites;
2. coordinate measures of fox activity at priority sites identified as requiring initial assessment;
3. coordinate field trials to be undertaken by NPWS and SFNSW to measure bait uptake by foxes and non-target species as a function of bait station type;

4. complete the best-practice guidelines for fox control;
5. coordinate the implementation of experiments to measure the response of priority threatened species to fox control;
6. review and analyse data collected through the implementation of the plan, particularly from the experiments to measure the response of priority threatened species to fox control; and
7. prepare a revised plan within five years of the date of commencement of this plan.

The NPWS has established a temporary position to evaluate the effectiveness of its pest control programmes. Included in the brief of this position are actions to:

1. design, implement and report on a programme to measure the response of threatened species to fox control programmes established under the *NSW threat abatement plan for predation by the red fox*; and
2. undertake a review of fox control methods and develop best-practice guidelines for fox control for the conservation of native fauna.

The position is funded by the NSW Biodiversity Strategy until February 2003. This position will be extended to fulfill the role of plan coordinator for the duration of the plan.

5.6.2 Actions and performance criteria

Action 4.1. NPWS to support a position to coordinate the implementation of the plan.

Performance criteria. That the current position funded through the NSW Biodiversity Strategy be maintained for the duration of the plan. That the coordinator review the current plan and prepare a second plan within five years of the date of commencement of this plan.

6 ECONOMIC AND SOCIAL IMPACTS OF THE PLAN

The implementation of this plan is likely to have positive, though limited economic benefits for rural producers adjoining priority sites for fox control (Table 5.2). In Section 5.3.7, establishing collaborative programmes with landholders adjoining priority sites to increase the area under fox control was identified as a key action of the plan. This was motivated by the potential to increase the effectiveness of fox control for threatened species by reducing immigration into priority areas (Section 5.4.2). Fox predation may also be a significant source of mortality in new-born lambs; hence, the rural community expends considerable resources on fox control (Saunders *et al*. 1995). Collaborative programmes at priority sites may similarly improve the effectiveness of fox control in reducing impacts on lamb production.

Calculating the economic benefits of these programmes is difficult. Considerable variation in the level of fox predation on viable lambs has been reported, such that the impacts of fox predation on productivity remain unclear (Saunders *et al*. 1995). Saunders *et al*. (1997) attempted to quantify the effects of fox control on lamb production in a fox-removal experiment conducted in the Southern Tablelands of NSW. They observed no significant differences in lamb production between areas baited three-times per year, areas baited prior to lambing only and unbaited areas. Rapid immigration appeared to compensate for fox control as no significant differences in mortality due to fox predation were observed between treatments (cf. Section 5.4.2). However, greater collaboration between landholders is likely to increase the effectiveness of fox control in reducing predation on lambs. Subsequent cost-benefit analysis based on trends in the data suggested that fox control may be beneficial in areas of high lambing productivity (Saunders *et al*. 1997).

This plan establishes priorities for fox control to reduce the impacts of fox predation on threatened species. In doing so, some existing programmes undertaken by NPWS, SFNSW and DLWC may be discontinued (because they are predicted to be of little conservation benefit). Nevertheless, NPWS, SFNSW and DLWC will continue to be involved in many collaborative programmes aimed at reducing the agricultural impacts of fox predation. Furthermore, NPWS and SFNSW will continue wild dog control programmes on reserve boundaries to reduce the impacts of dogs on livestock.

Given the widespread perception of foxes as a threat to native fauna and as an agricultural pest, the implementation of the plan is likely to have positive social outcomes. However, prioritising fox control may have negative social impacts where existing programmes are discontinued. In particular, the perception that foxes cause environmental and/or agricultural damage wherever they persist may lead to the expectation that they should be controlled on all public lands. Public expectation for fox control may be especially great where foxes are more conspicuous, such as in urban reserves and at popular camping sites. However, as discussed in Section 5.4, effective fox control requires intensive and collaborative programmes and thus can only be achieved at a limited number of sites. Given that foxes do not have significant impacts on all prey species, it is expected that the community will generally be supportive of a plan that prioritises fox control for threatened species on the basis of where their impacts are greatest rather than where foxes are most conspicuous.

There are unlikely to be any significant animal welfare issues related to this plan. While animal welfare is an important consideration in the methods employed in fox control (see Saunders *et al*. 1995 for a discussion) this plan does not seek to change the methods currently used. Rather, it directs where and how they are applied. In particular, the best-practice guidelines proposed in Section 5.4.6 aim to minimise the negative impacts of fox control on non-target species while maintaining its effectiveness.

No other economic or social impacts from this plan are envisaged. There are no public health issues related to the implementation of the plan, other than existing considerations related to control methods (e.g. restrictions to the use of 1080 specified in the Off-label Permit; Section 2.1.6). The plan will not effect public access or recreational use of public lands significantly, although some existing baiting programmes to protect shore-nesting birds may limit the use of some beaches to exercise pets. The plan will not effect Development Applications or other activities that require approval under the EP&A Act (Section 2.2.3). No impacts on Aboriginal heritage are expected.

7 ALTERNATIVE MANAGEMENT OPTIONS

There were a number of potential management options considered in the development of this plan that did not result in proposed actions. These options are discussed briefly below.

7.1 No change in current management

At present, public land managers such as NPWS, SFNSW and DLWC are involved in a range of fox control programmes to conserve native fauna at various sites throughout New South Wales. At some of these sites, collaboration with private landholders and local Rural Lands Protection Boards is well established. However, there is a need for an overall strategy for fox control for threatened species because:

- the objectives of some programmes are unclear. In particular, the species that are expected to benefit from fox control are not always identified;
- where target prey species are identified, an objective basis for predicting that populations of the target species are limited by fox predation is not always provided. In particular, there may be no information that species targeted by fox control will benefit other than the observation that they are preyed upon (see Section 4 for a discussion);
- some programmes are likely to be ineffective because baiting is too infrequent and occurs over too small an area to compensate for immigration;
- there is no consistent plan applying across all land tenures. Greater collaboration between landholders is fundamental to the success of control programmes; and
- measures of effectiveness for these programmes are often inadequate and, in particular, do not measure the response of targeted threatened species to fox control. Thus, no feedback is provided as to whether target species are limited by fox predation or whether specific control programmes are effective.

7.2 Fertility control

The *Cooperative Research Centre for Biological Control of Vertebrate Pest Populations* was established by the Commonwealth in 1992 to investigate the potential for the biological control of vertebrate pests. Research focused initially on the development of fertility control for foxes and rabbits facilitated by the immune responses of animals to infection by genetically modified viruses. In theory, a self-disseminating virus could be used to achieve reductions in populations of pest species across the continent.

Due in part to technical difficulties in finding a suitable virus, research has since shifted to the development of bait-delivered fertility control (CRC 1999). Given that such a control method would not be self-disseminating, it could not be used to reduce fox populations on a continental scale. However, such a method could still provide humane, target specific and cost effective fox control that could be applied over large areas. The method would not be used in isolation, but rather be integrated with other control techniques to promote long-term reductions in fox populations. At present, these techniques are still being developed. Review of this plan will allow any future developments in control techniques to be incorporated into the management of foxes for threatened species.

7.3 Broadscale baiting of public lands "Eastern Shield"

As the result of experimental and circumstantial evidence implying that foxes were contributing to the decline of native fauna in south-west Western Australia (Christensen 1980, Kinnear *et al*. 1988, Kinnear 1990, Friend 1996), broadscale aerial baiting of crown lands commenced in 1994 under the *Western Shield* programme (Armstrong 1998). The programme involves the reintroduction of a range of rare and locally extinct species into areas where foxes are being controlled and population monitoring of selected native fauna (Armstrong 1998, de Tores *et al*. 1998). While Armstrong (1998) reported that benefits for a range of fauna have been observed, the success of the programme has been demonstrated most clearly by the significantly enhanced survival of brush-tailed bettongs translocated into areas under fox control (CRC 1999).

The scale and frequency of fox control is critical to the success of the programme. Under *Western Shield* up to 55 000 km^2 of mostly contiguous crown lands are baited aerially four times per year (Armstrong 1998). Frequent baiting over large contiguous areas improves the effectiveness of fox control by reducing immigration into target areas (Thomson *et al*. 1998, CRC 1999; cf. Section 5.4.2). Aerial baiting is possible because much of the fauna native to the area have a high tolerance to 1080, such that the risks of non-target poisoning are low (King *et al*. 1978).

The success of the *Western Shield* programme has motivated interest in establishing broadscale fox control on public lands in eastern Australia (Environment Australia 1999). In New South Wales, there are large contiguous areas of NPWS and State Forest estate which provide habitat for native fauna, particularly along the Great Dividing Range. Broadscale aerial baiting of these areas may similarly facilitate increases in populations of native fauna and the reintroduction of some locally extinct species. However, many fauna native to eastern

Australia have a low tolerance to 1080 compared to their western counterparts (McIlroy 1986). As a result, aerial baiting cannot be undertaken in many areas without potential negative impacts on some native species (McIlroy 1999; Section 5.4.5). In this plan, aerial baiting is advocated only in some reserves in the west of the state. Ground baiting, using techniques such as those proposed in the interim best practice guidelines (Section 5.4.6), is not achievable on the remaining public lands which provide habitat for native fauna.

As discussed in Section 4, foxes do not have a significant impact on populations of all species they prey upon. Furthermore, there are many areas where foxes are likely to be rare or absent, such as within areas of continuous forest in north-eastern New South Wales (Catling and Burt 1995, Williams and Marshall 2000). Therefore, sites for fox control can be prioritised to focus on areas where the impacts of foxes are likely to be greatest. Given that these areas of habitat are often fragmented, collaboration with surrounding landholders will be imperative to the success of fox control. Collaborative fox control programmes at sites where foxes are likely to be having greatest impacts on threatened fauna is the central objective of this plan.

7.4 Fox bounties

The control of fox populations through a bounty system has often been proposed as a method of reducing the impacts of foxes on native fauna and agriculture. However, reducing fox densities in any one area by shooting is likely to require considerable and ongoing effort (e.g. Newsome *et al*. 1989). Those animals most susceptible to shooting are often young and inexperienced. Thus bounties are unlikely to achieve broadscale reductions in fox numbers (Saunders *et al*. 1995). Bounties cannot be used to target fox control in priority areas.

7.5 Other priorities

Having acknowledged that fox control needs to be prioritised, there are many bases for selecting priority areas other than that proposed in this plan. Given that the overall objective of this plan is to reduce the impacts of foxes on threatened fauna, prioritisation must be based on impacts and not on fox densities. However, given that the impacts of fox predation on most native fauna are unknown, some objective criteria for predicting impacts from available data are necessary. Many such models are possible. The model proposed in this plan (Appendix 1) follows that proposed by Dickman (1996b) to predict the impacts on cats on native fauna, modified to take account of data on fox impacts. The key point is that the experiments proposed in Section 5.5 are used to provide feedback on the response of these species to fox control, thereby providing long-term justification for fox control on a species by species basis.

8 COSTS AND IMPLEMENTATION

8.1 Summary of costs and implementation

The total cost of implementing the plan is estimated to be $7.4 million over 5 years ($1.4-1.7 million per year). Table 8.1 partitions the total cost of the plan by year, action and agency responsible for implementing each action. The assumptions used to estimate the costs are outlined in Section 8.2. A complete costing by programme is available from the plan coordinator.

8.2 Costing assumptions

8.2.1 Priority fox control programmes

The costs of undertaking fox control at each of the priority sites (Action 1.1) were calculated assuming the use of best-practice methods (Section 5.4.6). Thus, where spotted-tailed quolls are likely to be present, costings are based on a twelve-day programme with daily monitoring of bait stations. This includes two days to establish bait stations. Where quolls are likely to be absent, costings typically assume a two-day programme which includes relaying baits after several days. The frequency of most programmes is assumed to be 4-12 times per year depending on the size and environment of the site. However, these frequencies are indicative only as the frequency of baiting programmes will vary in response to measures of fox activity at each site (see Section 5.5.1).

At the majority of priority sites listed for shore-nesting birds, weekly servicing of bait stations is assumed from 4 weeks prior to nesting until juveniles have fledged (14-22 weeks, depending on species and site). More frequent monitoring (e.g. daily) is assumed at some sites with high levels of human or domestic animal activity. Costs for exclusion fencing are included at some key sites where baiting is restricted (Section 5.4.4).

The estimated costs of fox control at Yathong and Nombinnie/Round Hill sites are based on the existing aerial and ground baiting programmes. These programmes are undertaken three times per year.

Salary costs for undertaking fox control are based on the pay rate for a Technical Officer Grade 2 year 3 ($25.72/hr). This is the highest grade of Technical Officer and reflects the level of many NPWS and SFNSW staff currently involved in pest control. Calculations of salary costs include 25% oncosts. A camping allowance of $80/night has been budgeted for several sites remote from operating bases. Vehicles are costed at 42 c/km. Vehicle costs are based on site-specific estimates of the distances covered to undertake fox control. The cost of baits and other consumables have been estimated and included.

Costs for fox control at priority sites designated as non-treatment sites in experiments to measure impact are not included (see Section 5.5.2). However, non-treatment sites for the proposed experiments for brush-tailed rock-wallaby, rufous bettong and Albert's lyrebird can not be designated until the preliminary assessment of sites has occurred (Action 1.2). Thus, for the purposes of costing the plan, half of the experimental sites for each species were selected arbitrarily as non-treatment sites. The costs of fox control at these sites are not included.

Costs for undertaking preliminary assessment of fox activity at new sites for brush-tailed rock wallabies, rufous bettong and Albert's lyrebird (Action 1.2) are based on two measurements of fox activity in the first year. The measure will be based on counts of footprints on sandplots over three consecutive days (Catling and Burt 1995, Mahon *et al*. 1998). Initial measures of brush-tailed rock-wallaby, rufous bettong and Albert's lyrebird populations at each site are also costed for; these data will provide the first year's data in experiments to measure impact where sites are subsequently rated as priority sites for fox control. Preliminary surveys to locate and map colonies of brush-tailed rock wallabies at new sites have been estimated and included.

8.2.2 Effective fox control programmes

No additional costs are identified for establishing collaborative fox control programmes with private landholders adjacent to priority sites (Action 2.1), although it will inevitably involve some staff time of participating agencies. However, funds to buy additional baits for use on adjacent private lands have been allowed for in costing fox control at some of the priority sites.

No additional costs were identified for field trials to measure bait uptake by foxes and non-target species as a function of bait station type (Action 2.2). These trials will be incorporated into fox control at priority sites (Action 1.1). Planning for these trials and subsequent data analysis will be done by the plan coordinator; these costs are covered in Action 4.1.

Field studies to assess mortality in spotted-tailed quolls during buried baiting programmes for foxes have commenced (Action 2.3). This project is being undertaken by the NPWS

Biodiversity Research and Management Division. Funding for the first year of this project has been obtained from the *Natural Heritage Trust* and NPWS Threatened Species funds.

No additional costs were identified for the preparation of best-practice guidelines (Action 2.4). These will be done by the plan coordinator; these costs are covered in Action 4.1.

8.2.3 Experiments measuring the response of prey species to fox control

Experiments to measure the response of yellow-footed rock wallabies, broad-toothed rats and southern brown bandicoots to fox control have commenced (Action 3.1). Monitoring of smoky mice and shore-nesting birds with fox control has been established. Costings for these actions follow the existing programmes. Assumed survey methods and sampling designs used in calculating the costs of proposed experiments for the brush-tailed rock-wallaby, rufous bettong, Albert's lyrebird, black-striped wallaby, malleefowl, plains-wanderer and Bellinger River emydura are available from the plan coordinator.

Changes in fox activity at experimental sites for the brush-tailed rock-wallaby, rufous bettong, Albert's lyrebird and southern brown bandicoot will be measured biannually using counts of footprints on sandplots (as before). Fox activity at experimental sites for the broad-toothed rat (Snowy Mountains and Kosciuszko North) will be monitored biannually using counts of prints on snow transects. At sites for black-striped wallabies and plains-wanderers, fox activity will be measured using spotlight counts. Costings for these actions are available from the plan coordinator. At other priority sites, fox activity will be measured using bait uptake rates. The costs of undertaking these counts are incorporated into the costs of fox control (Action 1.1). However, opportunities to establish more robust measures of fox activity based on counts of footprints on sandplots at these sites will be explored.

Costings for measuring the response of introduced carnivore populations and changes in the rate of predation on dense-understorey prey in response to logging and prescribed burning are available from the plan coordinator.

8.2.4 Plan coordination

The *NSW Biodiversity Strategy Implementation Group* has provided $80 000 per year for three years to fund and resource a position to measure the effectiveness of NPWS pest control programmes. This project will be completed in February 2003. It is assumed that extending this position to fulfill the role of plan coordinator for the life of the plan will require the same level of resources.

8.3 Review of the plan

This threat abatement plan will be implemented over a five-year period. Subsequent analysis of data from monitoring programmes will allow both the priorities for fox control to be reviewed and the methods employed in fox control to be refined. A revised plan will then be prepared.

Table 8.1 Summary of costs and implementation.

Action	Description	Agency	Year 1 ($,000)	Year 2 ($,000)	Year 3 ($,000)	Year 4 ($,000)	Year 5 ($,000)
1.1	Fox control at priority sites	NPWS	573	674	674	674	674
		SFNSW	53	211	211	211	211
		DLWC	27	27	27	27	27
1.2	Preliminary assessment of new sites	NPWS	186	0	0	0	0
		SFNSW	91	0	0	0	0
2.1	Establish collaborative programmes	NPWS SFNSW DLWC	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0
2.2	Experiments on bait station type	NPWS SFNSW	0 0	0 0	0 0	0 0	0 0
2.3	Quoll mortality study	NPWS	176	31	0	0	0
2.4	Complete best-practice guidelines	NPWS	0	0	0	0	0
3.1	Measuring the response of threatened species to fox control	NPWS	239	340	340	340	340
		SFNSW	26	97	97	97	97
3.2	Measuring predation/logging interactions	SFNSW	227[1]	0	0	0	0
3.3	Measuring the response of cats	NPWS, SFNSW	0 0	0 0	0 0	0 0	0 0
4.1	Provide organisational support	NPWS	80	80	80	80	80
	Annual cost of plan		**1687**	**1460**	**1429**	**1429**	**1429**

1 SFNSW in collaboration with NPWS will seek additional funding for this research project.