An assessment of habitat manipulation as a fox control strategy

Final Report to the National Feral Animal Control Program

A report from Deakin University and the Dandenong Creek Valley Co-ordinated Fox Control Committee

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Objectives of project

The main objective of this project was to determine if habitat manipulation has the potential to be used as a viable fox control strategy in agro/urban environments. This method of control was proposed because control options are limited at the urban agricultural interface due to risks associated with the use of poisons. Broadly, the project aimed to determine if there were any resources in the system that were selected or favoured by foxes that could be manipulated and converted to a less favoured state.

To determine this we needed to:-

- Characterise the seasonal diet of foxes in this environment and determine if any food resources could be manipulated.
- Characterise the home range size and habitat use of foxes in this environment to determine if foxes select specific habitats.
- Determine what habitats can be manipulated and suggest what effect such control may have on fox populations.

The following report is based on the work we conducted to determine what resources could be manipulated. We were unable to get to a stage of manipulating the actual resources due to difficulties associated with collecting the data on resource selection by foxes, and time shortages towards the conclusion of this project.

Introduction

In Australia many mammalian species have become extinct in the period since European settlement and many more have had their range and numbers severely restricted. The introduced predator Red Fox *Vulpes vulpes* has been implicated as one of the contributors to the decline of native species throughout Australia, particularly the critical weight range (35-5500 g) herbivores (Burbidge and McKenzie 1989; Morton 1990) and ground-dwelling birds (Catling and Burt 1995).

Foxes were introduced to Victoria in 1871 (Rolls 1969). Since that time they have become widespread over most of mainland Australia following the spread of the European Rabbit *Oryctolagus cuniculus* and Brown Hare *Lepus capensis* (Jarman 1986). In the United Kingdom foxes are abundant in urban areas where densities have been reported to be as high as 20 foxes per km^2 in Oxford and Bristol (Harris 1981).

Foxes were first reported in the Melbourne metropolitan area in the 1930s and are now common throughout the urban zone with densities of 16 foxes per km^2 (Seebeck 1977; Marks and Bloomfield 1999). This compares with rural areas where densities are reported at 3.5 – 7 foxes per km^2 (Coman *et al.* 1991).

The fox is a declared vermin species and as a result is the focus of pest management programs throughout Australia. These programs usually target

the population by increasing the level of mortality the population is subjected to. Poison baiting, shooting and trapping are the most common methods used to control mortality. The success of such programs is largely dependant on the size of the area treated, the intensity of treatment and the duration of treatment. Mortality based control, however, is limited in its effect due to the high fecundity of foxes and their ability to disperse long distances and recolonise treated areas. More recent attempts have been made to develop immunocontraceptive techniques that will target the fecundity of foxes. These techniques are not yet available but may be an important facit in the integrated control of fox populations.

The management of foxes in urban areas and at the urban agricultural interface is becoming increasingly difficult due to the lack of safe management options. In most cases baiting and shooting are not possible with den fumigation being one of the few practical control options available to managers. Techniques need to be developed that can be utilised in the urban environment and also enhance integrated management in agricultural areas. A potentially safe method of control that could be used in the urban environment is habitat manipulation. This type of strategy relies on manipulating the resources that allow populations to reach densities where they become a problem rather than attempting to manipulate the mortality of the population. The development of such strategies is dependant on a sound understanding of the relationship between the animal and its habitat. Currently, we have limited knowledge of how habitat and the subsequent resources within habitats drive fox population dynamics, and hence this study

was initiated to help fill this gap in our understanding.

The study of home range use, habitat selection within home ranges and diet are important aspects of ecology that allow us to develop ecological based management strategies for wildlife. Understanding what habitats or dietary items are selected or favoured by wildlife has aided in the development of both pest and conservation strategies. A number of these strategies are based on the concept of habitat manipulation, where favoured habitats are modified to less favourable habitats in the case of pest management (eg: Sullivan *et al*. 1998, White *et al*. 1997 & 1998) or habitats are modified to make them more favourable to wildlife in the case of conservation management (eg: provision of nest boxes to replace hollows post logging)

This report discusses aspects of fox habitat use and diet within the Dandenong Creek Valley with the aim of using this information to develop a habitat manipulation based management strategy. This approach is new to predator management, with most habitat manipulation strategies for pests targeting small herbivorous mammals such as rodents.

Materials and methods

Study sites

The Dandenong Creek Valley is a semi-urban riparian corridor in Melbourne's outer eastern suburbs, comprising a mix of parklands, farmlands, golf courses and waste refuse stations bordered on both sides by residential and commercial factory developments. The study area is 13 km long and 1-3 km wide.

Common to the Valley is the riparian zone and floodplains of the Creek. These consist of wetlands, ponds and small lakes throughout the study zone. Some native vegetation remnants remain although degraded and heavily invaded by weeds. Prior and current land use of the area involves a variety of farming enterprises such as sheep, cattle and goat farming. The area also has many fruit orchards and horse agistment paddocks. The eastern side is designated as a reserve for a proposed freeway development and has extensive weed infestations, cattle paddocks and horse paddocks. The entire area is bordered by residential areas, caravan parks and sporting clubs.

Live capture and handling

Foxes were captured over a 17 month period from November 2000 to April 2002 using Victor Soft-Catch™ traps (Woodstream Corporation, Lititz, PA, USA). Traps were set just below ground level and tethered to a peg driven below ground level. The traps were set along tracks, against fallen trees and fence holes and at other locations considered suitable for capturing foxes.

Trap sets were baited with meat baits (chicken, beef, salami) or lure (anal gland lure, synthetic fermented egg, tuna oil) or both.

Upon capture, foxes were anaesthetized with an intramuscular injection of Zoletil 100 (actives tiletamine and zolazepam) at a rate of 0.5-1ml per 5 kg of body mass. Each fox was fitted with a transmitter collar (150-151 MHz; Sirtrack™ Ltd, Havelock North, New Zealand). The transmitters had a duty cycle of 24 hours on and 24 hours off, potentially yielding a battery life of 2 years. Sedated animals were placed in the nearest available cover, to the point of capture, and left to recover.

Telemetry

Radio collared animals were tracked on foot using a Titley™ radio receiver with a three element Yagi antennae. Locations of foxes were recorded on an aerial photo and the type of habitat the animal was in was also recorded. Fox locations were taken during both the night and the day to reveal the nature of diurnal and nocturnal habitat selection. To avoid autocorrelation of locations (Swihart and Slade, 1985) only one daytime location was taken per day, meaning that at a maximum one diurnal location could be acquired every two days). Animals were more likely to move at night and hence reducing the risk of autocorrelation, we were therefore able to take more night time fox locations. The maximum number of night locations taken was four with a minimum of 1 hour between each location.

Home range estimation

All the locations for each animal (diurnal and nocturnal) were entered into the Biotas© home range analysis software package (Sallee, 2003). Both diurnal and nocturnal locations were used to estimate home range area because foxes have diurnal and nocturnal range shifts, and therefore any estimate of home range must incorporate the entire activity cycle of the animal (Harris *et al.*, 1990). Home range areas were determined using the minimum convex polygon (MCP) method (Mohr, 1947; Southward, 1966). This method was utilised because it is the most commonly reported method in the literature (Harris *et al.*, 1990) and therefore allows for some comparison with other studies. The harmonic mean home range estimator (Dixon and Chapman, 1980) was also used to estimate home range size (95% and 75% activity isopleths), shape and core areas of activity (50% activity isopleths). This method of estimation, while not without problems, showed the best performance in simulation trials of five estimators which also included the MCP (Boulanger and White, 1990).

Habitat assessment

To determine the availability of different habitat types within the foxes home range it was necessary to define a series of broad habitat types. We chose to lump habitats types into several groups which were based on vegetation structure. The final result was a group of 4 different habitat types: patches of blackberry and gorse; Native vegetation with a dense understorey (referred to as dense native vegetation); long unmanaged grass and reed beds; and areas of short grass and paddock.

Blackberry and gorse patches were often associated with areas that were largely unmanaged by landholders. Both these species form thickets offering high structure from the ground to a height of two metres. Areas of native vegetation with dense understorey also had high structure from the ground up to two metres. This structure was largely associated with native grasses and shrubs. Long grass and reed beds provided some structure at the ground level, however many of these areas were temporally inundated by water. The short grass and paddock habitat type was the broadest habitat type and represented areas with limited structure to a height of three metres. Other than paddocks, this habitat type also included areas of bare ground and also managed wind breaks with limited ground based vegetation.

All the areas where radio-tracking was being conducted were mapped for habitat types and then entered into a GIS layer. Once the home range analysis had being conducted this layer was utilised to estimate the amount of each habitat type that was in each fox's home range.

Dietary studies

Five 1 km^2 sites were randomly throughout the study area. These sites represented a variety of land uses including managed parklands, golf courses, farmland used for horse and cattle grazing, bike and walking paths, a waste refuse disposal landfill site and a field maintained for model aeroplane flying.

Each month for a period of one year the sites were searched on foot for fox scats. Although dogs and cats were also present in the study area, only fox scats were collected and these were determined by shape, size and likely contents as described by Triggs (1996).

Each scat was placed in a separate manilla envelope, which was labelled with site, transect and date (Brunner and Wallis 1986). The envelopes were placed in an oven and heated to 100^{o}C for at least 24 hours to kill any parasites that might be present. Scats were then washed in a sieve of 1 mm mesh size to separate the contents for easy analysis, placed back into their envelopes and dried in the oven.

When dry the contents were sorted using a dissecting microscope and grouped into eight main categories: mammal remains, bones, invertebrates, feathers, blackberry, seeds, vegetation and unidentifiable items. An estimate of the amount of each item in the scat was recorded (to the nearest 5% of composition) for each category. Any hair present in the scat was identified under a microscope using the techniques of whole mount and cross section as per Brunner and Coman (1974).

Data analysis

To determine if foxes were showing preference to particular habitats in their home range, Johnson's (1980) rank based preference technique was used. The proportional use of habitats both during the day and at night were compared to the proportional availability of habitats in the animal's home

range, described by Johnson (1980) as third order selection. The analysis was conducted using Prefer© (Pankratz and Schwartz, 1994). Where significant differences occurred between availability and use of habitats the Waller and Duncan (1969) method was used to determine the nature of these differences.

Results

Home range and habitat use

The ranging behaviour of foxes was determined from nine individuals. This involved 847 independent telemetry locations, at an average of 94±20 (mean± 1SE) fixes per fox (table 1). The mean home range size of foxes in this study was 44.6ha ± 13.2 (mean ± 1SE) when using the minimum convex polygon. Home range analysis using the harmonic mean 95% isopleth suggest the average home range size may be as small as 23.9 ha ± 5.7 (mean ± 1SE). The core component of the home range (HM 50%), representing the area most utilized, was only 1.8 ha ± 0.4 (mean ± 1SE) (Table 1).

Table 1. Home range estimates for all foxes. Estimates are derived from the minimum convex polygon method (MCP) and the harmonic mean method (HM) at 95%, 75% and 50% utilisation isopleths.

Fox	Number of locations		Duration	Home range estimates (ha)			
	Diurnal	Nocturnal	(Days)	MCP	HM 95%	HM 75%	HM 50%
F1	100	104	520	47.9	37.1	8.9	2.9
F2	87	94	485	21.9	20.5	9.1	1.8
F3	36	43	472	28.1	17.8	3.9	1.4
M1	35	42	98	19.2	14.5	3.6	0.5
M2	44	53	202	30.7	26.7	6.1	1.0
M3	31	40	113	22.3	11.6	3.1	1.5
M4	29	37	74	152.6	63.5	14.6	4.4
M5	14	24	35	29.6	11.7	8.0	1.8
M6	12	22	39	49.0	12.1	3.1	0.5
		Mean ± 1SE		44.6±13.2	23.9±5.7	6.7±1.3	1.8±0.4

The availability of different habitat types within the home range of foxes differed significantly ($F_{(3,32)}$=52.485, $p<0.01$), with areas of short managed grass being by far the most abundant habitat type (59.8% ± 8.5% of home range (mean ± 1SE)). Areas of blackberry/gorse, long grass and reeds, and dense native vegetation were all equally available within the animals' home ranges, all be it, at lower amounts than areas of short managed grass (SNK $p>0.05$) (Figure 1).

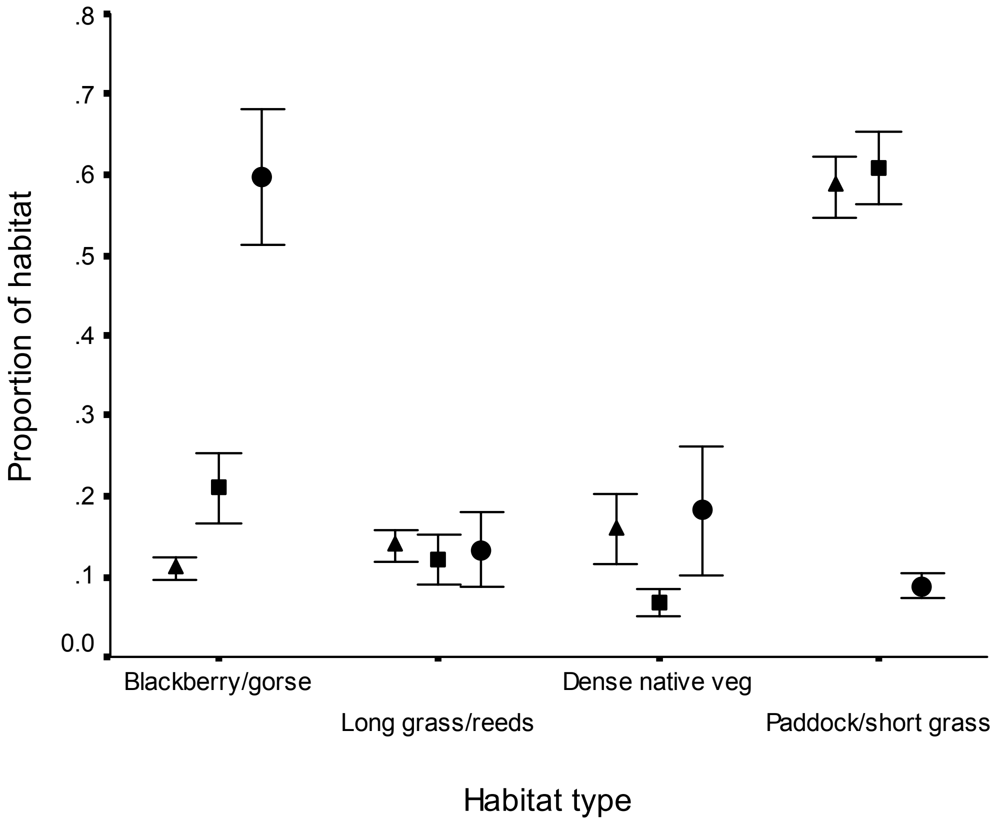

Figure 1. The proportion of each habitat type available in the foxes 95% home range (▲) compared with the nocturnal use (■) and the diurnal usage (●). Error bars represent mean ± 1 standard error.

In order to determine habitat preference of foxes within their home range the use of particular habitats was compared to the availability of habitats. During

the night foxes exhibited no third order selection of habitats within their home range ($F_{(3,6)}$=2.214, p>0.05), suggesting that nocturnal habitat use is random (figure 1). During the day however, foxes exhibited significant preference for habitats within their home range ($F_{(3,6)}$=31.658, p<0.01). Foxes exhibited a significant preference for blackberry and gorse over all other habitat types during the day, with the least favoured habitat being paddock or areas of short grass (figure 1; table 2).

Table 2. Ranking matrix for diurnal habitat selection by foxes, comparing proportions of radio locations of each animal in each habitat with the proportion of each habitat available in the 95% harmonic mean home range of each animal.

	Blackberry or Gorse	Dense native Vegetation	Long grass or reeds	Paddock or short grass	Rank
Blackberry or Gorse		++	++	++	3
Dense native Vegetation	--		NS	+	=2
Long grass or reeds	--	NS		++	=2
Paddock or short grass	--	-	--		1

The sign shows whether the habitat placed in the corresponding row was more or less (sign + or -) important than the corresponding column. A single sign represents a significant deviation from random at p<0.05 and a double sign represents a significant deviation from random at p<0.01, differences are based on the Waller and Duncan (1969) multiple comparison procedure. Habitats were ranked according to their importance from one (the least important habitat) to three (the most important).

When the proportion of habitats in the 95% home range was compared to the proportion of habitats available in the core areas (50% HR), a significant

change in composition occurred ($F_{(3,32)}$=25.350, p<0.001). The resulting change in composition indicated blackberry and gorse became more prevalent in the core areas and paddocks and short grassy habitats became less prevalent in the core areas (Figure 2). These results are all suggesting that blackberry and gorse are providing critical resources to foxes in this study. This is probably highlighted more by their preference for these habitats during the day.

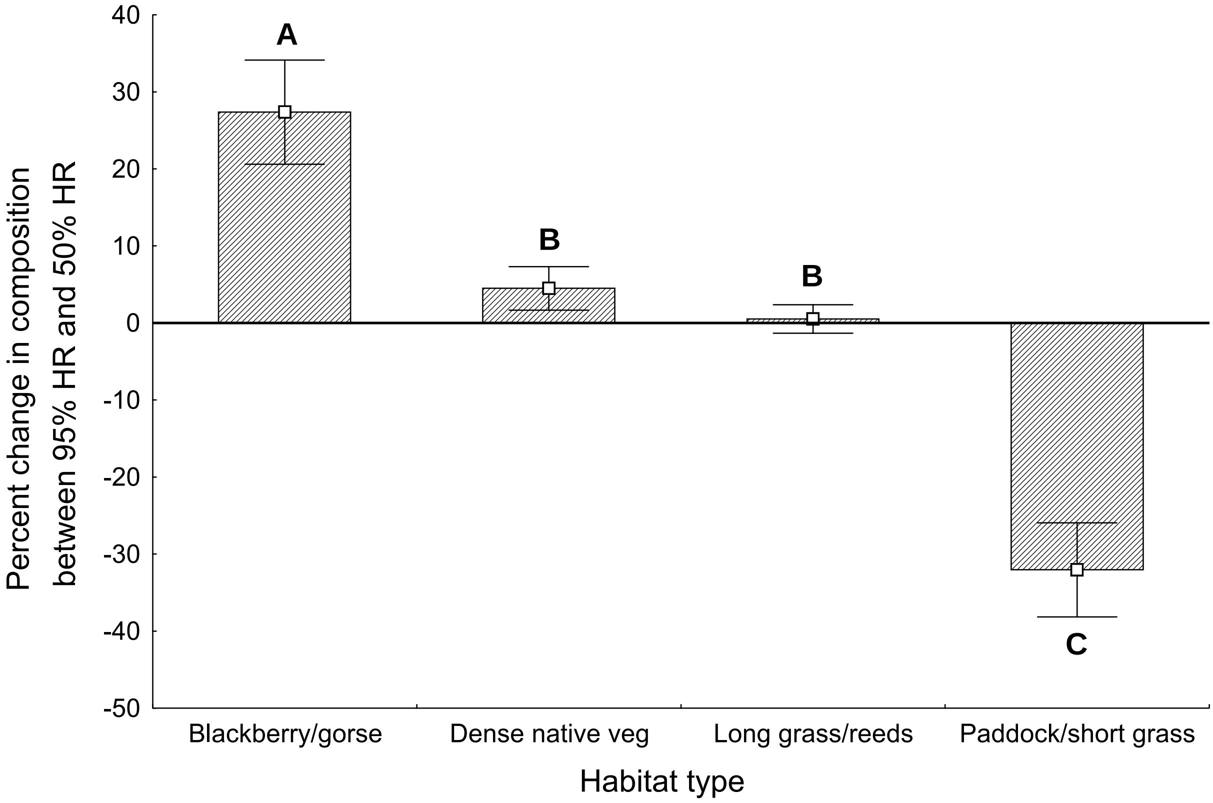

Figure 2. Percent change (mean ± 1SE) of different habitat components between the 95% harmonic mean home range and the 50% harmonic mean home range (core). Values greater than zero indicate and increase in that component in the 50% home range when compared to the 95% home range. Letters associated with error bars indicate homologous subgroups as revealed by the Student Newman Keuls test (α = 0.05).

Dietary studies

A total of 1317 fox scats were collected and analysed across four seasons from all five sites. The number of scats collected varied according to season ($F_{(3,16)}$=6.889, p=0.003) with significantly more scats occurring in summer and autumn than in winter and spring (SNK $p<0.05$).

The proportion of each broad dietary category was compared across seasons to determine if there were any differences. The proportion of mammalian prey in the diet did not differ significantly between seasons ($F_{(3,16)}$=1.441, p=0.268) and contributed to 21.8% of the fox diet. A non-significant trend does suggest that mammals may be more important in the diet during the winter and spring (figure 3). Five mammalian species contributed to the presence of mammals in the diet: brushtail possum, ringtail possum, European rabbit, black rat, house mouse and the sugar glider. While it was not possible to determine the relative contribution of these species to the overall diet of the foxes, it was possible to determine what species of mammal were in scats with mammalian hair present (n=514). The ringtail possum, black rat, rabbit and brushtail possum were the most commonly encountered mammals in the scats of foxes (Table 3). No significant trends occurred in the presence of these species across seasons. The brushtail possum, however, did appear to be more common during the spring, when population densities are likely to be at their highest. The black rat also appeared to be more common in the diet during the autumn and winter. This period of time would also be when the population is at its highest with the influx of juveniles in to the population after the spring and summer breeding.

Bone fragments contributed to 12% of the diet. It is not possible to determine the origin of these fragments, but it is likely that a great deal of these fragments were the result of scavenging discarded food scraps as there was often no hair in the scats. The proportion of bone fragments in the diet did not differ significantly between seasons ($F_{(3,16)}$=0.659, p=0.589) (figure 3).

Bird remains contributed to 5.2% of the annual diet and did not differ significantly across seasons ($F_{(3,16)}$=1.466, p=0.261) (figure 3). It was not possible to determine which species of birds had been consumed.

Invertebrates contributed a significant amount to the annual diet (17.9%). The proportion of insects in the diet differed significantly across seasons ($F_{(3,16)}$=3.257, p=0.049), with more occurring in the spring diet than in the winter diet (SNK p<0.05) (figure 3), this period of time also coincides with the period where insect densities are at their highest..

The proportion of blackberry seeds in the diet differed with season ($F_{(3,16)}$=30.515, p<0.001). Blackberry seeds were absent from the diet in winter and spring, but contributed significantly to the summer autumn diet (figure 3). As blackberries are only available for a period of three to four months of the year they appear to be a very important food source when they are available.

Other seeds while contributing a fairly small amount to the diet (1.8%) differed significantly between seasons ($F_{(3,16)}$=3.706, p=0.034). Seeds were more common in the summer diet than the winter and spring diet (SNK p<0.05) (figure 3). These seeds are mainly associated with animals eating plums, apples and pears, all of which are grown in the area.

A significant amount of unidentified vegetation also occurred in the diet (9.5%). The proportion did not differ significantly between seasons ($F_{(3,16)}$=0.053, p=0.983) (figure 3).

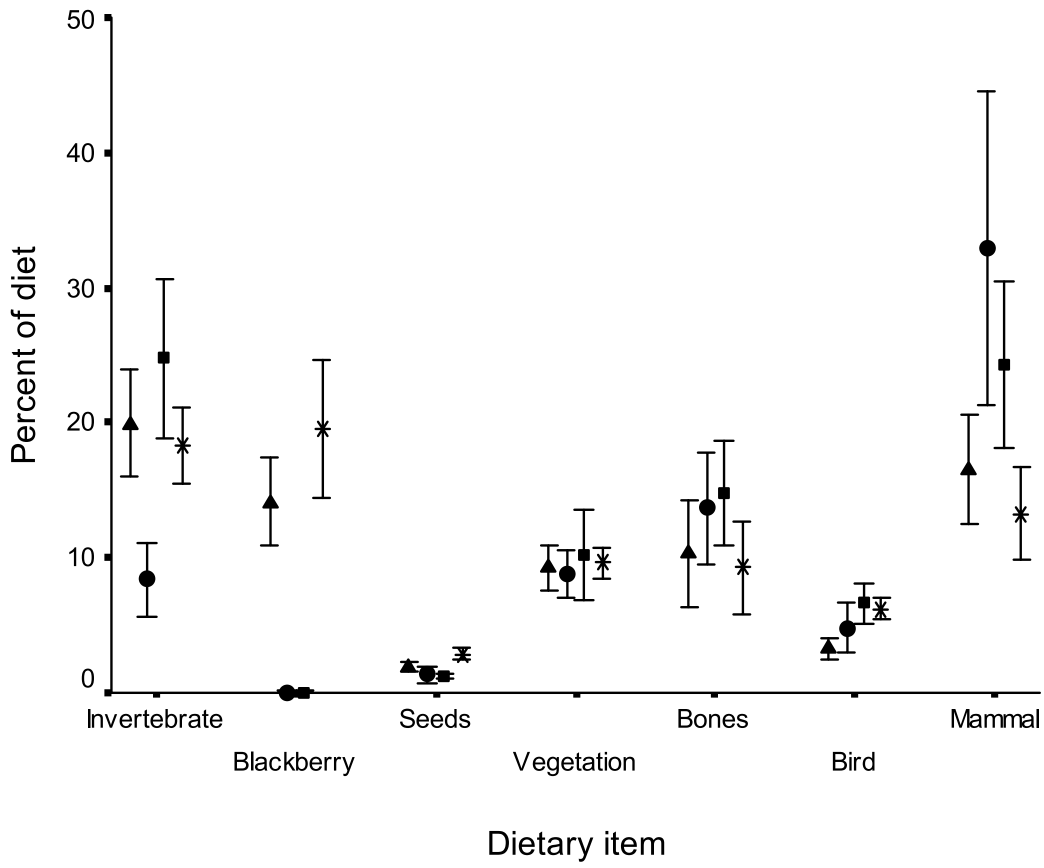

Figure 3. Seasonal dietary composition of foxes in the Dandenong creek valley. ▲=Autumn, ●=Winter, ■=Spring, ✱=Summer. Error bars represent the mean (± 1SE) percentage of each item in the diet.

Table 3. Percentage presence of mammalian hair in scats by season. All values are the percentage of scats containing mammalian hair. Values are not independent as the same scat can contain remains of more than one species.

Species	Season				% total	Total No.
	Autumn	Winter	Spring	Summer	for year	of scats
Ringtail possum	22	24	20	28	26.3	135
Brushtail possum	14	17	33	16	17.3	89
Sugar glider	0	0	3	1	0.4	2
Black rat	34	26	15	11	23.2	119
House mouse	21	17	3	13	12.6	65
Rabbit	13	13	15	18	18.1	93

Discussion

This project has been successful in providing baseline data on the use of habitats by foxes in the urban/agro interface. This type of information has not been previously provided in Australia, with most fox habitat use results concentrating more on home range size based on nocturnal data than exclusively targeting data on the use of specific habitats (e.g. Saunders *et al.* 2002).

The home range sizes reported in this study (44.6 ha by MCP method) are very small in comparison to most reported studies of fox home range size in Australia. Coman *et al.* 1991, reported home range sizes in the order of 90 hectares in suburban areas, and 600 hectares in agricultural areas of Victoria. Home range estimates from Saunders *et al*. 2002 in agricultural areas of NSW were approximately 300 hectares. Why are the home ranges of the foxes in this study so small? The answer probably lies in the availability of resources in the system this study was conducted in. There is an established relationship between home range size and resource availability for many species, with home range size decreasing as resources availability in an area increase (e.g. Damuth, 1991; Fridell and Litvaitis, 1991; Harestad and Bunnell, 1979). We propose that the incredibly small home ranges of animals in this study are the result of extremely high resource loads in the environment. A further relationship exists between home range size and the density of animals. As home range size decreases the carrying capacity of an area increases. This relationship would help to explain why fox densities are so high in urban fringe areas, given the small home range sizes. Overall, the

high fox densities in the urban fringe environments are the result of overabundant resources, with the resources that are generally attributed to changes in home range size being food and shelter.

The use of habitat at night suggests that foxes utilise their habitat at random and therefore nocturnal habitat use provides us with few opportunities for the development of a habitat manipulation strategy for foxes. The habitat use during the day, however, is far more revealing. Foxes during the day are showing a strong preference to patches of blackberry or gorse over all other habitat types. This suggests that the resource of dense structure for 'safe' diurnal resting sites may be involved in limiting fox populations.

The dietary results from this study, like the nocturnal habitat use data, suggest very little as far as the development of a management strategy for foxes. The fox diet is highly variable throughout the year and is composed of many different food items. Most of these food items appear to be used at times when you would expect these items to be most abundant in the environment (e.g. black rats more common in autumn and winter and blackberry more common in summer and autumn). Overall, the diet data suggests that foxes take advantage of all food resources as they become available.

These results provide us with a great deal of information to generate a potential management strategy for foxes in urban fringe areas. Foxes make strong and active selection of specific habitat types for diurnal resting areas. These habitats are comprised of two weed species (blackberry and gorse).

The availability of these two species of plant could be reduced dramatically by good land management practices. Effectively a habitat manipulation strategy for fox control could be developed on the basis of removing blackberry and gorse.

What effect would the removal of blackberry and gorse have on fox densities? It is most likely that removal of these species would have a significant effect on the availability of safe diurnal resting resources. A reduction of such a resource would force animals to increase their home range sizes to include diurnal resting habitats. This in turn should reduce the density of foxes in these areas due to increased competition for a depleted resource. If these habitats are almost completely removed we would expect to see a significant reduction in the density of foxes that can be maintained in these areas. This process has been described as a population following a negative feedback loop (Caughley and Sinclair, 1994). This is also the attractive aspect of habitat manipulation, as we can expect the population to maintain itself at this lowered density if the resource is maintained at low levels. This is conceptually different to mortality based control strategies where the population, once reduced in density, is continually trying to rebound towards the density that the resources in the system are dictating.

Developing such a strategy based on the removal of blackberry and gorse has a number of advantages. It allows us to integrate pest and weed management into one strategy that encourages good land use practices. Removal of these types of habitat should also have flow on effects for other

pest species such as rabbits and the black rat, both of which utilise blackberry and gorse. Reduction in the two species and the absence of blackberry as a summer/autumn food resource should further enhance any density reduction associated with the removal of these habitats. If the density of foxes is associated with the availability of patches of dense structural vegetation it is highly likely that this strategy could be carried to many agricultural areas. Other than blackberry and gorse which are widely spread in southern Australia, plants such as box thorn and lantana may also be capable of providing a similar resource in other areas. Hence this strategy may be transferable to other sites. Integrating this strategy with current baiting programs should have large long term effects on fox densities in many agricultural areas.

These results while representing very strong relationships should be viewed with a little care. Of the 27 animals that were collared we were only able to get enough radio locations for 9 animals. This is only a small sample and it may be beneficial to get information on more animals across a variety of land tenures. To get this information it will probably be worth investigating satellite tracking as an alternative method of data collection.

Where to from here?

The Dandenong Creek Valley Co-ordinated Fox Control Committee is dedicated to reducing fox densities in the area. This research has provided valuable information from which to develop a management strategy. Removal of blackberry and gorse is now being viewed and encouraged as a strategy for

controlling foxes. The committee is currently developing brochures on this strategy and the media are being approached to get this information to the public. We are also continuing to present seminars to local community groups to encourage up take of the strategy. Our main focus now is uptake and developing a long term monitoring strategy.

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Attachments

Attachment 1. Budget statement for NFACP grant.

Attachment 2. Copy of paper in the Victorian Naturalist.