

**Habitat use in a population of mainland Tasmanian feral  
cats, *Felis catus*.**

**by**

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## ABSTRACT

This study examined various aspects of the spatial ecology and diet of a mainland Tasmanian population of feral domestic cats, *Felis catus*, to provide data relevant to planning and implementing feral cat control programs.

Radio telemetry was used to quantify home ranges in three cats, two males and one female. Home ranges were relatively small for wild living feral cats, mean range area being 125 ha for males and 35 hectares for females. Home range size varied seasonally in males but not in females. Increases in male home range area, unusual movements and changes in den use occurred in July and August indicating this to be the mating season. Male cats ranged widely in search of receptive females.

Home range overlap varied extensively depending on sex and season. Inter-sexual overlap was extensive, all cats overlapped with at least one cat of the opposite sex. Intra-sexual overlap between males varied between the non-mating and mating season. Overlap was extensive in the non-mating season with adult males sharing core areas. However, overlap in the mating season was minimal and restricted to the edges of ranges. This suggested that seasonal territoriality occurred between the males in response to competition for a limited number of female cats.

Feral cats exhibited habitat preferences favouring habitats which included at least some ground cover and avoiding habitat where ground cover was absent, even where prey was abundant. Patchy type habitats were the most utilised and was favoured for foraging activity. This reflected prey availability in those areas, and the cover which the habitat provides for hunting. Dense habitat was favoured for the location of den sites.

The feral cats at Sandford were active throughout the period between dusk and dawn, while little activity occurred during the day. Distances travelled per hour were greatest at dawn and dusk, probably indicating that the (male) cats were moving to

and from foraging areas as opposed to actively hunting. Hunting probably occurs throughout the night, as the main prey species were nocturnal not crepuscular.

The diet of the feral cats at Sandford was dominated by introduced mammals, in particular rabbits. However, diet did not reflect prey availability. The occurrence of small native mammals in the diet was not consistent with their apparent abundance in the study area. This indicated that cats may selectively prey on these species.

The study concluded that the control of feral cat populations on a large scale in mainland Tasmania is not justifiable. However, selective control may be necessary and beneficial in special cases, such as to protect seabird rookeries and vulnerable or endangered populations of native animals.

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## Chapter 1

### 1.1 General introduction

Feral domestic cats *Felis catus* have long been recognised as posing a significant threat to indigenous fauna's around the world. Their introduction to new environments has frequently been associated with large scale changes in the abundance of indigenous fauna, particularly on islands (Merton 1977; Wilson *et al.* 1992). Even the earliest European visitors to New Zealand recognised and commented on the impact that domestic cats had on the avifauna of that region (King 1984). The domestic cat was introduced to Australia by the early European settlers, but it is probable that they also arrived earlier than this via shipwrecks on the north west coast or South-east Asian traders (Rolls 1969; Anon. 1994). Feral cats now occupy most habitats in Australia from arid deserts to the tropical north (Frith 1979), and many offshore islands (Anon. 1994).

Island faunas are particularly susceptible to introduced predators as those communities have generally evolved without mammalian predators and so lack well developed anti-predatory strategies (King 1984). With the introduction of predators such as domestic cats, these "naive" species are rapidly decimated, often becoming extinct in a relatively short period. Nesting seabirds typically comprise significant proportions of cats' total diet on islands (Anderson and Condry 1974; Jones 1977; FitzGerald *et al.* 1991; Chapuis *et al.* 1994), although where humans have introduced other species such as rabbits, mice and rats, these may also be major contributors to dietary intake (Jones 1977; Van Rensburg 1985; Tidemann *et al.* 1994).

Unlike island faunas, Australia's fauna have evolved with various small and medium sized terrestrial predators, mammalian and reptilian (King 1984), so anti-predatory behaviour was innate. The arrival of the cat would therefore not have resulted in a

profound influence on naive prey species as occurs on islands. However, habitat fragmentation and drought can effectively produce island conditions in mainland environments (Newsome 1991) and the impact that cats have had on isolated and remnant populations of small/medium native mammals has been reported to replicate the impact cats have had on 'real' islands (Spencer 1991; Horsup and Evans 1993). So while the exact impact due to cats in Australia is unclear and generally less dramatic than on islands, there is little doubt that cats have had a major impact and been the cause of various indigenous species going locally extinct, if not totally extinct.

The impact that introduced cats have had on 'mainland' or continental environments, such as Australia, is less clear than their impact on islands. Despite many studies having been carried out to assess their present impact by examining diet, the nature and severity of impacts are still unclear (Coman and Brunner 1972; Jones and Coman 1982; Triggs *et al.* 1984; Catling 1988). Although feral cat impact has generally been assumed to be severe, particularly on the small native fauna (Frith 1979), it is difficult to isolate the impact solely due to cats from that due to the introduced fox and other broad scale ecological changes that have occurred since European settlement (Jones 1987). In this context, Tasmania's fox free status provides an ideal location in which the impact of the cat can be isolated from that of the fox.

The utility of examining home range and related issues in a pest species is that a knowledge of these issues is essential in assessing appropriate control strategies (Bomford 1990) and allows management decisions to be made concerning how, where and when population reduction programs should take place. Home range size and the degree of overlap between individuals can also provide an indication of potential population densities in a given population and therefore potential impact on the species in an area.

While the diet of feral cats has received much attention in previous research, the spatial

and social aspects of feral cat ecology has received significantly less. Social organisation in feral cats is very flexible. Depending on the environment, feral cats may live in colonies or small groups (Neville 1989) or revert to a solitary social system (Jones 1987). In general, urban cats are more likely to associate in colonies, (e.g. Neville 1989), while rural cats may live in small groups or individually (e.g. Langham 1991), and cats occupying "natural" habitats tend to revert to a solitary social structure (Jones 1987; Jones and Coman 1982). Various social aspects of the ecology of *F. catus*, have been investigated, in particular the social organisation of rural (farm) and urban cats (Liberg 1980; Haspel and Calhoun 1989; Langham and Porter 1991 and Page *et al.* 1992). However, the spatial aspects of the ecology of 'wild' living feral cats, i.e. those having no contact with humans, has received little attention. In Australia only one previous study (Jones and Coman 1982) has examined the spatial ecology of feral cats. This was carried out in semi arid Victoria and so has little relevance to the Tasmanian situation.

## **1.2 Aims.**

The aims of this study were therefore to:

- 1) determine (i), overall home-ranges, (ii), seasonal variation in home-ranges, (iii), the extent of inter- and intra-sexual overlap of home-ranges;
- 2) determine whether feral cats show habitat preferences;
- 3) examine activity patterns;
- 4) assess diet in relation to prey availability.

## Chapter 2. The study site

### 2.1 Study site

The study site was located at Sandford (147°28' E and 42°57' S), 14 kilometres south east of Hobart adjoining Ralph's Bay and the Derwent Estuary, covering an area of approximately 4 km<sup>2</sup> (Fig.2.1). The northern end of the site is an intensively managed grazing property carrying sheep, while the southern end is a "derelict" farm which has not carried stock for several years.

#### 2.1.1 Vegetation

The site consisted of low rolling hills with woodland dominated by *Eucalyptus* spp. particularly *E. amygdalina* and *E. tenuiramis* with some areas of *E. globulus*. The understorey and ground cover included *Bedfordia salicina*, *Acacia dealbata*, *Dodonea viscosa*, *Cassinia aculeata*, *Exocarpus cupressiformis*, *Astroloma humifusum*, *Bursaria spinosa*, *Pultenea juniperina*, *Haloragis teucroides* and *Epacris impressa* (Davies 1988). Ground cover ranged from absent to dense. The southern section of the site had more understorey than the northern section. Sheltered gullies and lower hill slopes supported denser vegetation and a more developed understorey. The site also included areas of improved pasture, grasslands and regenerating areas of *Acacia dealbata* (Fig.2.1). The site was bordered on the west and south by Ralph's Bay with the coast line consisting of sandy beaches and extensive rocky shore platforms. Sand dunes were limited to a small area at the extreme north of the west coast.

#### 2.1.2 Geology

The geology of the area consisted predominantly of quartz sandstone and siltstone with soils being podsollic, very shallow and stoney and, as a result, very susceptible to erosion (Davies 1988). Flooding and waterlogging was common along drainage lines in several areas of the site. The upper hill slopes had extremely shallow soils with many areas suffering extensive erosion.

### **2.1.3 Study Period**

The study ran from late April to August 1995 with home range data being collected from June to August. Home-range data were collected continuously throughout that period, while fauna surveys were carried out an average of once a week from late April to August.

### **2.1.4 The cat population**

The local feral cat population was estimated to be at least seven, including one semi-domestic cat which frequently spent several days away from its residence. Of the seven individuals, two were known to be females and three to be males (including the semi domestic). The remaining two cats were of unknown sex. Corroborating evidence for the presence of untrapped cats included sightings of unknown cats, tracks and regular visits by males to areas during the mating season.

The estimated cat population indicated a cat density of approximately two per km<sup>2</sup> which was comparable to other populations of solitary wild living feral cats around the world; e.g. 0.74-2.4 per km<sup>2</sup>, semi-arid Victoria (Jones and Coman 1982), 1.1 per km<sup>2</sup> in New Zealand (FitzGerald and Karl 1986), but was substantially lower than the densities reported in feral cats more closely associated with humans, e.g. 10-15 per km<sup>2</sup> in Bristol, UK (Page *et al.* 1992), while densities of over 2000 per km<sup>2</sup> have been reported (Liberg and Sandell 1988).

On the present study site feral cats were regularly shot by the local landholder; however, as the site is reported to be a frequent 'dump site' for unwanted pet cats and litters of kittens, the local feral population is probably continuously replenished. Local residents were aware of the presence of only three resident cats, of which only one was trapped and collared during the study. The two other cats trapped on the site during the study were previously unknown by local residents, despite both using areas very near to houses. This illustrates the highly cryptic nature of feral cats and their ability to inhabit areas without being detected by humans. Taking this into account, it is quite likely that the estimates for both the total population and density of cats on the site are under-estimates.



Key to vegetation types;

- 1. *Eucalyptus* spp. woodland
- 2. open pasture
- 3. mixed forest and scrub
- 4. bracken and regrowth *Acacia* scrub.

**Figure 2.1** A view of the study site showing vegetation types and the boundary between the grazing property in the north, and the derelict farm in the south.

## CHAPTER 3. Home-range in the domestic cat *Felis catus*.

### 3.1 Introduction

The home-range of an animal has been defined as that area which an animal uses to obtain all of its normal nutritional, spatial and reproductive requirements (Burt 1943). Home range size is closely linked to the food requirements of the individual and the availability of that food in the environment (Linn 1984). A further advantage of home ranges stems from the occupants' familiarity with the area, enabling more efficient use of resources within it (Linn 1984). The concept of *home range* differs significantly from the concept of *territory*; territoriality involves some degree of defence, home range does not (Linn 1984).

Home ranges of cats have been examined in various habitat types and under varying degrees of association with man. The domestic cat has been found to exhibit a high degree of variation in home-range size, generally in response to food supplies and habitat type (Jones 1989). The size of their home ranges has been found to vary about 1000 fold (Liberg and Sandell 1988) in relation to a number of factors. Generally, the closer the association with humans the smaller a cats' home range will be. Urban cats have smaller home ranges (e.g. males 2.6 ha, females 1.7 ha; Haspell and Calhoun 1989;) than rural cats (e.g. males 240 ha, females 86 ha; Langham and Porter 1991), while rural cats consistently have smaller home ranges than cats living in the wild without any contact with humans (e.g. males 620 ha, females 170 ha; Jones and Coman 1982).

Spacing and home range size in populations of free living carnivores may also be determined by social organisation and social status (Liberg 1980). Male cats generally have larger home ranges than do females, typical of animals with a polygynous mating system (Gosling and Baker 1989). Male home ranges are on average 3.5 times larger (Liberg and Sandell 1988). Male home ranges generally overlap the ranges of several females while there are varying degrees of intra-sexual overlap. Intra-sexually exclusive home ranges have been reported for males (Jones and Coman 1982; Liberg 1980), while high levels of overlap have also been reported

in both sexes (Konecny 1987; FitzGerald and Karl 1986). Males have larger home range areas for both behavioural and physiological reasons (Langham and Porter 1991). A larger home range size increases the number of females a male is able to access, thereby potentially increasing its reproductive success. The influence of body weight is also significant and can account for a large portion of the variation between sexes in mammalian home range size (Harestead and Brunnel 1979). Gender differences in body weight accounted for the observed differences in home range size in free ranging urban cats in Brooklyn, New York (Haspel and Calhoun 1989), however, home range sizes for wild living feral cats on the Galapagos Islands showed no significant relationship with body weight (Konecny 1987). These differences illustrate that both food and reproductive requirements are capable of determining home range area depending on which is more or less abundant.

The size of home ranges and the extent of home-range overlap, especially intra-sexually, have important ramifications for the management of feral cat populations. They ultimately determine population densities and the feasibility of fertility control as a management tool, and also affect the implementation of trapping and poison baiting regimes. It is therefore essential to quantify home range as a precursor to management attempts. However, there have been no previous studies which have examined the spatial organisation in a Tasmanian population of feral cats. The aim of this chapter is therefore, to determine (i) home range size in a population of Tasmanian mainland feral cats, (ii) whether seasonal variation in home range size occurs, (iii) the extent of intra- and inter-sexual overlap of home ranges.

## **3.2 Methods**

### **3.2.1 *Determining home-range***

#### **3.2.1.1 *Location of cats***

There are various alternative methods available to determine home range, including;

1. Capture/mark/recapture and observation: this method is not very suitable

for studying cats as they are very elusive, and difficult to trap. It is therefore unlikely that sufficient data could be collected. Capture/mark/recapture is very intrusive and can cause changes in behaviour, including complete re-location of home range.

2. Satellite telemetry: would be ideal for the long term and seasonal home range component of the study but would be inappropriate for the activity component, due to the limited number of readings possible. Satellite telemetry is also very expensive.

3. Radio telemetry: allows location and activity data to be collected without disturbing the subjects normal behaviour and at moderate cost.

Radio telemetry was used to determine home-ranges. This method has the benefit of being unobtrusive and not affecting animal behaviour. Individual cats were caught in Mascot cage traps baited with fish meal pellets, restrained, and sedated with Zoletil (0.1 mg/kg). Radio collars (Sirtrack, NZ) weighing approximately 42 grams and transmitting on 151 MHz were then fitted, after which the cats were released.

The position of instrumented cats was fixed by triangulation. A compass bearing was taken for each cat from three different positions in the study area using a hand held Yagi directional antennae (Sirtrack, NZ) and Regal 2000 telemetry receiver (Titly Electronics, NSW). There was 400-500 metres between each successive position, the location of which were recorded on a base map. Collection of data for one 'triangulation' took 10-15 minutes from first to last fix. These fixes were then transferred to a base map of the area.

Due to the time lag of up to 15 minutes per fix there was potential for some error in the results. Calculating the potential distance travelled in 15 minutes from the mean value for distance travelled per hour in the most active hour indicated cats would move a maximum of 125 metres in that period and generally substantially less. This was considered to be acceptable, considering the scale of the home ranges being measured.

### 3.2.2 Analysis of data

Radio tracking involves locating instrumented individuals at given intervals and recording those locations in a systematic cartesian fashion. When transferred to a base map of the area the locations provide data on the attributes of an individuals home range; the extremities and infrequently visited areas and the "core" areas, or areas most frequently used. Various methods of analysis have been developed to quantify these parameters. These can be broadly classified into parametric and non-parametric techniques (Wray *et al.* 1992a). This study used examples of both types.

#### 3.2.2.1 *Minimum convex polygon method*

The minimum convex polygon method (MCP), a non-parametric method, defines the home range as the smallest convex polygon enclosing all the location points for an individual (Macdonald *et al.* 1980). This method has the advantage of being relatively simple and, as it has been one of the most commonly used in the analysis of home range data (Anderson 1982), it provides comparability with previous studies (Kenward 1992). However, it does have significant disadvantages including:

- (i) the method is very sensitive to movements on the periphery of the animal's home range (i.e. outliers), irrespective of the frequency with which that area is visited,

- (ii) large areas of land which are never visited can be included within the polygon if the animal's range is an irregular shape (Macdonald *et al.* 1980).

As a result, MCP may not accurately represent the minimum area of a home range. However, it does represent the minimum perimeter of a home range (Voigt and Tinline 1980), and thus the habitat types and neighbours it can potentially encounter (Kenward 1992). MCP was principally used in this study for comparison with other studies and for the calculation of habitat preferences.

#### 3.2.2.2 *Harmonic mean analysis*

Harmonic mean analysis (HMA), a parametric method, defines a harmonic mean centre of activity and correlates isopleths with areas of equal activity, thus excluding

areas of non-activity (Dixon and Chapman 1980). This method recognises that most animals do not utilise their whole home ranges equally and so, by calculating centres of activity and animal activity areas, it illustrates not only the overall home range but also major centres of activity. This is achieved by having isopleths correlating with areas of equal activity and excluding areas of non-activity (Dixon and Chapman 1980). As a result HMA gives a close approximation of the true pattern of use of a home range, as well as being able to define home ranges of any shape. This allows close comparisons to be made between an animal's activity and its habitat (Dixon and Chapman 1980). Certain conditions can however, result in poor home range depiction. Home range isopleths (i.e. 95%) for distributions that are strongly linear or disjunct, tend to encircle large areas of unused habitat (Spencer and Barret 1984). In this situation isopleths containing less than 80% of fixes correspond closely with the activity distribution and accurately define the core areas (Spencer and Barret 1984).

### **3.3 Estimation of number of fixes required**

To assess whether the values calculated for the overall home range size were an accurate representation of the animal's home ranges, the data were analysed to determine whether calculated home range areas had reached an asymptote or were still increasing with sample size (Wray *et al.* 1992b). The number of fixes required to reach an asymptote varies depending on the home range analysis method being used. With the convex minimum polygon method asymptotes can be reached with 25-50 fixes spread over a period of at least two weeks, while around 40-60 fixes may be required to obtain areal asymptotes with harmonic mean analysis (Kenward 1992). The presence of an areal asymptote was determined for the results of both harmonic mean and minimum convex polygon methods by plotting 'area of range' as determined by each method against 'randomly selected number of fixes'. Using the HMA results, the data for one of the males and the female collared during the study (section 3.4) produced asymptotes at around 25 fixes (Fig. 3.1). However, data for the second male collared in the study did not reach an asymptote, indicating more fixes were required to reach an asymptote with this analysis method. This was

probably a result of that individual's pattern of home range use (see section 3.4.3). Using the MCP results both males reached asymptotes at around 25 fixes, while the data from the female produced a less pronounced asymptote (Fig. 3.2). Incremental analysis was only carried out for the June/July data for both males as this was the period of most stable range use. After the end of July they continually expanded their ranges, therefore attaining an asymptote via incremental analysis was impossible. In contrast, due to the small total sample size ( $n = 40$ ), the females' complete data set was used.

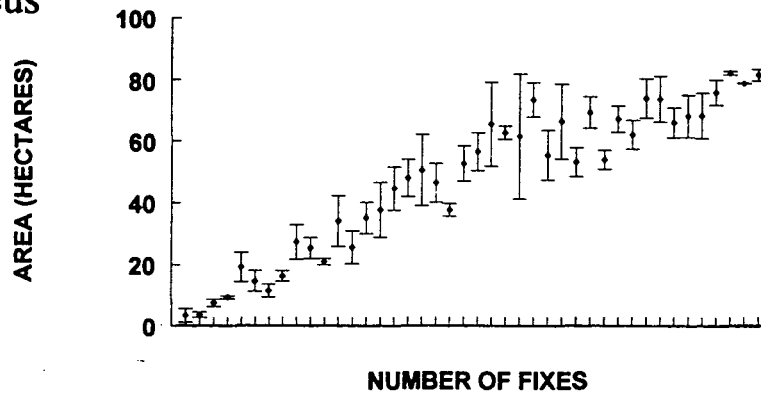
### **3.4 Results**

170 'trap nights' over 18 trapping sessions resulted in 3 cats being caught, 2 adult males and 1 adult female. A fourth cat, an adult semi-domestic male was collared in mid August, however this coincided with an apparent bout of 'domestication' as he rarely left the house during the remaining tracking sessions. Prior to being collared and immediately after the collar was removed, he was frequently absent for several days at a time. Cats were monitored over a three month period from the start of June to the end of August, with the number of locations generally numbering between one and six per day, several days a week. Amadeus and Leo, both adult males, were trapped on the same night within 100 metres of each other. Initially their home ranges almost totally overlapped although this changed after several weeks when Leo moved his centre of activity 800 metres north west. Suzi, an adult female, occupied a home range generally discrete from the two collared males, but which overlapped considerably with Morrabin, the semi-domestic male.

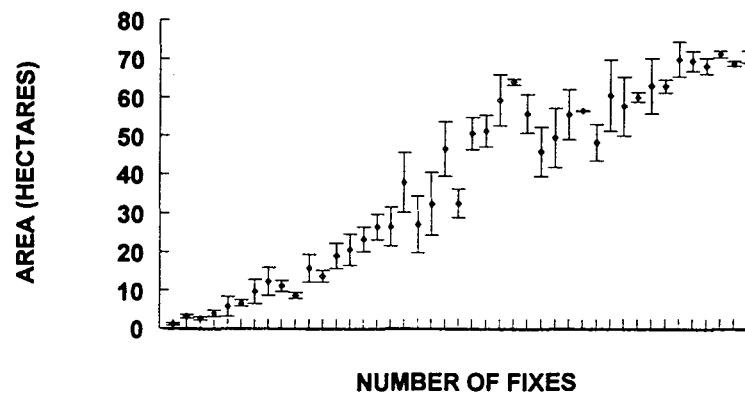
#### **3.4.1 Overall home range**

Overall home ranges (calculated by HMA) ranged from a minimum of 35 hectares in the female, to a maximum of 150 hectares for one of the males. The different results for range area calculated by the two analysis methods (Table 3.1) illustrate limitations present in both methods. Firstly, the larger area for MCP for the two males was due to the inclusion of areas not actually visited by them. In this case HMA provided the more accurate representation of range area. The reverse was true

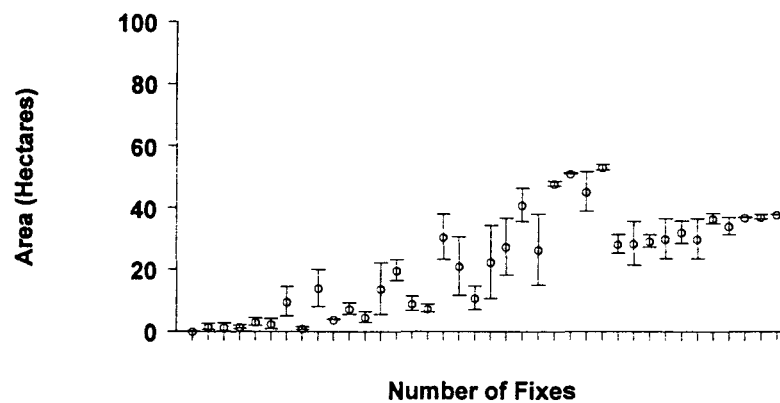
Amadeus



Leo

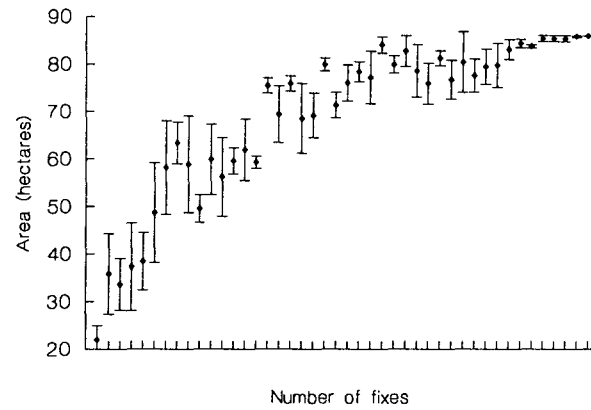


Suzi

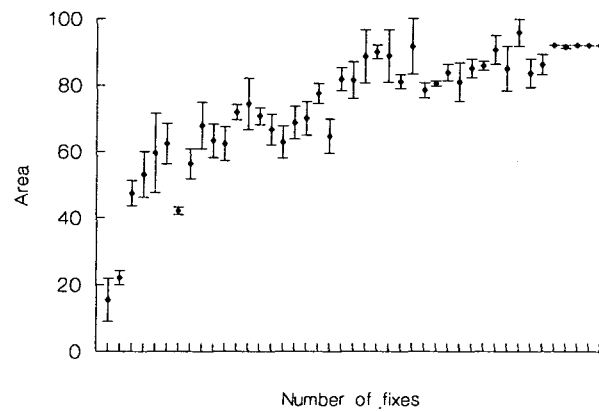


**Figure 3.1** Incremental analysis of HMA home range. Asymptotes indicate home range area is stable with increasing sample size.

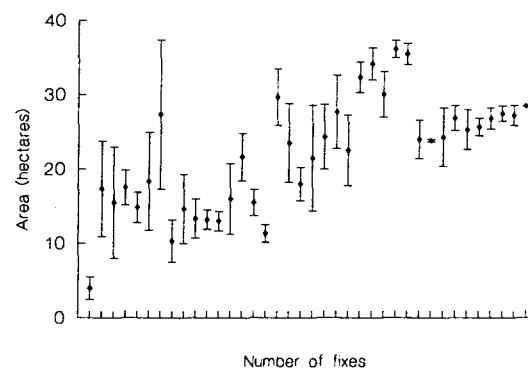
## Amadeus



## Leo



## Suzi



**Figure 3.2** Incremental analysis of MCP home range. Asymptotes indicate home range area is stable with increasing sample size.

for Suzi as, due to her range being linear, the 95% isopleth 'ballooned' in to unvisited areas (Section 3.2.1.2). Therefore, in this case the MCP provided the more accurate representation.

**Table 3.1.** Overall home ranges determined by radio telemetry for 3 feral cats. Range areas calculated using minimum convex polygon (MCP) and harmonic mean analysis (HMA)

Individual	Status	Tracking period	No. of locations	Home range (hectares)	
				MCP	HMA
Amadeus	adult male	6/6-27/8/95	143	175.5	149.2
Leo	adult male	6/6-27/8/95	98	132.0	101.4
Suzi	adult female	26/5-26/8/95	40	28.5	35.2

### 3.3.2 Seasonal variation

The home-range component of the study was conducted from June to August, which encompassed both the non-mating season and the mating season. Data were analysed to determine whether the home range area utilised altered during this period.

The major seasonal variation during the study period was considered to be "non-mating season" and "mating season", with the former being the period to the end of June and the latter in July and August. Data collection in July was restricted resulting in relatively few locations for both male cats ( $n = 21$  for Amadeus,  $n = 10$  for Leo), and none for Suzi, the smaller home range sizes for that month reflects this. Incremental analysis (section 3.3) suggests that the area calculated for Amadeus probably only slightly under represents the true size of his range for that period using either MCP or HMA. In comparison, HMA greatly under estimates Leo's range area (see Fig. 3.2), while MCP, although still under estimating range size by at least 33% would provide a more useful representation of range area (Fig. 3.1). Suzi was

particularly hard to locate for the first two months of the study, as a result of the small number of fixes in that period her data has been ignored for analysis of seasonal variation. The monthly breakdown of results as determined by HMA are shown in Table 3.2. and results for MCP in Table 3.3.

**Table 3.2.** Seasonal variation in home ranges areas, determined by harmonic mean analysis, of two male cats, showing number of locations.

INDIVIDUAL	HOME RANGE AREA (Ha) USING HMA					
	Non mating		Mating season			
	JUNE		JULY		AUGUST	
	Area	Fixes	Area	Fixes	Area	Fixes
Amadeus	73.17	38	63.1	21	123.2	61
Leo	48.52	36	4.4	10	103.4	81

**Table 3.3.** Seasonal variation in home ranges areas, determined by minimum convex polygon method, of two male cats , showing number of locations.

INDIVIDUAL	HOME RANGE AREA (Ha) USING MCP					
	Non mating		Mating season			
	JUNE		JULY		AUGUST	
	Area	Fixes	Area	Fixes	Area	Fixes
Amadeus	80.5	38	128.5	21	136	61
Leo	90.5	36	19	10	116	81

Both males exhibited differences in their patterns of home range use which correlated with the onset of the mating season. Amadeus utilised the same den site almost exclusively throughout June and the first half of July. Around dusk he moved out and headed rapidly to an area a kilometre north where he spent most of the night

foraging, returning to his den at around dawn (Fig 3.3). In mid July he used another den site for a period of several days, which was known to be associated with a female suspected to be in oestrus. In August he then began to regularly stay at another location approximately 500 metres south of the normal limits of his range. Despite being two kilometres from his usual foraging area he still travelled there each night, returning to his normal den site or the new one the following morning (Fig. 3.3). The new site was within the home range of a cat of unknown sex.

Similarly, Leo had a regular pattern of home range utilisation which involved remaining in relatively small areas for several weeks after which he moved his centre of activity to another area (Fig. 3.4). In August this changed and he undertook several long movements out of his previous range area but returned to his core area. He then began regularly visiting one of these sites.



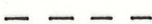
### ***3.3.3 Home-range overlap***

Inter- and intra-sexual overlap was assessed by comparison of the cats' home-ranges as determined by radio telemetry, as well as the minimum home ranges of other resident feral cats known to be on the site. The degree of overlap varied considerably during the study. All of the 7 cats known to be present on the site overlapped with the range of at least one other cat. Amadeus and Leo shared a core area for several weeks in June and a third cat of unknown sex or status (i.e. resident or transient) was observed in the same area on one occasion in the same period. From the end of June the overlap between the two males decreased. Unfortunately, due to only one female being collared in the study, no data were obtained concerning female intra-sexual overlap. The following section will therefore refer only to the males.

#### ***3.3.3.1 Intra-sexual overlap***

The degree of estimated overlap between the instrumented males varied considerably depending on the analysis method, time frame of the analysis and the isopleth value used. Both ranges were disjunct with large areas of unused habitat included within the 95% isopleth (Spencer and Barret 1984) and MCP outline. Therefore, use of an



den sites:   
June nightly movement:   
August nightly movement: 

**Figure 3.3** Den site location relative to foraging areas in June and August, illustrating the change in den use during the mating season.



**Figure 3.4** Leo's shifting pattern of home range use, illustrating the location of his various centres of activity. Each 'core' area was occupied for approximately 3-4 weeks.

isopleth value below 80% was required to more accurately describe the activity distributions and core areas (Spencer and Barret 1984). The 75% isopleth produced range morphologies closely resembling those expected as determined by the 'field workers estimate' (Macdonald *et al.* 1980).

Overlap peaked in June when the cats shared 33.4% to 43.0% of their ranges after which overlap greatly decreased; in July it was 0.2% to 1.1% and in August 4.7 to 8.0% (Fig. 3.5.).

**Table 3.4.** Monthly overlap matrix for Leo and Amadeus using (i) the 75% isopleth value (HMA) and (ii) the minimum convex polygon method, showing the percentage overlap of range areas on range areas. Range areas in rows are overlapped by range areas in columns, and bold figures represent overlap between the two individuals for each month. The two tables clearly illustrate the exaggeration of overlap using the MCP method of determining range area.

Table 3.4. (i) Harmonic mean analysis overlap

	Leo/June	Leo/July	Leo/Aug.	Am./June	Am./July	Am./Aug.
Leo/June	100	5.6	16.6	<b>43</b>	30.2	35.4
July	77	100	0.0	0.0	<b>1.1</b>	13.4
Aug.	12.7	0.0	100	<b>8.4</b>	11.3	<b>8.0</b>
Am./June	<b>33.4</b>	0.0	8.2	100	33.3	62.5
July	49.1	<b>0.2</b>	22.6	68.8	100	71.5
Aug.	14.9	0.5	<b>4.7</b>	33.1	18.5	100

Table 3.5. (ii) Minimum convex polygon overlap.

	Leo/June	Leo/July	Leo/Aug.	Am./June	Am./July	Am./Aug.
Leo/June	100	17.9	100	<b>50.1</b>	36.1	49.8
July	88.2	100	100	49.5	<b>41.2</b>	35.1
Aug.	59.9	12.7	100	37.6	30.7	<b>46.6</b>
Am./June	<b>55.1</b>	11.4	68.2	100	67.8	86.6
July	49.0	<b>11.7</b>	69.8	83.2	100	89.0
Aug.	32.9	4.9	<b>51.5</b>	52.8	43.7	100

### 3.3.3.2 *Inter-sexual overlap*

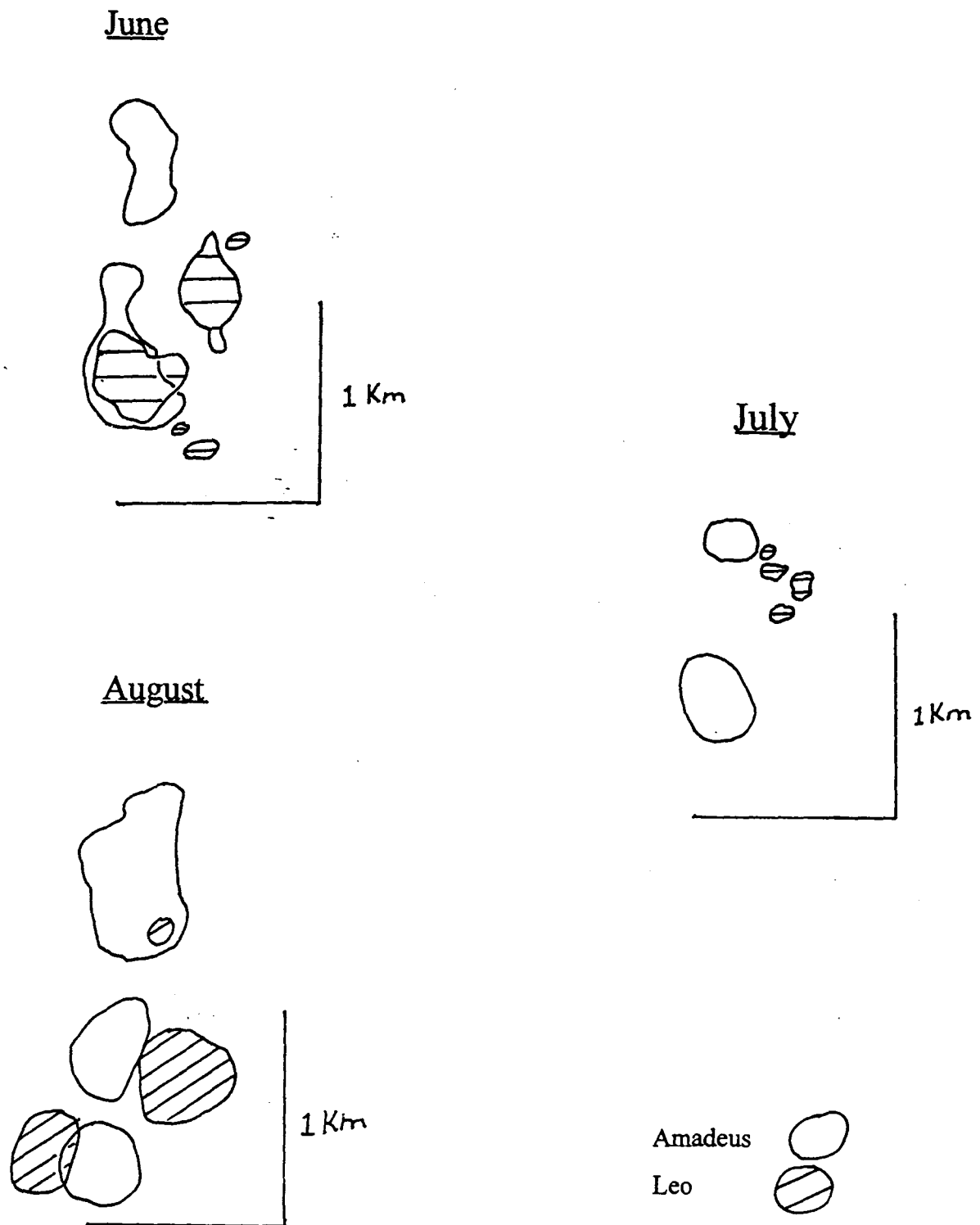
Few direct data were obtained from this study due to only one female being collared and her range being discrete from the two principle males. The fourth cat collared in the study, a semi-domestic male, which provided only a small amount of data, was known to almost completely overlap with Suzi, including the core area of her range. Another female cat was known to have a home range which overlapped considerably with both Leo and Amadeus' ranges. It is clear then, that intersexual overlap occurs and females can overlap with more than one male (Fig. 3.6).

## 3.4 Discussion

### 3.4.1 *Overall home-ranges*

There have been very few studies of home-range in truly feral cats (i.e. those having no association with man), (Table 3.5).

All the above studies (Jones and Coman 1982; FitzGerald and Karl 1986; Konecny 1987) employed radio telemetry to obtain data, however, only Konecny (1987; Galapagos Is) carried out nocturnal locations. Although the time of day that cats are most active can vary greatly, they usually tend to be crepuscular (Bradshaw 1992), suggesting that the results gained from daytime studies may under-estimate the real sizes of the home-ranges and also the full extent of home-range overlap. This



**Figure 3.5** Changes in home range overlap between two male cats associated with the mating season.

hypothesis is supported by the fact that of the three studies, two relied on daytime location of cats (Jones and Coman 1982; Langham and Porter 1991), and found almost exclusive home-ranges for males, while the third (Konecny 1987b), carried out nocturnal locations, and found over 94% overlap of male home-ranges. The larger home range in the Victorian study compared to the Galapagos study, despite only daytime fixes being used, is a reflection of the different habitat types, i.e. mainland environment compared to an oceanic island.

**Table 3.5.** Mean home range areas for male and female wild living feral cats determined by minimum convex polygon method.

Place	Density ( $n \text{ km}^{-2}$ )	Mean Fixes	Mean Range Size (ha)	
			females	males
Galapagos Is.	2-3	186	82	304
Semi-arid Victoria	0.74-2.4	78	170	620
New Zealand	1.1	57	80	140
Sandford (this study)	2	94	29	154

The overall home ranges determined for the cats at Sandford were relatively small in comparison with the home ranges of most populations of wild living feral cats, as described above, which generally vary in size from 10 to 1000 ha (Jones 1987). The small home range areas, high density of rabbits and their importance in the diet of the local cats (Chapter 6) supports the theory that home range size may reflect prey availability in the environment (Langham and Porter 1991). Male home ranges (mean) were 3.56 times larger than the female's which is very close to the average figure of 3.5.

The sexual dimorphism in home range size is often a result of a polygynous mating system. Polygamous mating systems generally occur where one sex, usually the male, does not participate in parental care and some critical resource has a limited distribution. Members of that sex can therefore expend more time and energy on

intra-sexual competition for resources and mates (Emlen and Oring 1977). If critical resources are evenly distributed in the environment, the breeding members of an animal population tend toward even dispersion and the potential for multiple matings would be low and hence polygamy unlikely. However, unevenly distributed resources increases the potential for obtaining multiple mates (and thus polygamy) as females will also tend to be clumped. Some male individuals may be able to control a larger or better quality of resource, thereby monopolising access to more females (Emlen and Oring 1977). At the Sandford study site the main prey item, rabbit (chapter 6), had a very clumped distribution, thus providing the basis for *resource defence polygyny*; that is, males defending resources essential to females, thereby monopolising access to the females.

Female home range size and location may be determined by several factors. Liberg and Sandell (1988) suggested that female range size was determined by food abundance and distribution, therefore their range would be expected to include just enough space to provide sufficient food throughout the year. While Konecny (1987) suggested that as females have smaller home ranges, with sometimes equivalent energy needs (i.e. when bearing and raising litters) to males, they should select areas of high productivity and be intra-sexually more exclusive to maximise individual access to the limited resource. Both females in this study were known to have very productive home ranges, focussing on areas with large rabbit concentrations (see Chapter 6). In comparison, both males had larger ranges which included far less productive areas. Distances travelled whilst foraging or travelled too foraging areas were correspondingly greater. For example Amadeus' nightly foraging area was located over a kilometre from his den site, while Suzi's den site was in the middle of her foraging area.

### **3.4.2 Seasonal variation**

Increases in home range areas by adult males in spring is consistent with them actively mating and defending females within their range (Langham and Porter 1991). This is a strategy widely reported in domestic cats (e.g. Liberg and Sandell

1988; Langham and Porter 1991) and mammals generally, including small rodents and mustelids (Linn 1984).

Both males exhibited marked seasonal variation in home range area. This difference reflects the fact that the range is determined by the availability of two different resources in the breeding and non breeding seasons. In the non-breeding season, range area for males is determined by the availability of food, while in the breeding season range area is determined by the availability of receptive females (Erlinge and Sandell 1986). As the availability of receptive females has a different spatial distribution in the environment compared with food (i.e. they occur at a much lower density), it can be expected to produce differences in the size, shape, and position of male home range areas (Erlinge and Sandell 1986).

An increase in home range area in response to the onset of the mating season was not evident from the July HMA data (although an increase was evident for Amadeus using MCP). The data collected did, however, indicate the change in Amadeus' denning habits in mid July, which may be linked to the onset of mating activity. At this time a female, whose behaviour (frequent yowling at night) indicated she was in oestrus, was known to be in the immediate vicinity of the new den site. An increase in range size would not have occurred as the female concerned already overlapped extensively with the northern half of Amadeus' range and the new den was located in the middle of his range. In fact, the use of this den caused a short term decrease in range area, as it halved the distance he travelled to and from his nightly foraging area.

In early August, Amadeus started using the den site 500 metres south of his normal range, while still returning to his usual foraging area each night. This resulted in a significant rise in range area recorded in August. Feral cats in semi-arid Victoria have a mating period in July and August with births peaking in September and October. A second less distinct peak occurs in the summer months, the exact timing depending on factors such as size and survival of the first litter (Jones 1987).

The changes in behaviour by Amadeus combined with Leo's shift in range at the end of June indicated that the mating season started in July and then carried on throughout August.

### **3.4.3 Short term use**

The pattern of short term (i.e. 3-4 weeks) use of range areas showed some variation between the three cats. Amadeus and Suzi exhibited very regular and even use of their overall home ranges throughout the study period. In comparison, Leo had a more 'shifting' pattern of use, utilising small areas within his range for a period and then shifting to another area. It may be possible that Leo remained in the same overall area moving around it in a cyclic fashion. Alternatively his movements may involve no cyclic element and his home range use pattern is truly "shifting". Shifting patterns of home range use have been described in prairie raccoons *Procyon lotor* (Fritzell 1978), and in some urban populations of red fox, *Vulpes vulpes* (Doncaster and Macdonald 1991). This occurs as a response to changes in food availability and is a continuous process, where parts of a range cease being visited and new areas are taken up, resulting in a gradual drift in range position (Doncaster and Macdonald 1991). Such a description fits Leo's pattern of use quite well; however, the data covers too short a period for a definite conclusion to be made. A potential hypothesis to explain the occurrence of such behaviour in only one of the three cats is that it reflects home range quality. Amadeus appeared to have a high quality range (Chapters 4 and 6) containing abundant prey, cover and resident females, therefore even if he did leave to find other females, it was worth his while to return. This was supported by him constantly returning to hunt, even when denning 2 kilometres away. In comparison, Leo had been ejected from the prime habitat by Amadeus in response to the onset of the mating season (section 3.4.4.2) and forced to occupy what appeared to be more marginal habitat, containing little dense cover and much lower densities of rabbits (Chapter 6). His regular shifting can therefore be seen as a result of having depleted a limited prey source and moving on to a fresh area.

### **3.4.4 Home-range overlap**

Degree of range overlap tells something of how animals in a population distribute the available resources among themselves (Liberg and Sandell 1988). A small degree of overlap can either be the result of (i) mutual avoidance and an equal sharing of resources and space at low population densities, or (ii) of territoriality, i.e. animals defending their ranges to exclude conspecifics, at least of their own sex. It is relatively easy to establish overlap of ranges. Data on two adult individuals of the same sex can be sufficient to establish this. Establishing territoriality is far more difficult as it requires more extensive data and a high degree of certainty that all individuals in the study area are monitored (Liberg and Sandell 1988). In this study the degree of range overlap varied extensively depending on sex and season.

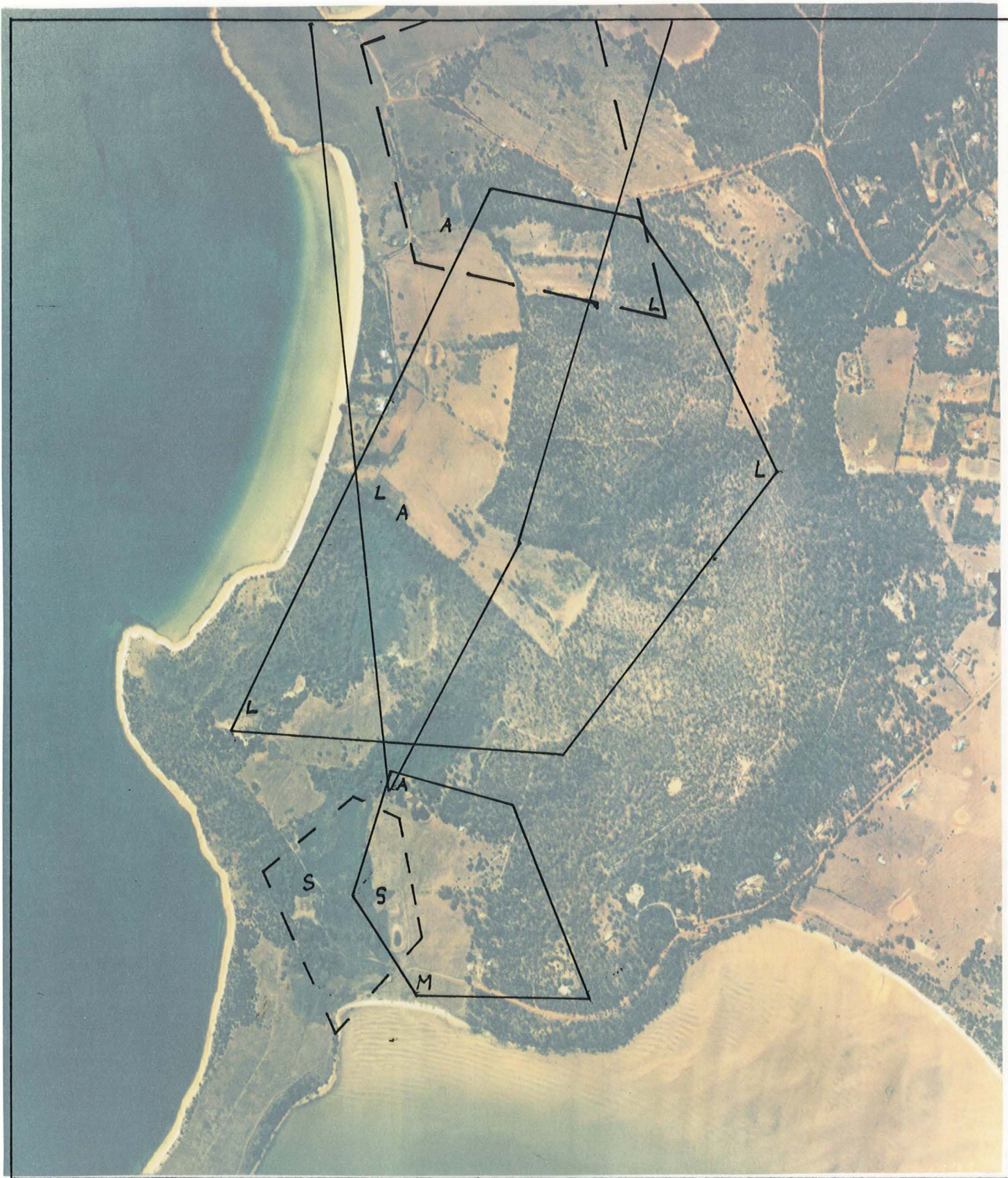
#### **3.4.4.1 *Inter-sexual overlap***

The results indicate that the home ranges of all cats overlapped with at least one other cat of the opposite sex (and a known maximum of three). This has been reported in previous studies (e.g. FitzGerald and Karl 1986; Konecny 1987). Using the changes in denning patterns and home range areas as a guide, the results suggest both collared males probably overlapped and mated with, at least two different females each during the second half of the study.

#### **3.4.4.2 *Intra-sexual overlap***

Seasonal variation in the degree of overlap between males has been documented as common in various species including cats (Bradshaw 1992). In domestic cats, male home ranges typically show little overlap outside the breeding season, (except at high population densities) but then overlap extensively during the mating season as they try to get access to as many females as possible (Bradshaw 1992). Here overlap peaked in the non-mating season and decreased dramatically during the mating season.

The variation in the level of intra-sexual overlap suggests a form of seasonal territoriality. Overlap occurred in the non breeding month June, when both males



Male cats ———  
 Female cats - - -

Den sites: A = Amadeus, L = Leo, S = Suzi, M = Morrabin

**Figure 3.6** Overlap of the home ranges of all known cats at Sandford (as determined by MCP), also showing den sites where known.

had core areas located in the same area. Overlap was lowest in July and August, being limited to the fringes of the respective ranges. The timing of Leo's first shift in home range in late June suggests that he either voluntarily moved, or was forced to take up another range, indicating a switch from a non-territorial to a territorial social organisation. Animals make the change from non-territorial to territorial social organisation when a threshold level for some critical resource is reached and the benefits of maintaining a territory outweigh the costs (Erlinge and Sandell 1986).

Three main factors influence the viability of territoriality, these are;

1. Resource quality and distribution in space,
2. Resource distribution in time, and
3. Competition for the resource. (Davies and Houston 1984).

Generally, the presence of abundant high quality resources does not necessitate territoriality (Davies and Houston 1984; Konecny 1987). Therefore, access to food resources is not a causal factor of seasonal territoriality in the male cats. Rabbits, the principle food item, were abundant throughout the study period and further increased in abundance in late July and August (see Chapter 6). If food resources were the cause of territoriality, home ranges for June should have had the highest level of exclusivity, rather than the lowest, as that was the period of lowest prey availability. Conversely, the availability of receptive females was limited by the small total number (estimated as 3-4) and the time period that they were receptive (only for a short period in July/August). Competition for this resource can therefore be assumed to be strong, and indeed, the correlation of increasing exclusivity with the onset of the mating period strongly supports this hypothesis.

### **3.5 Conclusion**

Home range sizes for feral cats at Sandford were relatively small compared to the home range areas reported in other feral cats populations in mainland environments. Mean home range areas calculated using harmonic mean analysis were 125 ha for males and 35 ha for females. The small home range areas, high density of rabbits on the study site and their importance in the diet of the local cats supports the theory that home range size may reflect prey availability in the environment.

Male cats exhibited marked seasonal variation in home range area. Increases in home range area, unusual movements and changes in the pattern of den use occurred in July and August indicating this to be the mating season. Females showed no changes in home range area.

Home range overlap varied extensively depending on sex and season. Inter-sexual overlap was extensive, with all cats overlapping with at least one cat of the opposite sex. Intra-sexual overlap between males varied between the non mating and mating season. Overlap was extensive in the non mating season with adult males sharing core areas. However, overlap in the mating season was minimal and restricted to the edges of ranges, suggesting that seasonal territoriality was occurring.

## Chapter 4. Habitat use by *F. catus*

### 4.1 Introduction

The domestic cat is one of the most adaptable of all mammals, being found in habitats ranging from sub-antarctic islands to inner cities (Passinisi *et al.* 1989). In Australia the feral cat occupies most habitats ranging from the arid centre to the tropical north (Frith 1979), and many offshore islands (Anon. 1994). However, despite occupying such a diverse range of habitats, some habitat preferences seem to exist within populations; for example closed forests have been suggested as a habitat type avoided by cats (Copson 1991; Gordon 1991). It is also likely that habitat preferences occur on a smaller scale such as in preferred areas for hunting and the location of den sites.

Predation by an opportunistic predator is clearly influenced by the potential for encounters between predator and prey. Optimal foraging theory suggests foraging activity should be carried out in locations and habitat types which maximise the potential for a successful hunt. Therefore, determining the habitats utilised by a predator will give some indication of the types and numbers of prey they are likely to encounter and impact upon (Fritzell 1978).

The diet of feral cats in Australia has been shown to vary depending on the habitat type they occupy. In predominantly agricultural areas introduced rodents comprise the bulk of food intake, while in undisturbed bush areas small native mammals and birds form the bulk of the diet (Coman and Brunner 1972). As diet varies according to habitat on a broad scale, habitat use on a local scale (i.e. a few km<sup>2</sup>) may also influence diet. Therefore by determining whether cats show preferences for or against any particular habitat type at the local scale, and comparing those preferences to the habitats favoured by the small native mammal species, potential impact on those species may be assessed.

A further, more utilitarian benefit can be derived from determining habitat preferences, that is it allows the targeting of smaller areas in cat control programs. By having a knowledge of cat habitat preferences, likely areas can be targeted in a concentrated manner instead of a less efficient blanket approach being employed.

The aim of this chapter is therefore to determine whether a population of mainland Tasmanian feral cats show habitat preferences.

## **4.2 Methods**

### **4.2.1 *Habitat description***

Six categories were used to described the broad types (after Aebischer and Robertson 1992). These were:

1. Canopy absent/ground cover absent,
2. Canopy absent/ground cover patchy,
3. Canopy absent/ground cover dense,
4. Canopy present/ground cover absent,
5. Canopy present/ground cover patchy,
6. Canopy present/ground cover dense;

'Ground cover absent' included areas of pasture with uniform short grass; 'dense' included those areas in which the ground cover was continuous, consisting of either small shrubs, tussocks, sedges and/or bracken with little or no inter-tussock space; while 'patchy' included areas of interspersed ground cover. The study site was divided into a grid of one hectare squares with the dominant vegetation structure present in each square, as described above, being assigned to the square as a whole (Fig.4.1). A 'dominant' habitat type was determined as the one which occupied more than half of a given square if there were two types present, or if more then two types were present, the one covering the greatest portion of a square was considered dominant. Description of the habitat was carried out with the aid of aerial photographs and ground surveys.



Habitat types:

- 1 = ground cover absent, canopy absent
- 2 = ground cover patchy, canopy absent
- 3 = ground cover dense, canopy absent

- 4 = ground cover absent, canopy present
- 5 = ground cover patchy, canopy present
- 6 = ground cover dense, canopy present

**Figure 4.1** Habitat at the Sandford study site as described using six major categories. Grid size is 1 hectare per grid square

#### 4.2.2 *Habitat preferences*

To analyse habitat preferences it was necessary to determine (i) what habitat was available in the study site (A), and (ii) what was used by each animal (U).

"A" is defined as:

$$A = \frac{a_i}{A_t}$$

Where:  $a_i$  = area of habitat  $i$   
 $A_t$  = area of all habitats,

"U" is defined as:

$$U = \frac{O_i}{O_t}$$

Where:  $O_i$  = observations in habitat  $i$   
 $O_t$  = observations in all habitats

It was then possible to, (i) compare the habitat within individual home ranges with that available on the study site, to see whether animals located their home ranges in particular parts of the site in respect to habitat; (ii) compare the habitat at individual fixes with that available within home ranges, to see whether animals preferred particular parts within their ranges, and; (iii) compare habitat at individual fixes with that available on the study site (Kenward 1992).

The number of blocks of each habitat type were calculated as a percentage of the total study site. Similar values were also calculated for the areas within the home ranges of

each cat, determined by minimum convex polygon (Aebischer and Robertson 1992).

The telemetry fixes were then individually examined by overlaying them on the 'habitat' grid to determine the habitat type at each location. For consistency, locations which lay between two squares were allocated to the square on the right. If locations were between four squares they were allocated to the top right square. The number of locations occurring in each of the six habitat categories were then tallied and converted to a percentage of all locations. Suzi's habitat use was not analysed using the one hectare grid method. Due to the small size of her range and the habitat patches in it, the resolution of the one hectare grid, although satisfactory for the males, proved unsuitable and produced an inaccurate description of her range and its use. A grid of half hectare squares was therefore used to allow finer resolution of home range habitat composition, while description of the habitat at fixes was carried out directly from an aerial photograph.

#### **4.2.2.1 *Den sites***

Den sites were located to within an area of tens of metres using radio tracking and triangulation. However, the exact location of dens required "walking up" individual cats. This was best achieved on wet windy days by approaching a cat from a down wind direction, thus reducing the possibility of being detected by the cat; wet conditions assist by greatly reducing the noise produced by large human feet.

### **4.3 Results**

#### **4.3.1 *Habitat preferences***

The percentage occurrence, of each habitat category present in the site ranged from 3.5% (category 1) to 29% (category 5) (see Table 4.1). While the distributions of each also varied. Habitats 1 and 2 were predominantly found along the coastal flats used for grazing or where clearings occurred in the forested area of the southern property.

Habitats 3 and 6 were restricted to the southern property, except a few isolated patches on the northern property, while habitats 4 and 5 were a dominant feature of the hills forming the eastern half of the site. Overall, the southern property had consistently more ground cover and understorey than did the northern property.

**Table 4.1.** Breakdown of habitats occurring on the study site and in the individual home ranges. Areas of each habitat are expressed as a percentage of the total site area, or, for individual home ranges, as a percentage of that range area.

HABITAT TYPE	AREA OF SITE (%)	AREA IN INDIVIDUAL RANGES (%)		
		Amadeus	Leo	Suzi
1	23.2	25.4	3.0	13.3
2	19.1	35.7	30.7	13.3
3	3.5	4.76	3.96	30
4	11.3	2.38	15.84	0
5	29	15.08	29.7	16.62
6	13.9	16.67	16.83	26.67

#### 4.3.1.1 *Home range habitat content*

To determine whether the presence or absence of a canopy was a factor influencing the distribution of cats, a Chi<sup>2</sup> analysis was carried out comparing the mean level of use of habitats with and without a canopy. The presence or absence of a canopy was found not to be significant (Chi<sup>2</sup> = 0.685, 1 *d.f.*  $p < 0.2$ ) therefore the six habitat categories were reduced to three based on the degree of ground cover alone (Fig. 4.2).

To determine the significance of the differences in the habitat available in the site, to the habitat being used, Chi<sup>2</sup> tests were carried out using the percentage occurrence of each habitat type on the study site as the 'expected' and the percentage occurrence of each type

occurring in the individual home ranges as the 'observed'. Analysis of the mean habitat content of home ranges compared to the habitat available within the study site indicated home ranges were located in a non random fashion ( $\chi^2 = 47.204$ , 2 *d.f.*  $p < 0.001$ ). Analysis of individual home ranges (Table 4.2) indicated Leo and Suzi demonstrated significant differences ( $p > 0.001$ ). Leo had a low proportion of 'absent' habitat within his range ( $p < 0.001$ ), while Suzi had a high proportion of 'dense' ( $p < 0.001$ ) and a low proportion of 'patchy' ( $p > 0.001$ ).

**Table 4.2.** Percentage areas of the three habitat types present in the study site and individual home ranges, also listing p values from the respective  $\chi^2$  tests indicating significance of habitat selection by each cat.

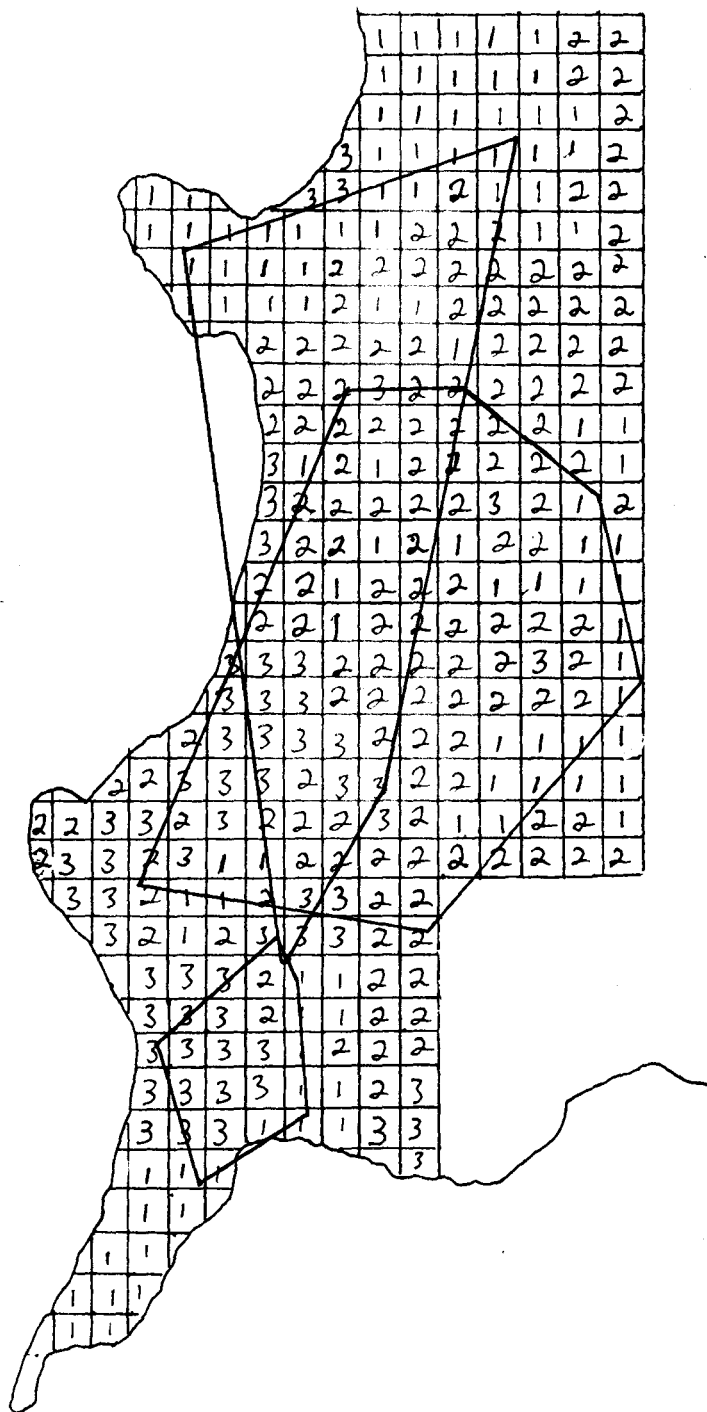
	HABITAT TYPES			P VALUES
	Absent	Patchy	Dense	
%Area of site	34.5	48.1	17.4	N.A.
%Am. HR	27.78	50.78	21.43	$P < 0.2$
%Leo HR	18.84	60.39	20.79	$P > 0.001$
%Suzi HR	13.3	29.92	56.67	$P > 0.001$

#### **4.3.1.2 *Habitat use within home ranges***

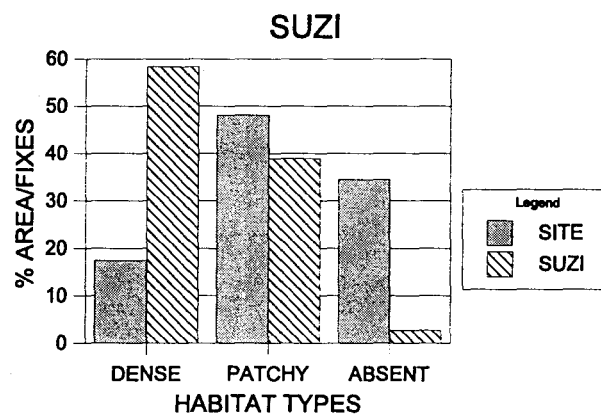
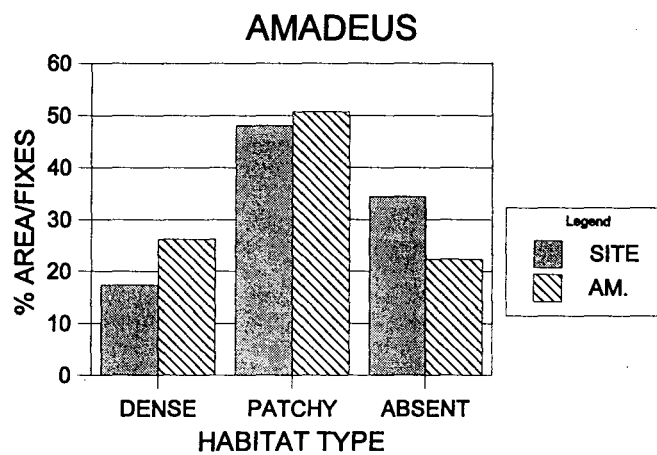
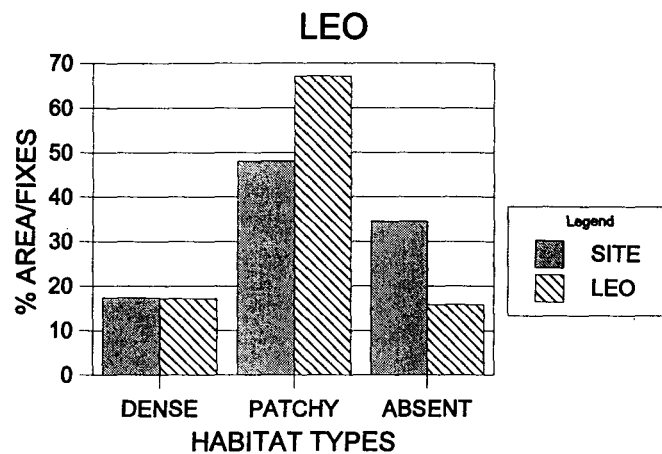
$\chi^2$  tests indicated that within home range habitat use was random for the males ( $p < 0.2$ ), but not for the female who avoided 'absent' ( $p < 0.01$ ). This may indicate individual variation in habitat preferences or broader inter-sex differences in habitat use patterns as recorded in some other medium sized predators (Fritzell 1978).

#### **4.3.1.3 *Habitat use within the study site***

Comparison of 'habitat in home ranges' versus 'habitat in the site' suggested some habitat selection in the studied cats. Although, as 'selection' was not identified, nor consistent,



**Figure 4.2** Location of home ranges relative to the type of ground cover.



**Figure 4.3** Individual habitat use by feral cats at Sandford. A comparison of habitat used with habitat available, illustrating the under-utilisation of 'absent' habitat and the preference for 'patchy' and 'dense' habitats.

in all cats it may have been a reflection of the home range niches available to the cats rather than active selection for a habitat type. However, comparison of 'habitat at fixes' with 'habitat in the site' indicated consistent and significant selection for and against particular habitat types for all cats. (Figure 4.3)

#### ***4.3.2.1 Habitat, den sites and foraging***

If an individual was located in the same position for consecutive locations (when fixes were taken every hour), the individual was assumed to be resting and not pursuing a stationary hunting strategy. If an individual was located in the same position for consecutive locations it was assumed not to have moved since the previous fix. If an individual moved between consecutive fixes it was assumed to be foraging.

The location and pattern of use for den sites showed some individual variation (Table 4.2), although in general habitat type 6, or 'canopy present/ground cover dense' was the preferred location. Of 13 located den sites 10 were situated in this habitat type. Scrub, rabbit burrows in thick scrub, and hollow trees were favoured, the latter being used when scrub was not available. Farm buildings were only occasionally used.

Stability of den site use also varied between cats. Amadeus occupied the same principle den site throughout the study, Suzi shifted her den site at least once, while Leo regularly moved den sites, reflected in his shifting pattern of home range use (Chapter 3). When Leo was first 'collared', his den site was located in thick scrub within approximately 100 metres of Amadeus. After shifting to an area of woodland with very little understorey Leo was found to be utilising hollow trees. The variety of sites used indicates a high degree of flexibility and agrees with previous studies (e.g. Langham 1992) that any situation that provides cover and protection will suffice as a den site.

There was no preference in the location of den sites with regard to aspect, although sites with a northerly aspect may have been used slightly more frequently. All known den

sites (13) for all three cats were situated immediately adjacent to areas of open and/or patchy ground cover (Figure 3.6), indicating proximity to a potential prey source was important in selecting sites. Distances between den sites and foraging area varied from 1 kilometre for Amadeus, and 50-500 metres for Leo, while Suzi denned in the middle of her foraging area. Despite suitable foraging habitat in the immediate vicinity of Amadeus' den area, including a large rabbit population, he visited the distant site on a nightly basis.

**Table 4.2.** Summary of den sites used by the three cats.

	SITE	ASPECT	LEVEL OF USE
LEO	SCRUB 1	NW	REGULAR
	SCRUB 2	SW	ONCE
	SCRUB 3	NW	REGULAR
	HOLLOW TREE 1	NW	REGULAR
	HOLLOW TREE 2	S	REGULAR
	HOLLOW TREE 3	SSW	REGULAR
AMADEUS	SCRUB 1	NW	REGULAR
	SCRUB 2	NONE*	ONCE
	RABBIT BUR. 1	SE	OCCASIONAL
	RABBIT BUR. 2	SE	REGULAR
	FARM SHED	NONE	OCCASIONAL
SUZI	SCRUB/BURROW	SW	REGULAR
	SCRUB/BURROW	SE	REGULAR

\* "None" refers to den sites located on the coastal flats.

#### 4.4 Discussion

The broad habitat composition of the site exhibited a marked dichotomy between the two different properties. The northern property was more open, lacking an understorey even in much of the *Eucalypt* forests on the eastern hills, while the southern property included extensive areas of scrub and bracken. Approximately half of the site was woodland (54.2%), and half had no canopy (45.8%) but these were not significant factors in

determining habitat usage by cats.

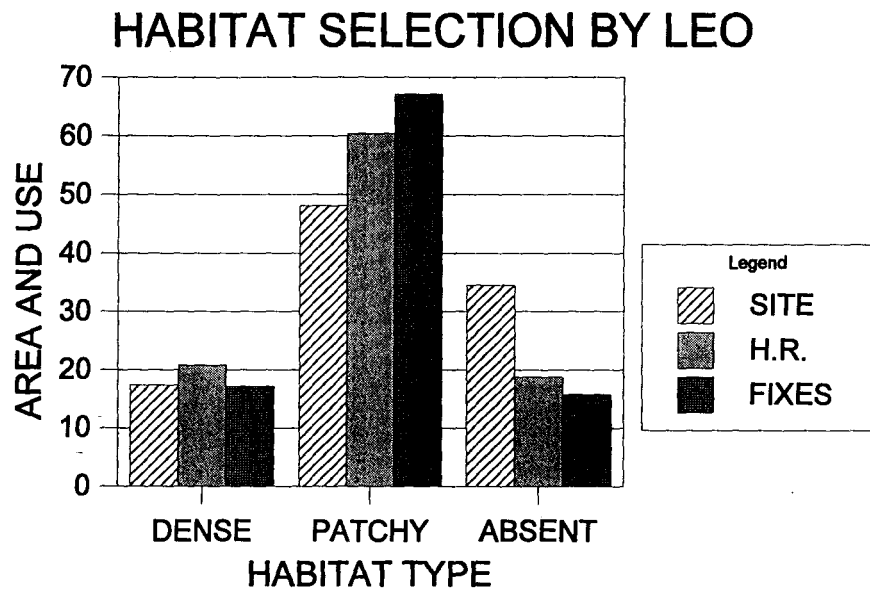
#### ***4.4.1 Habitat preferences***

There was an increase in the degree of habitat selection at each level of comparison (Fig.4.4) and each cat showed increases in selectivity for at least two habitat categories.

Both males had higher percentage areas of 'patchy' habitat in their ranges than was available in the site and similarly, both had lower percentage areas of 'absent' than in the site. Suzi demonstrated the highest level of habitat preference, selecting for 'dense' habitat and against 'absent'. In summary there was a consistent under utilisation of 'absent' habitat in home range areas, and a corresponding over utilisation of 'patchy' or 'dense' ground cover habitats. These results agree with Konecny (1987) who reported that cats utilised 'shrubby' habitats more than 'grassy plains,' suggesting the extent of ground cover is a determining factor in habitat use by feral cats.

#### ***4.4.2 Reasons for habitat preferences***

The habitat preferences displayed in this study can best be explained by the hunting and shelter requirements of the cats. The preference for dense ground cover reflects the protective nature of this habitat type and cats preference for 'laying up' in patches of scrub. The avoidance of 'absent' habitat and preference for 'patchy' habitat is probably a reflection of the hunting methods employed by cats. Depending on the type of prey being sought, cats generally use either a sit-and-wait strategy or a stalking strategy (Bradshaw 1992). Both methods require the presence of some cover. The avoidance of open habitat, despite rabbits being very abundant in these areas, reflects the lack of cover available, making the stalking of prey very difficult and also leaving the cats vulnerable (to dogs and man). The high level of activity in patchy habitat (>52%) and the times at which it was most utilised (dusk to dawn) suggests this habitat type is optimal for hunting as it provides both cover and open spaces allowing cats to employ either hunting strategy. The fact that core areas and prey concentrations were associated with the same



**Figure 4.4** Habitat selection by a feral cat, illustrating the increasing selection for 'patchy' habitat at each level, and a corresponding increasing avoidance of 'absent' habitat.

areas of patchy habitat confirms their identity as the primary hunting areas (Birks and Linn 1982).

#### **4.4.3 *Management implications***

The results of this study have identified two aspects of cat habitat use which may be exploited to maximise the effect of cat control programs, i.e. preferential use of patchy habitat and ecotones. The results have demonstrated that these areas are preferentially used by cats, indicating that cat densities are likely to be higher there than in the general environment. By focussing control effort on these areas control impact can therefore be maximised. When planning control operations, the densest patches of scrub in close proximity to open patchy habitat should be identified in an area, and then trapping and poison baiting efforts should be focussed on the ecotones around it. Cats moving to and from den sites within the scrub are therefore likely to encounter traps, as well as cats hunting or traversing along the ecotone. Nearby areas of patchy habitat with good populations of potential prey species could also be targeted.

#### **4.5 Conclusions**

The feral cats at Sandford exhibited clear habitat preferences for various aspects of their activity. There was selection evident in both the positioning of home range areas relative to the habitat available, and in the overall use of the habitat. Patchy habitat was preferred for foraging activity, dense habitat for the location of den sites and open (ground cover absent) habitat was avoided.

## **Chapter 5. Activity Patterns**

### **5.1 Introduction**

Domestic cats living with humans are not particularly nocturnal, either as a result of domestication or as a behavioural adaptation to life with diurnal humans (Turner and Meister 1988). However, despite having been domesticated since around 4000 BC the association with man has apparently had little effect on the cat's inherent behaviour patterns (Liberg and Sandell 1988), as wild living cats rapidly return to a more nocturnal lifestyle (e.g. Jones and Coman 1982; Langham 1992). This shows cats to be opportunistic and capable of varying their activity patterns to accommodate the availability of food in their environment (Bradshaw 1992). As their activity patterns are linked to the availability of food, determining activity patterns in cats may therefore give some indication as to which species are potentially being preyed upon (Fritzell 1978).

Activity patterns have been examined in several studies of feral cats with results typically indicating a nocturnal or crepuscular pattern, with peaks of activity occurring at dusk and dawn but with activity generally occurring throughout the night (Jones and Coman 1982; Konecny 1987). Hunting activity has been associated with dawn and dusk as opposed to during the night (Scott 1972), although considering activity in small predators is generally synchronised with that of prey species (Langham 1992), and that rabbits (and cats) are active throughout the night, this seems unlikely.

Activity patterns of feral cats in Tasmania have not previously been examined. The aim of this chapter is therefore to determine the activity patterns of a population of mainland Tasmanian feral cats.

### **5.2 Methods**

Cats were located by triangulation every hour during six hour blocks (00:00-06:00, 06:00-12:00, 12:00-18:00 and 18:00-24:00 hours). There were three repetitions of

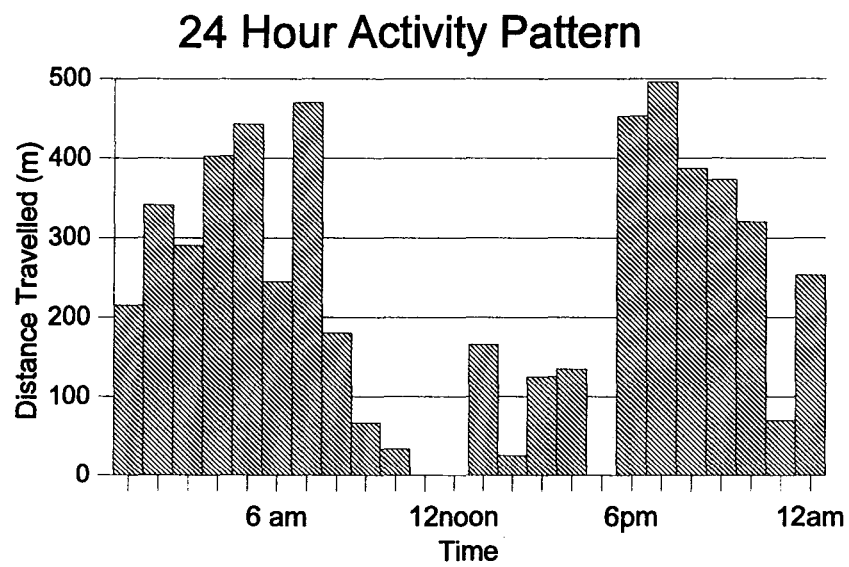
each 6 hour block carried out over a six week period. Data collected during the six hour radio tracking sessions were analysed using the Ranges IV program to calculate interfix distance. Activity was therefore assessed as a function of distance travelled per hour. Data for each hour was pooled and activity levels calculated as the mean distance travelled in each hour.

### **5.3 Results**

Of the three cats only the two males provided sufficient data to allow activity to be analysed; 12 six hour blocks for Amadeus and 5 for Leo. The smaller sample size for Leo is a reflection of the location and habitat of his home range and centres of activity. Leo's home range centred on the hills along the eastern half of the site; the extensive tree cover and more rugged topography both factors which muffle telemetry signals (Tester 1971). As a result, Leo was often only sporadically located during a tracking session. The data from those sessions were not included in this analysis. In comparison, Amadeus' home range was located on the lower slopes and coastal fringe areas which consisted predominantly of relatively flat open pasture. This habitat type is ideal for radio telemetry (Tester 1971)

Both cats displayed similar overall patterns of activity, being most active at night with little activity during the day. Figure 5.1 illustrates the activity pattern in an hourly breakdown, showing the period from 08:00-17:00 hours to be the period of least activity which the cats spent in some form of cover. However, Leo was observed out in the open on two separate occasions at approximately 15:00 hrs.

The cats tended to move out of their dens an hour before sunset, and return an hour after sunrise. Amadeus regularly travelled over a kilometre in a single hour at these times. Prior to the mating season, his den site was located at almost the southern extremity of his range while his nightly foraging area was located a kilometre further north. His daily activity pattern therefore involved moving rapidly between these two areas at dawn and dusk. Even when Amadeus started using the new den site located approximately two kilometres from his usual foraging area, he continued to



**Figure 5.1** 24 hour activity pattern for Amadeus illustrating the bi-modal activity pattern and peaks in activity dawn and dusk.

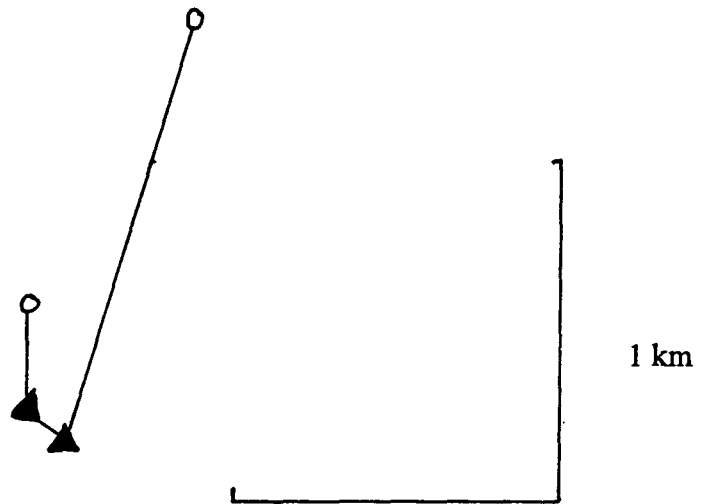
travel that distance and use his usual hunting area every night (Chapter 3). Leo also occasionally covered large areas in his nightly foraging, but generally he tended to cover a smaller area focussed more closely around his core area of the time.

Weather did not appear to have a major impact on activity patterns. The only exception being very heavy and continuous rain, in which case the cats tended to stay in cover. On two occasions of heavy rain Amadeus was located under a shed floor as opposed to his usual area of scrub, suggesting he may preferentially use this more effective shelter in very bad weather. Windy and squally weather did not appear to obviously change activity patterns.

#### **5.4 Discussion**

The activity patterns determined in this study fit the typical bimodal pattern described in cats (e.g. Scott 1972; Jones and Coman 1982; Langham 1992), with peaks of activity as measured by distance travelled per hour occurring at dawn and dusk and little activity during the day. Some movements of up to several hundred metres were recorded and even observed during the day however, lengthy movements were generally not made during the day.

The peaks in activity are generally associated with hunting activity (Scott 1972), as well as travelling to and from foraging areas. Distances travelled per hour around dusk were commonly measured at over one kilometre (Fig. 5.2) suggesting that the principle activity occurring at this time was travelling rather than hunting. Therefore, it is unlikely that peaks in activity as recorded by 'distance travelled per hour' can be associated with hunting activity. In fact, considering the hunting methods employed by cats (stalking and sit-and-wait) periods of relatively low activity during the night are probably more likely to represent hunting activity. This hypothesis is supported by the fact that cat activity usually coincides with the main activity period of the most readily available prey (Bradshaw 1992) and in this study they were rabbits, which are nocturnal not crepuscular. It is unclear whether hunting success influences nightly activity patterns. Cats are often described as 'ecologically surplus killers',



- = one fix in a given location.  
▲ = consecutive fixes in one location

**Figure 5.2** Amadeus' movements over a six hour period from 12:00-18:00. Low levels of activity during the day are illustrated by short distances between fixes or remaining in one position for consecutive fixes. While the activity peaks at dusk are clearly shown by a straight line movement of 1260 metres in a single hour.

i.e. they continue to hunt when they already have a surplus of food (Bradshaw 1992).

Cat activity patterns can vary in response to extremes in weather conditions. In particular avoidance of very hot or cold weather, resulting in daytime hunting in very cold weather and night time hunting in very hot (Bradshaw 1992; Langham 1992). As this study was carried out over winter, data on the response to hot temperatures is obviously lacking however, there was no evidence of a change in activity pattern during periods of very cold temperatures.

The activity patterns determined in this study have limited implications for the management of feral cat populations. The results suggest two variations of shooting to affect a reduction in cat numbers or to target known individuals. Firstly, as cats are inactive during the day, generally occupying areas of thick scrub, shooting 'drives' using dogs in sites known or suspected to harbour cats could be carried out. However, feral cats are often very difficult to flush from cover, even with the aid of dogs (Coman 1991). Secondly, night shooting with a spotlight in areas suspected to be suitable habitat. However, high levels of reduction are difficult to achieve without sustained input, and in habitat with any degree of ground cover it is virtually useless (Coman 1991).

## **5.5 Conclusions**

The feral cats at Sandford were active throughout the period between dusk and dawn, while little activity occurred during the day. Distances travelled per hour were greatest at dawn and dusk, probably indicating the (male) cats were moving to and from foraging areas as opposed to actively hunting. Hunting probably occurs throughout the night.

## Chapter 6. Diet analysis of feral *F. catus*

### 6.1 Introduction

The diets of feral cat populations have been extensively examined on the Australian mainland and various off shore islands but not in Tasmania, with the exception of a limited study of only 10 scats and 3 stomach contents (Taylor 1986). The diet of cats in Tasmania is of particular interest for two reasons. Firstly, as Tasmania remains the last strong hold of several 'critical weight range' species including the eastern barred bandicoot (Anon. 1987), it is essential to qualify the impact of cats on these species. Secondly, Tasmania's fox-free status provides a unique opportunity to assess the diet of the feral cat in Australia in the absence of the fox.

Cats are solitary and versatile hunters (Mellon 1991), having a diet which includes small mammals, birds and insects (Macdonald *et al.* 1991). They are opportunistic (Jones and Coman 1981) capable of killing prey approaching their own size (Jones 1989), with the level of predation depending on the abundance and availability of any given prey item (Coman and Brunner 1972). When more traditional prey items are scarce, cats switch to various 'unusual' prey items such as invertebrates and even potentially harmful prey such as poisonous snakes, spiders and scorpions (Hayde 1992). Scavenging has also been recorded but generally only as a response to a lack of live prey (Jones 1977; Hayde 1992).

On the Australian mainland various studies have illustrated that there are two general patterns of diet depending on habitat type (Coman and Brunner 1972). These are:

1. Predominantly undeveloped bush country, or 'primary habitat'.

Generally feral cats rely heavily on the smaller native mammals. In a national park in southeast Victoria the major prey items for cats were ring-tailed possum (*Pseudocheirus perigrinus*), (56%), bush rat, (*Rattus fuscipes*), (19%), and brown antechinus, (*Antechinus stuartii*), (15%); 71% in total. Birds and reptiles were also significant items (Triggs *et al.* 1984). Rabbits appeared much less frequently in the diet of 'primary' cats, ranging from 1% to 43% (Brunner and Coman 1972; Jones and

Coman 1981; Triggs *et al.* 1984; Catling 1988).

## 2. Open improved, and grazing areas or 'secondary habitat';

Research suggests that the present impact of feral cats on native fauna in 'secondary areas' is minimal. The dominant items in the diet of feral cats in secondary habitat are introduced rodents, particularly European rabbits, *Oryctolagus cuniculus*, and house mice, *Mus musculus*. Rabbits alone make up to 53% of prey taken by frequency of occurrence, and 82.6% occurrence by weight (Coman and Brunner 1972). In total, introduced mammals make up to 74.1% by occurrence and 90.5% by weight (Coman and Brunner 1972). Birds feature consistently in the diet, their importance ranging from "relatively unimportant" (Coman and Brunner 1972), to being an important food (Jones and Coman 1981). However, eggs and nestlings may not be identifiable in cat stomachs, and so studies may under-estimate predation of birds (Davies and Prentice 1980). The bird species most frequently taken are those which occupy the ground or lower shrubs (Catling 1988). Insects, reptiles and amphibians appear frequently in the diet of most cats but are generally of little overall importance.

Overall, cats are not thought to show prey preferences (Jones and Coman 1981). Rather they are considered to be opportunistic predators whose level of predation on a given prey species reflects its availability in the environment. However, few studies of the diet of cats provide measurements of prey densities to provide quantitative support for this notion (FitzGerald 1988).

The aims of this chapter are, therefore to; 1. assess the diet of a population of mainland Tasmanian feral cats, 2. determine relative abundances of prey species inhabiting the site, and 3. compare diet with prey availability to determine whether predation is opportunistic or selective.

## 6.2 Methods

### 6.2.1 *Dietary analysis*

A total of 47 scats were collected during the study. Initially, collection of scats along a transect was attempted, but due to the low incidence of scats this was abandoned and collection carried out on an opportunistic basis. Likely areas, such as along ecotones, around rabbit kills, and core areas of activity, were checked in the course of field work. Carrying out trapping surveys allowed relatively large areas to be thoroughly searched in the process of setting and clearing traps over several days.

Scat analysis (Brunner *et al.* 1976) was used to determine the diet of the cats on the study site. Scats were soaked in 70% alcohol for 48 hours to eliminate any parasites present. After macroscopic examination, scats were washed through a 1 millimetre aperture sieve to retain hair, feathers and bone matter. Scat contents were determined principally via hair identification by the method of Brunner and Coman (1974), which involves mounting and taking cross sections of individual hairs to expose the cross sectional structure which, when viewed under a compound microscope, is diagnostic for a given species.

Comparison of the relative proportions of prey items appearing in scats with their relative abundances in the environment (methods in section 6.2.2), allowed diet preferences to be determined. The occurrence of prey items appearing in the scats was expressed as a percentage of the total sample of scats.

#### 6.2.1.1 *Advantages and limitations of predator scat analysis*

The use of scat analysis to determine diet in a predator has various benefits and limitations (Brunner *et al.* 1975). The benefits include:

1. Field collection of scats requires little skill or time, particularly when carried out in conjunction with other field work.
3. Scat analysis has no damaging effect on wildlife.
4. The cost of equipment for field collection and hair identification is low.

The disadvantages are:

1. Although scat analysis can be used to indicate the presence of species in a predators diet, it gives little information on the ecology of the prey species. Also, figures for the occurrence in scats of each prey species are difficult to relate to the differences in the density of each species.

2. Scat analysis requires some experience in identification of mammalian hairs.

3. Scat analysis gives no indication of actual volumes for each type of food ingested.

4. Easily digested foods, such as birds eggs and nestlings, may not be identifiable. Therefore, scat analysis may under-estimate consumption of these food types (Davies and Prentice 1980).

Overall, scat analysis does provide useful information on the range of foods eaten and also on their seasonal variation in incidence (Brunner *et al.* 1975).

### **6.2.2 Fauna surveys**

It was necessary to use a variety of fauna survey methods to sample all the potential prey populations. Each method produced its own indice of relative abundance and due to their different methods of derivation direct comparison between those indeces was not possible. Therefore, to enable comparisons to be made the respective results were used to group species into relative abundance classes using an ordinal scale.

The classes were;

1. present, probably rare,
2. present,
3. present, possibly common in suitable habitat,
4. common,
5. abundant.

Species that were sampled by more than one survey method allowed some standardisation between indices. For example, the relative abundance of possums compared to rabbits was known from the spotlight surveys, while the relative abundance of possums compared to bandicoots and potoroos was known from

trapping surveys. This allowed some conclusions to be drawn about other species not directly compared, in particular the difference in relative abundance between rabbits and the small native mammals.

The fauna survey methods used included; small and medium mammal trapping using 'Elliott' and 'Mascot' type cage traps; spotlight surveys; and walked transect surveys for birds.

#### **6.2.2.1 *Trapping surveys***

The trapping surveys were carried out on average once a week over four months (April-August) at various locations within the study site to sample the fauna in the principal habitat types and in those areas in which collared cats were known to frequent. Mascot traps (average of 15 traps/night) were set in a grid fashion 50 metres apart and baited with apple and peanut butter. Elliott traps (26/night) were set 5-10 metres apart, depending on habitat, and baited with a mix of bird seed, oats, Promite and honey. Each site was sampled over two nights. When heavy rain occurred on trapping nights the results for that night were ignored and the site retrapped. The sex and age (juvenile or adult) of trapped individuals were recorded and individually numbered ear tattoos given to each animal to allow recaptured animals to be identified.

As the total number of individuals trapped was so low (section 6.3.2.1), mark/recapture analysis methods were not possible. Therefore, the results were used to calculate an index of relative density, the 'catch frequency'. The catch frequency transforms raw trapping data obtained from single-catch traps into a density index by recognising that each time an animal is caught one trap is put out of action for the remainder of the night, resulting in a progressive reduction in the number of active traps throughout the night (Caughley 1977).

#### **6.2.2.2 *Spotlight surveys***

Spotlight surveys were conducted from a vehicle travelling less than 5 kph. One

observer was used, riding on the back of a 4 wheel drive utility surveying only to one side of the vehicle. Two separate transects were required to sample both ends of the site as it was not possible to travel between the properties by vehicle. It also allowed the differences in habitat and rabbit populations to be highlighted. On the northern property transect length was 1.9 kilometres and traversed the coastal pastures allowing excellent coverage with the spotlight. On the southern property transect length was 2.4 kilometres and traversed open pasture and open forest. Coverage with the spotlight ranged from excellent to poor. The first survey was conducted in July and the second in early August with total spotlighting time being approximately 2.25 hours. The results from spotlight surveys were converted to a relative abundance, i.e. the number of animals per kilometre.

#### **6.2.2.3 *Bird transects***

A transect of 2.1 kilometres length was used which traversed the southern end of the northern property and most of the southern property. The survey method entailed 5 minute stops at transect points located approximately 200 metre apart. At each stop all species were recorded by sightings and calls, and the number of individuals of each species recorded where possible. Transect points were subjectively bound to a radius of approximately 100 metres to limit bias toward highly visible or vocal species, and to limit the possibility of recording the same individual at several stops. Two repetitions were carried out in autumn. Surveys were discontinued when it became evident that birds were only a minor part of the diet. Relative abundance of each species was expressed as a percentage of all transect points at which a given species was observed.

### **6.3 Results**

#### **6.3.1 *Diet as indicated by scat analysis***

Mammals comprised the bulk of the diet being absent from only 2% of scats ( $n = 1$ ) The major food groups present in the sample are listed in Table 6.1.

<b>Table 6.1. Principal food types</b>
1. Introduced and native mammals
2. Invertebrates
3. Birds
4. Lizards
5. Vegetable matter

Introduced mammals were the major food type with a percentage occurrence of 93.6%, native mammals had an occurrence of 14.9%, birds 8.5%, lizards 8.5%, invertebrates 40.4%, vegetable matter 10.6% and unidentified mammal 2.1%. Table 6.2. lists the percentage occurrence of all prey items present in the scats (P.T.O).

Rabbits were the principal component of the diet. In total 85% of scats contained some rabbit; 42.5% of scats contained solely rabbit, and a further 25.5% contained principally rabbit with minor quantities of insects and/or lizard. The second most common food item by occurrence was invertebrates; however, this illustrates the limitations of 'percentage occurrence' in assessing scat contents. While it is a useful measure of the frequency of occurrence in the scats, it can mis-represent the relative importance of some prey items. 'Invertebrates' and 'lizards' illustrate the most significant mis-representation. Although present in a large number of scats, only one or two individuals were generally present in each scat. Taking this into consideration the second most important item was black rat, 14.9%. There appeared to be a some variation in the level of invertebrates and lizard appearing in the scats, with none appearing in scats collected later in the study period with the exception of those scats which were obviously old. Overall, 'invertebrates' and 'lizard' were of relatively minor importance, as were bird (8.5%), barred bandicoot (6.4%), brown bandicoot (4.25%) and potoroo (4.25%).

Table 6.2. Percentage occurrence of prey items in scats (n = 47);

Food Item	Percentage occurrence
1. rabbit	85
2. invertebrates	40.4
3. black rat	14.9
4. lizard	8.5
5. bird	8.5
6. barred bandicoot	6.4
7. brown bandicoot	4.25
8. potoroo	4.25
9. house mouse	4.25
10. dog	4.25
11. vegetation	10.6
12. unident. mammal	2.1

The presence of dog appears to be an anomaly; however, the land owner was known to have shot several dogs in the study period. This indicated scavenging by cats even though abundant prey was available (i.e. rabbits). Scavenging by cats has usually been cited as a response to a shortage of live prey (Jones 1977; Hayde 1992).

### **6.3.2 Relative abundances of prey species**

#### **6.3.2.1 Trapping results**

258 trap nights over 17 nights were carried out with Mascot traps. A total of 14 brown bandicoots (including 7 brown bandicoots trapped when cat trapping, the additional 'trap nights' were taken into account when calculating catch densities). 4 potoroos, 1 barred bandicoot, 36 possums and 2 black rats were trapped (recaptures not included).

189 trap nights over 9 nights were carried out using Elliott traps. A total of 4 house mice were trapped. Due to the very low success rate in a number of locations and habitats Elliott trapping was discontinued at the end of July.

Overall catch densities were calculated from both sets of trapping results;

brush possums,	0.25
brown bandicoot,	0.04
potoroo,	0.02
house mouse,	0.02
black rat,	0.01
barred bandicoot	0.005

#### 6.3.2.2 *Spotlight surveys*

The results of the spotlight surveys (Table 6.3) clearly reflect the different densities of rabbits occurring on the study site. Although the denser habitat on the south of the site undoubtedly reduced the accuracy of the spotlight surveys it was felt that the recorded differences in rabbit densities was accurate. The recorded relative abundance of both barred bandicoot and hare are probably an artefact of the small sample size, and in fact, over estimates.

**Table 6.3.** Relative abundances of mammals at Sandford as determined by spotlight surveys. 'North' refers to the grazing property and 'south' to the derelict farm.

	Species	Relative Abundance $n\ km^{-1}$
North	rabbit	138.95
	brush possum	15
	barred bandicoot	0.25
	hare	0.25
South	rabbit	32.95
	brush possum	3.75

### 6.3.2.3 *Bird transects*

Twenty six species were recorded during the bird surveys (n = 2). Regular surveys were discontinued when it became evident that birds made up only a small part of the diet of resident cats, however general observations made as field work was carried out showed the area to have a rich and varied avifauna (see Table 6.4 for incidental sightings). Thirty six native and four introduced species (black bird, European starling, common sky lark and European goldfinch) were recorded in the course of the study .

Relative abundances (as percentages) were;

noisy miner,	54.2
yellow throated honey eater,	33.3
blue wren,	33.3
green rosella,	25.0
crescent honey eater,	16.7
magpie,	12.5
forest raven,	12.5
eastern rosella,	12.5
striated pardalote,	12.5
flame robin,	8.3
black headed honey eater,	8.3
grey thrush shrike,	8.3
Tasmanian thornbill,	8.3
dusky robin	8.3
scarlet robin	8.3
European goldfinch,	4.2
silver eye,	4.2
black currawong,	4.2
eastern spinebill,	4.2
golden whistler,	4.2
swift parrot,	4.2

yellow tailed black cockatoo,	4.2
grey butcher bird,	4.2
European starling,	4.2
masked plover	4.2
common sky lark,	4.2

**Table 6.4.** Bird species recorded on an incidental basis

SPECIES NAME	APPARENT STATUS
bronze-wing pigeon	present
white faced heron	common
kookaburra	present
Tasmanian native hen	present
yellow rumped thorn bill	common
dusky wood swallow	present
black bird	common
black duck	present
wood duck	present
chestnut teal	present
brown falcon	present
mopoke owl	present
white-breasted sea eagle	present

#### **6.3.2.4 Relative abundance classes**

Of the seven prey species recorded at Sandford only brush possum and barred bandicoot were recorded in more than one survey method. This reflects the size, trappability and habitat preferences of the various species. Potoroos and bandicoots are generally easily trappable but prefer areas containing some ground cover hence their low representation in the spotlighting results. The small size of rats and mice makes it likely they could enter and leave mascot traps without setting the trap off. Their small size and habitat

preferences also makes detection of them unlikely during spotlighting. Rabbits were the most numerous and obvious species on the site, which is reflected in the spotlight results, however, they are were untrappable. Possums provided the main point of comparison between the two mammal survey methods as they were easily trapped (although recaptures were infrequent), and were highly visible when spotlighting due to a distinct eye shine, relatively large size, and a tendency to move into open pasture or up trees when feeding.

**Table 6.5.** Relative abundances for prey species at Sandford

SPECIES	ABUNDANCE
Rabbits	5
Brush possums	4
Brown bandicoot	3
House mouse	2
Potoroo	2
Black rat	2
Barred bandicoot	1

## 6.4 Discussion

### 6.4.1 *Diet analysis*

The diet of feral cats at Sandford was comparable with the results of previous research.

A comparison of the main food types found in several studies is summarised in Table 6.6

Rabbit was the principal component of cat diets at Sandford as also recorded in other studies in secondary habitats (Coman and Brunner 1972; Jones and Coman 1981; Catling 1988). However, the percentage occurrence of rabbit (85%) was markedly higher than in most previous studies (Fig. 6.7). Probably reflecting a high abundance of rabbits on the site (139 per km) compared to other studies, e.g. Jones and Coman

(1982) a maximum of 30 per km.

**Table 6.6** Percentage occurrence of the major prey items in the diet of cats from several locations.

Location	Mammals	Birds	reptiles	Invert's	Veg.
Victoria*	67	7.5	5	15	44
Victoria**	97	27	23	17	19
NSW"	87	21	4.7	42.5	-
Sandford	97	8.5	8.5	40	11

\*determined by stomach analysis of cats collected from throughout Victoria (Coman and Brunner 1972).

\*\* determined by scat analysis. Scats were collected from 'primary' habitat (Triggs *et al.* 1984).

" determined by stomach analysis of cats collected in semi-arid NSW (Catling 1988).

Other items in the diet were of relatively minor importance. All mammals recorded were predominantly nocturnal, as opposed to crepuscular, supporting the hypothesis that cats hunt throughout the night and not just at dawn and dusk.

**Table 6.7.** Occurrence of rabbit in the diet of feral cats. A summary of studies conducted in secondary habitat.

Study	% Occ.
Coman and Brunner (1972)	30
Jones and Coman (1981) two sites	68
	48
Catling (1988)	54
This Study	85

#### **6.4.2 *Prey availability***

The results from the mammal surveys provide a reasonable estimate of the abundance of most species. In particular the result obtained for brown bandicoot, "present, possibly common in suitable habitat" was supported by the observed incidence of bandicoot tracks and scrapes in parts of the study site (although it was not possible to differentiate barred bandicoot tracks from those of the brown bandicoot). Further evidence supporting the estimates was the incidence of recaptures for the various species: Possums, 36 trapped, 3 recaptured; brown bandicoots 14 trapped, 4 recaptured; potoroos 4 trapped, 3 recaptured; barred bandicoot 1 trapped, 1 recaptured. The higher proportion of recaptures for each successive species suggests there is a smaller population of trappable individuals.

The least accurate abundance estimate is for rabbits. Only two surveys were carried out, one before and one after a peak in rabbit births (indicated by the marked increase of young rabbits on the study site in August). The mean value calculated as the abundance is therefore unlikely to accurately estimate rabbit abundance.

The low number of native animals recorded in the mammal surveys reflect the apparent abundances of species observed in the course of the study. The field work involved many hours of night work around the site and throughout this very few native animals were observed apart from brush possums. The total number of non-possum natives sighted were one Tasmanian devil, one brown bandicoot and three sightings of barred bandicoot (possibly the same individual as all sightings were within about 50 metres of each other).

The results of the scat analysis are also consistent with observations made in the course of field work. Over the study period numerous rabbit 'kills' were found around the site, the time since death ranging from months to less than twenty four hours. While rabbits clearly die from causes other than cat predation many of the remains could be identified with a high degree of certainty as cat kills by the presence of teeth marks in bones and the manner in which carcasses had been skinned. In the same period only a small number of bird kills were found, three of which were

recent (a European starling, silver gull and masked plover), while a similar number of very old kills of green rosella were also found. These birds were frequently observed feeding on the ground in the open and in cover, and probably represent a relatively easy target for cats. In fact, a limited study of cat diets in western Tasmania found green rosella had a relatively high percentage occurrence in their sample (4 of 13 scats) (Taylor 1986). However in the present study, green rosellas were very common on the site indicating that the impact of cat predation was minimal. No remains of other mammal species were found during the course of the study. However, it is recognised that due to the small native mammals preferring denser habitat than rabbits the likelihood of finding remains of these species is less.

#### **6.4.3 Diet in relation to prey availability**

The results of the diet analysis conducted in this study only partly agree with previous studies which showed that (i) the level of predation on a given prey item generally reflected its availability in the environment and (ii) that introduced mammals form the bulk of the diet of feral cats in 'secondary' habitat (Coman and Brunner 1972). In this study introduced mammals formed the bulk of the diet of feral cat, but the occurrence of small native mammals in the diet was found not to be consistent with their relative abundances in the environment, suggesting that either the trapping results were not an accurate reflection of the relative abundances of the prey species, or, that preferential predation on these species occurs. This does not agree with other studies. However, as few previous studies of the diet of cats provided measurements of prey density (FitzGerald 1988), the theory that predation levels by cats reflect availability may be based on anecdotal evidence.

The common belief that feral cats are an important predator of birds was not supported by the results of this study. Although birds were abundant in the study site they comprised only a minor part of the total diet, occurring in only 4% of scats. This was relatively low compared with most previous studies e.g. Jones and Coman (1982), three samples ranging from 18-46%; Triggs *et al.* (1984) 27%; Catling (1988) 21.2%, but in agreement with Coman and Brunner (1972) 7.5%.

#### **6.4.4 Potential impact of cat predation on the native fauna**

Although the incidence of the small native mammals in the diet (e.g. potoroo, 4.25%) is not at the high levels recorded for the introduced rabbit (85%) and black rat (14.9%), it can not be assumed that the impact cats are having on the native species is not deleterious (Coman and Brunner 1972). A distinction must be made between the possible effects of predation on the smaller native mammals, and predation on the introduced mammals. The native species have lower population densities and therefore small losses due to predation in absolute terms might be sufficiently large in relative terms to result in a significant reduction in the population. Rabbit (and possibly black rat) population densities are much higher, and consequently heavy predation might do little more than remove surplus animals (Coman and Brunner 1972). Also, the introduced rodents have a far greater reproductive capacity than do the small native mammals [e.g. the black rat; six litters of 5-10 young each year, potoroo; two litters of 1 young per year (Anon. 1987)], which further increases their ability to absorb and recover from predation compared to the native mammals.

While the dietary analysis shows that feral cats do eat small native mammals, it does not demonstrate that feral cats are having a detrimental impact on those species (Newsome 1991). The fact that a predator has eaten a prey animal says nothing about the prior status of the individual prey, or the relationship between the predator and prey species at the population level (Brunner *et al* 1976). Also, the death of individuals is not necessarily a problem as most animals produce more young each year than are needed to replace normal mortality. It is only when predation levels are relatively high compared with recruitment, and/or recruitment is reduced by other factors that predation can have a serious effect (King 1984). Considering the low potential rates of recruitment and the low population densities of the small native mammals in this study, the relatively high incidence of those species in the diet indicates predation by feral cats may be having a serious impact on their populations. These results suggest that the control of feral cats would be beneficial to the small native mammals by reducing predation pressure, hopefully leading to increases in population densities. However, reducing predation does not automatically result in

population increases in a prey species, particularly if the prey species population is actually limited by some other factor (King 1984). These issues and their implications for the management of feral cat populations will be examined in Chapter 7.

### **6.5 Conclusion**

The diet of the feral cats at Sandford was dominated by introduced mammals, in particular, rabbits. Small native mammal's were a relatively minor component of the diet, as were birds and reptiles. Invertebrates had a high occurrence in the diet but their overall importance was minor.

Diet did not reflect prey availability. The occurrence of the small native mammals in the diet was not consistent with their apparent abundance in the environment, suggesting that the feral cats at Sandford may selectively prey on these species.

## **Chapter. 7 General discussion and conclusions**

This study has examined various aspects of the spatial ecology and diet of a mainland Tasmanian population of feral domestic cats, *Felis catus*. Temporal and inter- and intra-sexual differences in home range size and overlap were identified, while diet, habitat preferences and activity patterns were quantified.

Although this study was based on a small sample of cats ( $n = 3$ ), the sample size was not significantly less than that used in at least one major previous study of wild living feral cats (Jones and Coman 1982;  $n = 4$ ) and the results gained were consistent with that and other previous relevant studies (Chapter 3).

The aim of this study was to provide data essential for the more efficient planning of feral cat control operations, as well as qualifying the impact of a feral cat population on the local fauna. This chapter will therefore discuss the results of this study with respect to both these issues. The implications for future feral cat management in Tasmania will also be assessed.

### **7.1 Control options for feral cats**

Feral cats have increasingly become the target of population reduction programs, both in Australia and overseas. Numerous methods of control have been used or suggested, ranging from the traditional methods of shooting, trapping and poisoning (FitzGerald *et al.* 1991) to more modern alternatives such as fertility and biological control (Bloomer and Bester 1992). In each case the spatial organisation of the target population is an important factor in planning and implementing population control methods.

Determining the factors which regulate density in a population is an essential first step in assessing appropriate control strategies (Bomford 1990) and will give a good indication of the potential impact of various methods. The results of this study allow several conclusions to be made about the suitability of various control methods in a

mainland environment:

Fertility control is an unsuitable control option. Although it has been suggested as having the capacity to significantly reduce the biotic potential of a population (Knipling 1959), its relative effectiveness depends on the mating and dispersal habits of the target species. Strongly monogamous mating systems are ideal, while polygamous mating systems decrease its effectiveness. Also the effectiveness of fertility control is directly proportional to the ratio of sterile to fertile males competing for mates. Considering that cats are polygamous and females overlap ranges with at least two males, (Chapter 3) the ratio of sterile to fertile males necessary to significantly effect recruitment to the adult population would need to be very high. Additionally, given present technology in this field (Bomford 1990) and the high incidence of fertile 'dumped' and stray domestic cats, this is probably unachievable.

The results of this study, and previous experience (Brothers *et al.* 1985; Chapius *et al.* 1994) indicate that the use of the traditional methods of trapping, shooting and poison baiting are unlikely to succeed in the long term. The specific difficulties of using traditional methods against feral cats include: (i) Cats are generally very trap shy (as illustrated in this study; 3 cats in 170 trap nights), and it is estimated that only 40% of a given cat population is actually trappable when using 'walk-in' type traps (Veitch 1991); (ii) shooting of cats is likely to be highly ineffective considering their small size, cryptic nature and preference for dense and patchy habitats (Chapter 5) (Coman 1991); (iii) poison baiting relies on cats 'scavenging', a behaviour usually only associated with a lack of live prey (Chapter 6) and so has limited potential impact.

Even if local eradication can be achieved in a mainland environment, the effort can be rapidly negated by immigration from nearby uncontrolled areas (King 1984). Control of 'pest' predator species using the above methods has repeatedly failed in mainland environments around the world (Connolly 1978; Stubbe 1980), control

efforts essentially become an exercise in sustained-yield harvesting (Caughley 1977).

Biological methods of cat control have been successfully used in some circumstances (Bloomer and Bester 1992), although their utility is presently limited to island populations. Introduction of the highly contagious viral disease *feline panleucopaenia* greatly reduced the density of feral cats on sub-Antarctic Marion Island. However, considering the mixing which undoubtedly occurs between the domestic and feral cat populations in Tasmania (Chapter 3), introduction of that virus would first require compulsory vaccination of all pet cats.

## **7.2 Is cat control justified?**

While there is ample evidence that predation by feral cats does have an impact on Australia's native fauna and has caused local if not total extinctions (e.g. Kinnear 1991), the distribution and abundance of the small native mammal species which have managed to survive the introduction of cats is now largely determined by factors other than predation, the most typical being habitat availability (Frith 1979). This point, combined with the fact that feral cats are reported to have been on the Sandford study site for at least 25 years, indicates that the local small native mammals still present on the site may be able to sustain the impact cats are having on them. However, as land clearance for grazing and subdivision continues, resulting in smaller, more isolated populations, the impact that cats have is likely to increase. In this situation predation by cats may become the proverbial "straw that breaks the camels back", driving the species to local extinction. There are a number of other potential "straws" however, including wild fire, disease, and in the longer term, inbreeding (King 1984).

The fox and cat have together been blamed for causing the extinction of numerous native animals, although, as previously stated, it is sometimes difficult to isolate their impact from that of European settlement. The results of this study, and others, (Kinnear 1991) indicate that feral cats may have had less of an impact on Australia's

fauna than the fox. Tasmania has been settled by Europeans for nearly two hundred years and the domestic cat can be assumed to have been present in many areas for much of that time, yet Tasmania still has a relatively intact native fauna, including several species which have become extinct or extremely rare on the mainland (Anon. 1987; Copson 1991). The two major differences between the settlement process in Tasmania and the Australian mainland is a lower level of habitat clearance (Anon.1987) and the absence of the fox.

There is strong evidence then, that the indigenous fauna can cope with the presence of cats as long as the original habitat is reasonably intact. This has been demonstrated in mainland Australia (Frith 1979) and in Tasmania. In fact, in Victoria it has been hypothesised that feral cats may be doing little more than filling an ecological niche left vacant by the near disappearance of the eastern quoll, *Dasyurus viverrinus* in that state (Coman and Brunner 1972). In Tasmania, where both the eastern and spotted tail quolls are common in suitable habitat, direct competition between those species and feral cats has been suggested as a potential threat (Anon. 1987) and the absence of eastern quolls from the Sandford site may support this. However, as previously stated, the fact that quolls still are common in suitable habitat indicates that something other than feral cats are probably controlling their distribution.

It appears then, that the impact of feral cats on Tasmania's native mammals is of secondary importance, when compared to habitat loss. Feral cats may contribute to local extinctions by exacerbating and possibly even accelerating the effects of habitat loss by preying on vulnerable remnant populations, but the principal reason for that vulnerability is habitat loss.

### **7.3 Conclusions**

In mainland environments cat control programs are very expensive and ineffective in the long term. Traditional methods of control (trapping, shooting and poisoning) have been found to be incapable of providing long term control of feral cat

populations without sustained effort over long periods. Any control achieved can soon be negated by immigration from uncontrolled areas, including the domestic cat population. The ineffectiveness of these control methods reflects the trap shyness of cats, their habitat preferences, and their preferences for live prey as opposed to scavenging.

There is little evidence that cats in mainland Tasmania are having a significant negative impact on the native fauna. Despite cats having been present in Tasmania for up to nearly 200 years, the native fauna is still relatively intact, including species which have gone extinct or suffered major reductions in distribution on the mainland. Cats may have an impact on small or vulnerable populations of small native animals, however, those populations are vulnerable generally as a result of habitat loss, not cat predation.

Considering these points it is difficult to justify the allocation of limited conservation resources (i.e. people and funds) to control cats on a large scale in mainland Tasmania. However, selective control may be required and beneficial in special cases (King 1984), such as to protect seabird rookeries and vulnerable or endangered populations of native animals.

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THE IMPACT AND CONTROL OF INTRODUCED PREDATORS IN AUSTRALIA:  
A LITERATURE REVIEW.

By Eric Schwarz.

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## 1.INTRODUCTION

The introduction of exotic animals to new environments has been carried out by humans for thousands of years; where humans go favoured animals are taken, and invariably, other "pest" species follow. It is a practice that has not been limited to the latter day Europeans as they 'colonised' the globe. Polynesians introduced dogs and rats to New Zealand centuries before Europeans arrived (King 1984); and South-east Asians brought the dingo to Australia several thousand years before Europeans settled (Anon. 1990). In both cases, the impact on the indigenous fauna can be reckoned to be massive. These and other ecosystems around the world had evolved in isolation over aeons and the addition of new species, and in particular, new predators, has consistently had devastating results. This review will assess the impacts, the animals involved, and possible methods of control and eradication.

Controlling and eradicating introduced and pest predators is not a problem limited to Australia; however, considering the enormity of attempting to review this topic on a broader scale this discussion will examine the Australian situation. Examples will, however, also be used from other regions where applicable. This review will focus on the feral domestic cat (*Felis catus*), and the European red fox (*Vulpes vulpes*), as well as the "wild dogs". After a brief outline of the species involved and their arrival in Australia, the relevant impact of the each species, and predators in general, will be discussed. This will be followed by a detailed examination of the control of animal populations: including, its effects on the populations being controlled, the advantages and disadvantages of the so-called "traditional" mortality enhancing methods, fertility control as a means of population management; and finally, predator control by aversion therapy will be briefly discussed.

## 2. PREDATOR INTRODUCTIONS

### 2.1 The dingo

The first of Australia's carnivorous "late comers", the dingo is believed to have arrived in northern Australia about 4000 years ago (Breckwoldt 1988). Their means of arrival is uncertain (Newsome and Coman 1989; MacIntosh 1975), but it seems likely to have been by South-east Asian seafarers (Breckwoldt 1988). At the time, the largest and most abundant predator in Australia was the thylacine (*Thylacinus cynocephalus*). The dingo soon replaced it and the Tasmanian devil (*Sarcophilus harrisii*) on the mainland (Anon. 1990), the thylacine becoming extinct there about 3000 years ago (Breckwoldt 1988). The dingo probably had a massive impact on the native fauna when it first arrived. It was larger than the thylacine and was also a (sometimes) social hunter, unlike the native predators. Dingoes came into conflict with Europeans almost as soon as livestock was introduced into Australia. By 1836 there was already a bounty offered for dingoes in an attempt to protect the budding Victorian grazing industry (Breckwoldt 1988).

### 2.2 The domestic cat

Domestic cats (*Felis catus*), are also thought to be early arrivals in Australia. They probably reached parts of Australia before Europeans (Rolls 1969; Anon. 1994), as sightings were reported by the early explorers in some of the remotest parts of central Australia; it is hypothesised that they may have arrived via ship wrecks or Maccassan traders. Certainly, in southern Australia they spread with the early settlers. By the early 1880's cats were being actively transported around much of the country afflicted by rabbits and released in a bid to reduce rabbit numbers (Rolls 1969). As a result they now occupy most habitats in Australia from the arid centre to the tropical north (Frith 1979), and many offshore islands (Anon. 1994). Possible exceptions are the rainforests and button grass plains of Tasmania (Copson 1991). Feral populations are continually added

to by pets being dumped or going stray in bush and rural areas (Coman 1975). Control of feral cats has only become a conservation issue relatively recently and has generally focussed on islands. Control of the animals on mainland situations has generally been on an *ad hoc* basis, with short term reductions in sensitive areas the aim or result (Anon. 1994).

### 2.3 The European red fox

The red fox (*Vulpes vulpes*) was introduced to Australia in the early 1800's to provide hunting sport. However, it was not until the 1870's that it became established in the wild (Rolls 1969). Today its range covers most of the continent except Tasmania and the tropical far north (Coman *et al.* 1991), and occupies all habitats except the densest forests (Frith 1979). Foxes have been implicated in predation on livestock, particularly lambs, but this is no longer held to be as serious as traditionally believed (Dennis 1969). Due to their perceived role in livestock predation, bounties for foxes were offered by many states in Australia; in Victoria alone, this accounted for about 60 000 foxes per year (Coman 1973). Until recently foxes were also exploited for the international fur trade, with around 300 000 skins sold annually. Despite these forms of control, there is no definite evidence that man-imposed control has drastically altered fox numbers in the long term (Newsome and Coman 1989).

In all other continents, other than Australia (and Antarctica), foxes are responsible for the maintenance and spread of the zoonosis rabies (Wandeler 1980). Australia is free of rabies but it is recognised that if the virus does enter the country foxes will be a potentially major vector (Newsome and Coman 1989). Therefore the potential to control an out-break of the disease will rely heavily on the ability of wildlife managers to carry out rapid and effective control and eradication programs on foxes (Coman *et al.* 1991).

### 2.4 The domestic dog

Domestic dogs (*Canis familiaris familiaris*), arrived in Australia with European settlers and soon began going feral and interbreeding with the dingo population (Anon. 1990). This has resulted in Australia's "wild dog" population consisting of dingoes, feral domestic dogs, and their hybrids. There has been concern that hybridisation would lead to the evolution of a "master race" of wild dogs as dingoes interbreed with the larger and fiercer domestic breeds, but this has not yet occurred (Breckwoldt 1988). Most breeds of domestic dog are able to have two litters per year, whereas dingoes are only capable of having one. As a consequence of this, it is thought that as feral domestic dogs and hybrids increase as a proportion of the total wild dog population, the potential rate of recovery from control measures may increase (Anon. 1990). All wild dogs in sheep areas are a potential problem and have long been subject to control as a result (Breckwoldt 1988; Anon. 1990). The impact of feral domestic and hybrid dogs on the native fauna is probably negligible, as Australia's fauna has evolved with large carnivores, first the thylacine and then the dingo. Due to the similarities, and the level of hybridisation between dingoes (*Canis familiaris dingo*) and feral domestic dogs (*Canis familiaris familiaris*) in south-eastern Australia, the following sections on control will refer to them collectively as "wild dogs".

### 3. THE ANIMALS AND THEIR IMPACT.

This section will briefly discuss the various animals and review their respective impacts on Australia's native fauna. As feral cats are a major problem in many parts of the world, particularly on offshore and oceanic islands, they will be more extensively discussed.

#### 3.1 Feral cats and their impact

The domestic cat, *F. catus*, is thought to originate from the North African sub-species of the wild cat, *F. silvestris libyca*, (Serpell 1991). Depending on the environment, feral domestic cats may live in colonies or small groups (Neville 1989), or revert to a solitary

social system (Jones 1989). In general, urban cats are more likely to associate in colonies, (e.g. Neville 1989), while rural cats may live in small groups or individually (e.g. Langham 1991), and cats occupying "natural" habitats tend to revert to a solitary social structure (Jones 1989; Jones and Coman 1982). The truly feral cat shows many behavioural and other similarities to its cousin, *F.s. libyca*. Both have solitary social structures, occupy a wide range of habitats, and have a diet which includes small mammals, birds and insects (Passanisi *et al.* 1991). The cat is a solitary hunter, even when living in groups (Mellon 1991). It is a versatile (Mellon 1991), and opportunistic predator (Jones and Coman 1981), and scavenger (Coman and Brunner 1974; Konecny 1987), whose level of predation on any given prey item varies depending on its abundance and availability.

The introduction of the cat into new environments has frequently been blamed for large scale changes in the abundance of indigenous fauna, particularly on islands (Wilson *et al.* 1992). The impact of cats on the Australian mainland is less clear than their impact on islands. However, it has generally been assumed that their impact on the small native fauna is severe (Frith 1979). Others (e.g. Davies and Prentice 1980), suggest the most severe impact has already been felt in Australia's mainland ecosystems. Much of the evidence supporting the view that feral cats do impact heavily on Australia's fauna is either indirect or anecdotal, as it is difficult to isolate the impact solely due to cats from that due to the introduced fox and other broad scale ecological changes that have occurred in Australia since European settlement (Jones 1989).

Many studies have been carried out attempting to determine the impact cats have on both islands (e.g. Hayde 1992; Brothers *et al.* 1985; Jones 1977; Konecny 1987; Anderson and Condy 1974), while there have been fewer studies in "mainland" situations (e.g. Jones and Coman 1982; Coman and Brunner 1974; Triggs *et al.* 1984; Catling 1988). The results of these studies will now be discussed.

### 3.1.1 The impact of cats on islands

The role and impact of cats on island faunas is generally unambiguous and devastating (e.g. FitzGerald *et al.* 1991), with the introduction of cats to islands generally being catastrophic to the endemic avifauna. On fifteen islands in New Zealand waters alone, cats have been implicated in the extinction of at least six endemic species and seventy local extinctions (Merton 1977). Cats (and other introduced species, particularly *Rattus* spp.) have had a particularly severe impact on island faunas because in most instances, island fauna have, after colonising the island environment, lost anti-predatory behaviours. Many island residents also increase in size and become flightless (mainly birds but also some invertebrates) (King 1984).

Nesting colonies of various seabirds have also been adversely effected on many islands, particularly burrow-nesting petrels, as they comprise significant proportions of cats' total diets on islands (e.g. Anderson and Condry 1974; Jones 1977; FitzGerald *et al.* 1991; Chapuis *et al.* 1994), with many becoming extinct.

Most islands with feral cat populations also have populations of introduced rats (*Rattus rattus* and/or *R. norvegicus*), house mouse (*Mus musculus*), and/or rabbits (*Oryctolagus cuniculus*). Although seabirds initially formed a large part of cats' diets on many islands, cats often come to depend on the introduced rodent species for prey (Jones 1977; FitzGerald *et al.* 1991), or both rodents and burrow-nesting petrels (Anderson and Condry 1974; Brothers *et al.* 1985; Chapuis *et al.* 1994). The potential importance of cat predation upon other introduced animals, principally rabbits and rats, has been recognised to be a significant management issue (Jones 1977; FitzGerald *et al.* 1991; King 1984). Rats are important predators on some islands, and removing their main predator could have worse results for the island avifauna than continued predation by cats.

### 3.1.2 The impact of cats on "mainland" Australia

Various studies have illustrated that there are two general patterns of cat predation, depending on habitat type (e.g. Coman and Brunner 1972; Jones and Coman 1981; Triggs *et al.* 1984; Catling 1988), (1). "predominantly undeveloped bush country", or "primary habitat"; and, (2). "open improved, and grazing areas" or "secondary habitat" (after Coman and Brunner 1972). The dominant items in the diet of feral cats in "secondary habitat" are introduced rodents, particularly the European rabbit, *Oryctolagus cuniculus*, and house mouse, *Mus musculus*. Rabbits alone make up to 53% of prey taken by frequency of occurrence, and 82.6% occurrence by weight (Coman and Brunner 1974). In total, introduced mammals make up to 74.1% by occurrence and 90.5% by weight (Coman and Brunner 1974). Birds feature consistently in the diet, their importance ranging from "relatively unimportant" (Coman and Brunner 1972), to being an important food (Jones and Coman 1981). However, eggs and nestlings may not be identifiable in cat stomachs, and so studies may under-estimate predation of birds (Davies and Prentice 1980). The bird species most frequently taken were those which occupied the ground or lower shrubs (Catling 1988). Insects, reptiles and amphibians appear frequently in the diet of most cats but are generally of little overall importance. Overall, research suggests that the present impact of feral cats on native fauna in "secondary areas" is minimal.

There are fewer studies in "primary" habitats, but generally, feral cats rely heavily on the smaller native mammals. Triggs *et al.* (1984), found the major prey items for cats in a national park in southeast Victoria to be ring-tailed possum (*Pseudocheirus perigrinus*), (56%), bush rat, (*Rattus fuscipes*), (19%), and brown antechinus, (*Antechinus stuartii*), (15%); 71% in total. Birds and reptiles were also significant items. Rabbits appeared much less frequently in the diets of "primary" cats, ranging from 1% to 43% (Brunner and Coman 1972; Jones and Coman 1981; Triggs *et al.* 1984; Catling 1988).

### 3.2 Foxes and their impacts

The fox is an opportunist: it is a carnivore which can be an active predator, a scavenger,

a frugivore, an insectivore, or a vegetarian. It is a proficient hunter over a wide variety of habitats and can hunt in daylight or darkness (Lloyd 1975). Foxes are usually solitary animals and may be strongly territorial. In some cases individuals have been reported to occupy exclusive areas and possibly only come together during mating (Niewold 1980; Phillips and Catling 1991). Social groups consisting of one adult male and several related vixens have also been reported in some habitats (Macdonald 1979; Macdonald 1980). These groups occupy territories from which neighbouring groups are excluded. When foxes are seen together they are generally mating pairs or young with parents (Niewold 1980). However, in habitats where groups occur non-breeding vixens have been reported to act as "helpers" to breeding vixens (Macdonald 1979).

It has been a commonly held view that predation by foxes, like cats, has had a substantial impact on Australia's small native mammal fauna (Kinnear *et al.* 1988). Generally, anecdotal or indirect evidence has been offered; such as the greater abundance of small ground living marsupials in many fox free areas (Coman 1973), or the profound change which occurred in the small and medium sized mammal fauna in (apparent) association with the spread of the foxes range (Kinnear *et al.* 1988). However, as with the impact of the cat, it is difficult to separate the effects of fox predation from the other broadscale changes which occurred at the same time. As a result, clear evidence supporting the culpability of the fox is lacking. Various studies on the fox in Australia have been carried out (e.g. Coman 1973; Brunner *et al.* 1975; Seebeck 1978; Croft and Hone 1978; Green and Osborne 1981; Kinnear *et al.* 1988; Coman *et al.* 1991), most attempting to determine impact via dietary analysis.

The long term effects of fox predation on any prey species is difficult to measure and, while dietary analysis does little to measure such effects, it does provide some basic information which can serve as a guide (Coman 1973). Overall, most studies show fox diets to be remarkably similar to cat diets (e.g. Triggs *et al.* 1984). Catling (1988), suggests that foxes and cats co-exist by primarily utilising different age groups of the

same staple prey, while also utilising slightly different supplementary prey. In agricultural areas, and anywhere rabbits and house mice are present, they make up the major proportion of foxes diets (Brunner *et al.* 1975; Seebeck 1978; Croft and Hone 1978). Unlike those of cats, fox diets also include sheep as an important component, principally in the form of carrion (Coman 1973; Croft and Hone 1978). Native mammals form only a minor part of the diet of foxes in rural areas, but it needs to be pointed out that these species are in the relatively low abundance in these areas (Croft and Hone 1978). While generally described as an opportunistic predator (e.g. Coman 1973; Lloyd 1975; Catling 1988), there are also reports of selective predation by the fox (e.g. Brunner *et al.* 1975; Seebeck 1978; Croft and Hone 1981). For example, at a forest study site rabbits were selectively preyed upon by resident foxes, despite the rabbits being restricted in range and not apparently abundant (Brunner *et al.* 1975). Similarly, at a second forest site, rabbits were selectively preyed upon despite there being an abundance of suitably sized native mammals and birds also present (Seebeck 1978). Croft and Hone (1981), reported that foxes in alpine and sub-alpine habitats in New South Wales selectively preyed on the broad toothed rat, *Mastacomys fuscus*, despite it having a significantly lower abundance than the bush rat, *Rattus fuscipes*. They also suggested that foxes may impose a heavy toll on the alpine/sub-alpine ecosystem, as it originally lacked a carnivore of comparable feeding habits.

Foxes may also be important predators of native birds, particularly the ground nesting species (Coman 1973). However, various studies agree that in terms of quantity, birds are a relatively unimportant item in fox diets (Coman 1973; Brunner *et al.* 1975; Seebeck 1978 Green and Osborne 1981).

Overall, the research reviewed suggests that as native fauna generally has only a low occurrence in fox diets, foxes may not have a great impact on the small/medium indigenous mammal fauna. However, it must be remembered that a low percentage occurrence of a given species in scat or stomach analysis, does not necessarily mean a

low impact on that species. This point will be further discussed in section 4. (Implications of predation). Brunner *et al.* (1975), Green and Osborne (1981), and Triggs *et al.* (1984), all found that predation on indigenous fauna was significantly higher in the absence of small introduced mammals; this suggests that foxes could detrimentally impact on the native fauna in these situations. Kinnear *et al.* (1988), found that five remnant populations of rock-wallaby were declining purely as a result of fox predation. The populations had been declining or static for several years with a sixth population going extinct. Fox control programs were initiated around two colonies and maintained for four years with the result that the two populations increased by 138 and 223% respectively. Two populations at locations not subject to fox control declined by 14 and 85%, while a third site increased by 29%. It was concluded that foxes had probably been a significant factor in the decline of native mammals in the past and that they still threatened surviving populations.

### 3.3 Wild dogs and their impacts

Because introduced predators have their most significant impact on a new eco-system in the period immediately after arrival (King 1984), discussion of the impact of the dingo, which arrived at least 4000 years ago, would be a difficult and theoretical exercise. For the purpose of this review it is sufficient to recognise that the dingo probably had a massive impact when it first arrived (Breckwoldt 1988), but after 4000 years, the species which remain are those that can cope with the "new" predator (King 1984). The subsequent introduction of the domestic dog, of which the dingo is a sub-species (Anon. 1990), is, therefore, unlikely to have had a significantly different ecological impact than the "native" dingo (Breckwoldt 1988). Several studies support this suggestion (e.g. Triggs *et al.* 1984; Lunney *et al.* 1990; Brown and Triggs 1990). Dingoes are often referred to as opportunistic predators because of the wide range of prey species that they exploit, but generally a small number of species make up a large proportion of the diet (Caughley *et al.* 1980; Shepherd 1981; Robertshaw and Harden 1986). Large macropods

and, where they occur, wombats, are generally the most frequent prey of dingoes (Whitehouse 1977; Newsome *et al.* 1983; Robertshaw and Harden 1985). Dingoes have been shown to be selective predators of particular macropod species (Caughley *et al.* 1980; Robertshaw and Harden 1986; Thompson 1986), emus (Caughley *et al.* 1980), and rabbits (Marsack and Campbell 1990), and also to be capable of having some regulatory effect on prey numbers (Caughley *et al.* 1980; Robertshaw and Harden 1986; Thompson 1986). This latter point is supported by observations in the 1860's that, following the decline in dingo numbers areas experienced a "startling build up of wildlife" (Rolls 1969:361).

Like dingoes, feral dogs prey on the larger native mammals but are more opportunistic. For example, Lunney *et al.* (1990), found dogs principally took large mammalian prey, but seasonal variation in the occurrence of insects and reptiles in their diets showed dogs to be opportunistic predators. Triggs *et al.* (1984), and Brown and Triggs (1990), found dogs favoured macropods and wombats (as do dingoes), but included small mammals and carrion (unlike dingoes). A study on feral dogs in a wildlife refuge in the USA also found them to be opportunistic, eating crippled water birds, road killed animals and other carrion, crippled and young deer, and occasionally garbage from a refuse dump (Nesbitt 1975). The study concluded that feral dogs do not appear to be a regulatory force of any magnitude on animals in the study site, and that they were a valuable part of the fauna by their sanitary predation activities.

Despite fears of hybridisation leading to wild dogs capable of producing two litters per year, hybrids have so far maintained a reproductive pattern similar to that of the dingo, with a single breeding season, and not that of a domestic dog (Jones and Stevens 1988). As the dingo becomes increasingly accepted as a native animal (Breckwoldt 1988), the single major impact of feral dogs may not be on the prey species, but on the dingo. Hybridisation is increasing, especially in south eastern Australia (Breckwoldt 1988), and the end result is potentially the disappearance of the pure dingo; the incidence of true

dingoes amongst wild dogs in the settled areas of south-eastern Australia is only 55.3% in comparison with 97.5% for central Australia (Newsome and Corbett 1985).

#### 4. IMPLICATIONS OF PREDATION

Although predation on native mammals by foxes and cats has not been recorded at the high levels that have been recorded for the introduced rabbit and mouse, it can not be assumed that the predation that does occur is not deleterious to those native animals which are exploited (Coman and Brunner 1972). A distinction must be made between the possible effects of predation on the smaller native mammals, and predation on the rabbit and mouse. Most of the smaller native species have low population densities and therefore small losses due to predation in absolute terms might be sufficiently large in relative terms to result in a significant reduction in the population. For the introduced rabbit and mouse, population densities are usually much higher, and consequently heavy predation might do little more than remove a surplus of animals that was doomed irrespective of predators (Coman and Brunner 1972).

Predators can inhibit the population growth of mammalian prey, particularly when prey numbers are low and after the intervention of a "widespread environmental variable", e.g. drought or fire (Newsome *et al.* 1989). If European settlement is considered a widespread environmental variable, then combining the findings of Coman and Brunner, and Newsome *et al.*, provides good support for the popularly held belief that cats and foxes have greatly assisted in the decline in abundance of small native mammals. Various recent studies also support this view: Spencer (1991), and Horsup and Evans (1993), suggest that predation by feral cats could be a significant detrimental impact on native mammals by reducing adult recruitment via heavy predation on the "young at foot". Spencer (1991), found a feral cat killed 45.5% (5 of 11), of young at foot rock wallabies, *Petrogale assimilis*, in an isolated colony. Horsup and Evans (1993), also found evidence of predation on the young at foot of the endangered bridled nail-tail wallaby,

*Onychogalea fraenata*. Gibson (1994), reported that heavy predation by feral cats threatened a re-introduction program of another endangered macropod, the rufous hare wallaby, *Lagorchestes hirstus*. The program was only saved by a campaign to control cat numbers in the release area. Kinnear *et al.* (1988), reported that not only did fox control around rock-wallaby colonies result in large population increases, but also in increased use of habitat. This indicates that fox predation is a major factor responsible for the presently very limited range of this species. The few areas where rock-wallabies are able to co-exist with foxes are where the habitat provides protective shelter and food nearby; these location essentially serve as refugia for the rock-wallaby (Kinnear *et al.* 1988).

As stated earlier, an introduced predator has its greatest impact during the period immediately following its arrival. During this period, the species which are unable to cope with the new predator are decimated, probably becoming extinct quite rapidly (King 1984). Those which survive the initial period are the species which can cope with the new predator to at least some extent. This is an important point, considering that the range of the fox has been stable since at least the 1930's (Kinnear *et al.* 1988), and feral cats reached much of Australia before Europeans (Anon 1994); in other words both predators have gone through the "introduction" stage and had their major impact. There is ample evidence that predation by introduced predators has been the cause of many local and total extinctions (King 1984). However, the distribution and abundance of most of those species which have managed to survive and cope with these predators to some degree, are now largely determined by factors other than predation; the most typical being habitat availability (or more accurately, rate of habitat fragmentation) (King 1984). Taking this into account plus the findings of the reviewed research, it seems fair to conclude that while cats and foxes undoubtedly did initially have a major impact on the native fauna, that impact is now generally minimal. There are exceptions to this, particularly in the case of isolated and remnant populations, as illustrated by Kinnear *et al.* (1988), Spencer (1991), Horsup and Evans (1992) and Gibson (1994).

## 5. CONTROL AND INTRODUCED OR PEST PREDATOR POPULATIONS

Predators are controlled for one reason; because they conflict with the interests of humans. Predation on livestock, and health issues, such as the potential spread of rabies by foxes, have traditionally been the rationale for controlling predators, principally wild dogs and foxes, in Australia. More recently, control of introduced predators has been carried out for environmental reasons, *i.e.* to reduce their impact on native fauna. Yet despite having been severely persecuted, these and other "pest" predators around the world, including the fox in Europe (Stubbe 1980), and the coyote in North America (Connolly 1978), are still abundant and in some cases have even expanded their range.

### 5.1 "Controlling" populations: a definition and a problem

King (1984), defines "control" as "the artificial reduction in numbers of a species, temporary or permanent, for the benefit of some other species". Caughley and Sinclair (1994), define "control" to be reducing the density of a population to a lower density and enforcing that lower density by continuous control operations. This latter definition highlights the fact that population control is not a "one off" operation, in fact, control of a population by traditional means, *i.e.* hunting, trapping or poisoning, is essentially "an exercise in sustained-yield harvesting" (Caughley 1977).

It has become increasingly clear that the traditional approach of increasing mortality in a population of pest individuals, has many problems. Most pest species have 'boom and bust' reproductive strategies, and therefore any population reduction achieved, short of eradication, is usually short lived (Putman 1989). Local reductions in population density elicit various responses from the remaining and surrounding populations, and an understanding of these population dynamics is essential when contemplating control of a population. This will now be briefly discussed.

### 5.1.1 Basic population dynamics

A vertebrate population's rate of increase usually fluctuates around a mean of zero. When conditions become more favourable the population increases, environmental favourability being reflected in a rise of fecundity and a decline in mortality. The rate at which the population increases is determined by two factors; the amount of food available, and the intrinsic ability of the species to convert that extra energy into enhanced fecundity and diminished mortality. Thus, it depends on an environmental effect and an intrinsic effect, both with limits (Caughley and Sinclair 1994). There comes a point where the animal has all the food it can eat and further increases do not effect its chances of survival or reproductive rate (fixed by the animals physiology). Therefore, all species have a maximum rate of increase or an *intrinsic rate of increase* (Caughley and Sinclair 1994). This maximum is rarely attained (Villemée *et al.* 1989), as it requires a very high availability of food and a low density of animals so there is negligible competition for food (Caughley and Sinclair 1994). These conditions are basically those experienced by introduced predators, particularly in island environments.

### 5.1.2 The effects of control on populations

These conditions are also relevant to the situation of a population reduced by a control operation (Connolly 1978). If population levels are artificially reduced, the density dependent restraints on population growth are removed (Putman 1989), generating a potential increase which will become manifest if the control is stopped (Caughley and Sinclair 1994). As a result, keeping populations of pests below a given level requires a continued input of effort, in fact, it may require ever-increasing efforts merely to achieve the same effect (Putman 1989). Animals are not equally catchable and a control operation progressively culls out those least able to adapt to it. The survivors at low density comprise a large proportion of animals that are either extremely wary or that have home ranges in areas that are difficult to hunt across. Hence a unit effort expended when

density is low will reduce the population by a lesser fraction than when density is high (Caughly 1977; Boulton and Freeland 1991).

An important finding of various studies into a variety of vertebrate pest species is that mortality factors are usually compensatory, not additive (King 1984), *i.e.* if mortality due to control is less than natural mortality it will probably only replace it. This means much effort can be expended killing a proportion of a population, while having no real effect on long term density (Connolly 1978; King 1984). Newsome and Coman (1989) suggest this has been the case with the fox in Australia.

## 6. "TRADITIONAL" CONTROL METHODS

Most "traditional" methods of control generally involve attempts to reduce the population of a given pest by various lethal means; the methods discussed here will be poisoning, trapping and shooting. Others include denning (*i.e.* locating maternal dens and digging them up or fumigating them), and exclusion fencing. Denning has been used against various predator pests including dingoes (Rolls 1969), and coyotes (Till and Knowlton 1983). It has been found to be an effective and selective method of reducing the incidence of predation by predators (Till and Knowlton 1983), but is highly labour intensive and limited in use. The best example of exclusion fencing is found in Australia; *i.e.* the "Dingo Fence". The Dingo Fence runs 5614 km across Australia from South Australia to Queensland, and is intended to keep dingoes out of the sheep country of the south-east corner of Australia. This fence highlights the problems of exclusion fencing; it is expensive to maintain, dingoes regularly cross it (Breckwoldt 1988), and it impedes the movement of other animals (Caughley *et al.* 1980).

### 6.1 The advantages and disadvantages

The advantage of traditional lethal control methods is that they are an immediate solution,

and in the short term they may prove effective, e.g. if foxes are killing a lot of lambs. The disadvantages are generally less obvious and longer term. Eradication of populations, except on small islands, is generally impossible. Considering the apparent ease with which human-kind has made various species extinct, this is surprising. However, this becomes less puzzling when it is realised that most extinctions have been caused by a change in the animals habitat, whereas control operations are usually aimed at the actual population (Caughley 1977). Unlike the populations forced to extinction, those under-going control by shooting and other lethal means, do not suffer from a deteriorating environment. In fact, the opposite is true. The reduction in density improves the quality of the environment for the surviving population (Caughley 1977), generating the 'potential increase' discussed earlier. Eradication is further complicated by immigration and capture rates. A high capture rate can be achieved, but only in a small area and with great effort, but immigration constantly counter-acts this unless the controlled area is, or can be, completely isolated (King 1984). The findings of Coman *et al.* (1991), illustrate this. After a short term, intensive (260 man-hours), control program using a variety of techniques, only an estimated 60% of resident foxes were killed. During the subsequent breeding season, the number of breeding dens detected rose from 13 (pre-control) to 17 (post-control).

It can be seen then, that as eradication is generally impossible, except in small island situations (e.g FitzGerald *et al.* 1991: Bloomer and Bester 1992), any reduction is probably short term, and so must be repeated indefinitely. Population reduction is thus a "perpetual treadmill" (Putman 1989: Neville 1989), and as a long term solution it can be an extremely expensive option. The main methods used will now be discussed.

## 6.2 Baiting/poisoning

Mass baiting with poison as a means of predator control was used as early as 1946 in Western Australia. Meat treated with strychnine was dropped by plane in an attempt to

control dingoes (Rolls 1969). This method did not prove very successful and was discontinued after a number of years (Breckwoldt 1988). Monofluoroacetate, or compound 1080, which has generally replaced strychnine, is a tasteless and odourless water soluble poison used to control both native and introduced pests, including foxes, cats and wild dogs (McIlroy 1981a). As a result of the much higher susceptibility placental mammals have to 1080, compared to most marsupials, it is a very useful poison to control the introduced predators, all of which are placental (McIlroy 1981b).

Aerial baiting with 1080 has been used to deliver baits to remote and inaccessible areas frequented by dingoes (Rolls 1969: Thompson 1986). It has been found to be more successful in areas with drier climates (e.g. Thompson 1986), then in the wetter areas typical of south east Australia (e.g. McIlroy 1986b). This type of use is cause for concern, and can be used to illustrate the problems of poisoning as a control method.

#### 6.2.1 Impact on non-target species

Poison baiting is infamously species non-specific, and has been described as "...scattering poison ...for whatever chances to take it." (Rolls 1969). Aerial baiting is the ultimate in "scattering poison" and those areas in which dingoes remain, and hence this type of baiting occurs, are often also important refuges for many native mammals.

Australia's marsupials have varying degrees of tolerance to 1080, as it occurs naturally in some native plants, particularly in western Australia. However, the naturally higher tolerance marsupials have compared to placentals, is negated in some species by their smaller size. As a result, some of the marsupial carnivores are at risk from consuming meat baits laid for control of wild dogs (and pigs) (McIlroy 1986a). It is, therefore, distinctly possible that aerial baiting could (have) assist(ed) in the extinction of some remnant populations, e.g the Eastern Quoll, *Dasyurus viverrinus*, (Frith 1979: Breckwoldt 1988). However, despite concerns over the impacts of 1080 poisoning campaigns on native animals few studies have been carried out to determine those

impacts. In the Kosciusko National Park in south east Australia, McIlroy *et al.* (1986), found that two wild dog control programs had no significant effect on the populations of birds and small mammals monitored in the area.

#### 6.2.2 Increasing species-specificity of baiting

When baits are laid by hand, there is greater potential to reduce the impact on non-target species by varying the bait presentation. For example baits can be buried to target foxes (Allen *et al.* 1989), or dingoes/wild dogs (Breckwoldt 1988), and reduce bait removal by non-target animals, especially birds (Allen *et al.* 1989). Lures and attractants have been tested in various studies to attract target animals to both traps and baits, with varying degrees of success (e.g. Jolly and Jolly 1992; Clapperton *et al.* 1994). The development of good species-specific odour lures would result in fewer baits and traps being needed, and more target animals and less non-target animals being removed per bait or trap (Jolly and Jolly 1992). Clapperton *et al.* (1994), found that some lures have a potentially important role to play in modifying the behaviour of cats at a trap or bait station, by stimulating close investigation and sniffing, licking and chewing; behaviours that will increase the success of control devices. They do not, however, demonstrate the ability to act as a lure to attract a cat too a control device.

McIlroy (1986a), suggests that some reduction in bait consumption by non-target species can be achieved by; (i) the time of year baiting is done in relation to the availability of other foods; (ii) reducing the dose size per bait to an effective minimum; (iii) manipulating bait size; (iv) modification of baiting method to increase specificity (e.g. using lures), or (iv) reducing the hazard to non-target species (e.g. dying baits or exposing them only during darkness). Allen *et al.* (1989), found factory produced baits to be significantly more species specific for dingoes/wild dogs, than fresh meat baits, the majority of which were taken by non-target species.

One of the problems with using poisons, particularly with insects and rodents, is that regular and continued use may result in the development of strains, within the target population, resistant to the poisons used. Resistance may take two major forms; acquired phenotypic resistance by an individual from continuous exposure to sub-lethal dosages of a poison, or genetic resistance in the evolution of resistant strains within the population (Putman 1989). Individual "resistance" may also occur through learnt bait avoidance as a result of exposure to a sub-lethal dose (Rolls 1969). Acquired resistance can only be slowed by eliminating unnecessary baiting and over-use of poison, and by ensuring that dose rates used are lethal (Putman 1989). As the toxicity of baits containing 1080 declines with time and weathering (Fleming and Parker 1991), removal of uneaten baits may be an essential part of managing effective long term poisoning campaigns, but in reality it is probably only feasible in very small-scale or localised control. Thompson (1986), sees the temporal decline in toxicity of 1080 baits as advantageous as it probably reduces the long term hazards to non-target species where baits are not removed after a control operation.

Overall, poisoning is a cheap and effective method of achieving short term reductions in population, particularly when techniques are used to increase the species specificity of the kill. These techniques, however, generally mean increased effort and cost for a given result, thereby reducing the scale of control program they can effectively be used on.

### 6.3 Trapping

Trapping has been used as a very successful method of controlling various pest predators (e.g. Andrews and Boggess 1978: Breckwoldt 1988: FitzGerald *et al.* 1991: Bloomer and Bester 1992). It is, however, very labour intensive and baiting programs can cover more country faster and more economically. Despite this, in some instances trapping has been found to be more effective at reducing predator populations than baiting (McIlroy 1986b). Trapping does have the advantage of being able to target particular individuals

(Breckwoldt 1988: Bloomer and Bester 1992).

Use of 'walk-in' cage traps allows non-target species to be released, but gin traps (or steel leg-hold traps), are generally used. Bloomer and Bester (1992), found cage traps to be impractical for large scale trapping of feral cats in an eradication program on sub-Antarctic Marion Island, preferring gin traps instead. These are, of course, not target species specific. For example, Newsome *et al.* (1983), found that in one trapping operation where 146 dingoes were trapped, 513 non-target animals were also trapped.

It is inevitable that non-target species will be trapped, but this can be reduced by careful placement of traps (Bloomer and Bester 1992), the use of species specific lures (Jolly and Jolly 1992), and by using more modern versions of the gin trap (Newsome *et al.* 1983). In a study comparing two trap types, the traditional 'Lane' trap and the 'Oneida' trap (a smaller version of the 'Lane' type steel jaw trap), Newsome *et al.* (1983), found the latter caught proportionally fewer non-target species than the former. Overall, 'Lane' traps caught on average 1.9 individuals of protected wildlife for every target animal (dingo), compared with 0.3 individuals for every dingo in 'Oneida' traps. One of the negatives of traditional trapping methods, increasingly unacceptable in modern society, is that they are very cruel. Steel jaw gin traps often break the caught leg in more than one place; first where the jaws actually fasten on the leg, and secondly, during the following violent struggles by the animal the leg may break again higher up (Breckwoldt 1988). As these injuries are normally not fatal (in the short term), animals caught remain in great pain until the traps are checked and the animals are killed. Traps are often not regularly checked, and so it is not uncommon for animals to die in traps (Breckwoldt 1988).

Gin traps can be made slightly more humane by binding poison wads on to the jaws so that when the trapped animal bites at the trap to free itself it receives a dose of poison and dies soon after (Rolls 1969). Alternatively, tranquillisers can be used, decreasing the incidence of leg damage (Sterner and Shumake 1978), and also potentially allowing the

safe release of non-target animals.

The capture of non-target species is generally not condoned but is accepted as it is usually not detrimental to the species populations (Newsome *et al.* 1983). In the case of island eradication programs, such deaths are accepted because of the long-term benefits of predator removal to the indigenous populations as a whole (Merton 1977: Bloomer and Bester 1992).

Overall then, trapping is most useful on smaller populations of pests because individuals can be targeted. For example, Bloomer and Bester (1992), found that having first reduced a feral cat population by other means, trapping allowed individuals located by night sightings and tracking to be specifically and intensively targeted. On higher population densities it is too slow and laborious a method, providing only very short term (if any) benefit.

#### 6.4 Shooting

Shooting is generally not a reliable method of predator control by itself (Brothers *et al.* 1985: Breckwoldt 1988: Bloomer and Bester 1992: Chapuis *et al.* 1994). Despite intensive efforts of shooting and trapping, only 10-15% of the adult cat population was removed each year from Macquarie Island (Brothers *et al.* 1985). On Kerguelen Island cat control programs based solely on shooting have failed as a result of the extensive distribution of the cats. Despite the almost complete elimination of cats on two separate occasions, the cat population fully recovered after both (Chapuis *et al.* 1994). On Marion Island, shooting was only found to be a feasible option after biological control was used to reduce the initial population density of feral cats, and then it had to be carried out in an intensive fashion (Bloomer and Bester 1992). Trapping was incorporated in the final stages of the campaign, and as population decreased, it was found to be a more effective method than shooting alone.

Culling populations by shooting can induce behavioural changes such as shyness and increased use of cover, resulting in further culling being problematical (Putman 1989). This has been the experience of various culling programs (e.g. Challies 1985: Saunders and Freeland 1991: Boulton and Kay 1991: Bloomer and Bester 1992), where intensive use of helicopter based shooting has resulted in target populations avoiding the more habitats where they are more exposed to attack. While population reductions have been achieved, evidence such as pellet group counts, point to the reductions being much lower than hunting returns suggest (Challies 1985). The benefits of shooting as a control method lie in it being highly selective, humane and immediate.

## 6.5 Summary

It is generally rare for a predator control program to consist of only one of the above methods (e.g. Chapuis *et al.* 1994). More typically, control involves some sort of "integrated management" involving some or all of the above methods (e.g. Brothers *et al.* 1985: FitzGerald *et al.* 1991: Hayde 1992). Increasingly though, control efforts are combining traditional methods with more sophisticated techniques, including the use of biological agents (e.g. Bloomer and Bester 1992), and fertility control.

## 7. FERTILITY CONTROL AND WILDLIFE MANAGEMENT

The validity of continuing to control populations of wild animals by traditional means has been increasingly questioned, by both wildlife managers and the public. Greater public awareness of animal welfare and general environmental issues associated with traditional control methods has focussed interest on non-lethal, non-toxic, and humane alternatives (Bomford 1990). These alternatives, as well as being of significant utility, would elicit wider social acceptance (Kirkpatrick and Turner 1985: Bomford 1990). Unfortunately, despite much research effort into the development of such alternatives,

in particular fertility control, little has actually been achieved.

Knipling (1959), originally proposed the manipulation of fertility to control vertebrate populations, citing successful attempts at using the "sterile male method" in the control of some insect pests. He suggested the introduction of sexually sterile, but otherwise sexually vigorous males (and to a lesser extent females), into the natural population of an animal species would have greater influence in reducing the biotic potential of the population than removing the same number of individuals. The relative effectiveness would depend on the mating and dispersal habits of a given species, with the ideal habits including strongly monogamous mating systems. Furthermore, effectiveness is also directly proportional to the ratio of sterile to fertile males competing for mates. While acknowledging that a polygamous mating system would decrease the effectiveness of this method, Knipling held that the presence of substantial infertile males would still have a greater effect than their removal.

Knipling's work preceded substantial research on sterilisation as a means of control. Various logistical problems were encountered of which many have been found to be universal. These are still the major factors preventing the widespread use of chemosterilization (Bomford 1990). Before these difficulties are discussed, the theoretical and real benefits of sterilization will be further examined. It is also worth noting that some of the "benefits" of sterilization are not necessarily so in the context of controlling and eradicating introduced predators.

#### 7.1 Advantages of fertility control.

1. Kirkpatrick and Turner (1985), describe chemical fertility control as a flexible management tool, which allows a large range of control manipulations to be carried out, allowing local populations to be managed as required, rather than using a blanket approach.

2. It is reversible, as a result of the short term action of the drugs used, and individuals are not permanently removed from the gene pool; both important consideration when dealing with populations being managed for conservation purposes, but not if control/eradication is the aim.

3. If done properly chemical fertility control will not influence the social structure of the target population. As sexually mature individuals are not actually removed and so still occupy their territories, the social structure and hierarchy of the population remains intact (Kirkpatrick and Turner 1985; Putman 1989). As territories have not been vacated, outsiders are prevented from entering the population. This method therefore, behaviourally reduces immigration while at the same time reducing reproductive recruitment by induced infertility (Putman 1989; Neville 1989).

4. Increasing mortality factors often results in compensatory increases in reproduction and/or survival. Effectiveness of control by increasing mortality is often reduced by a rebound in reproduction (e.g. Connelly 1978); suppressing reproduction is expected to prevent the population rebounding (Balser 1964).

5. Non-toxic anti-fertility drugs are safer to use and more readily acceptable to the public.

## 7.2 The problems with fertility control

The principal logistical difficulties originally associated with chemosterilization, i.e. (i) the selection of suitable anti-fertility agents for a particular target species, and (ii) the development of effective application methods which provide a high degree of selectivity and safety, will now be discussed.

### 7.2.1 Anti-fertility agents

The agents used must produce sterility without affecting behaviour. Should treated individuals lose aggressiveness and become submissive, then the population threshold

might actually increase due to the presence of sterile individuals that do not become actual participants in establishing the social hierarchy (Howard 1967). For example, surgical castration of male feral domestic cats results in behavioural changes; Neville (1989), reports that castration of males reliably reduces home-range size, and makes them more tolerant of other cats. This may be a desirable outcome for urban feral cats, but is totally unacceptable for 'wild' feral cats, as it effectively increases their potential density and therefore their potential impact on native fauna.

Despite much research, there are as yet no chemosterilant drugs available that can be field delivered to cause permanent, humane, non-toxic sterility in both sexes of target wildlife species (Bomford 1990). This means agents must be re-applied regularly, therefore requiring efficient methods of application.

#### 7.2.2 Application methods

Drugs and delivery techniques developed so far, are only of use in the management of small intensively managed populations. These include using steroid releasing implants (Matschke 1977c), or oral baiting with various drugs (Matschke 1977a; Roughton 1979).

Matschke (1977b), found steroid releasing implants achieved exceptional results in preventing pregnancy in white tailed deer, with no treated animals becoming pregnant. The implant system was found to be more effective than oral administration, and more practical than daily sub-cutaneous injections, inhibiting fertility for two breeding seasons (Matschke 1980). However, the combination of the relatively short life of the implants and the high cost of capture and recapture, make this method unfeasible for general use (Matschke 1980). For implants to be an effective management tool, individual implants need to last for the duration of the reproductive life of the target species.

The major difficulty with applying anti-fertility agents using the oral baiting method, is effectively treating the target species at the appropriate period in the breeding cycle (Oleyar and McGuinness 1974). Supporting this, Lacombe *et al.* (1987), found treatment of red-wing blackbirds with the anti-fertility agent Ornitrol had to occur before testicular development was complete each breeding season. If the drug was given to sexually active birds it had no effect. Roughton (1979), using an oral anti-ovulatory treatment in free ranging white tailed deer (*Odocoileus virginianus*), found that the drug had to be ingested in treated food material almost daily for 5-6 months, and even a brief interruption of treatment might allow conception. Continual successful baiting for a period of up to six months seems logistically improbable and economically unfeasible for anything except very small and confined populations. Lacombe *et al.* (1986), found that oral baiting was a potentially viable control method for red wing blackbirds, but the level of success depended heavily on the food availability in the environment, which showed large yearly variation; and hence the level of control achieved was subject to similar variation.

These examples illustrate the difficulties associated with applying anti-fertility agents, and highlight the need for agents capable of permanently sterilising an animal. Roughton (1979), points out that, superficially, oral application of infertility agents appears attractive because capturing and handling of animals is not required, this is advantageous (especially when dealing with predators), but must, however, be balanced against the uncertainty of how many and which animals will be treated, and the generally short duration of treatment effects. According to Roughton, the ideal form of reproductive inhibitor for free ranging animals that cannot be treated individually would be a post implantation, oral gametocide with single dose effectiveness. Such a drug could be distributed once at the right time to prevent or nullify conceptions for the entire breeding season.

The need for a permanently sterilising agent, requiring only a single dose, is particularly

urgent when dealing with introduced predators. These animals are elusive, widespread and occur at low densities; and, considering the problems encountered with baiting other less elusive animals the chances of broad-scale administration of an anti-fertility agent by bait on anything but an occasional basis is highly unlikely. Considerable research has been carried out, particularly in the USA attempting to develop effective techniques for inhibiting reproduction in coyotes. However, this work was eventually abandoned as a result of major logistical difficulties, particularly the short duration of induced infertility, and the difficulty of delivery to target populations (Sturner and Shumake 1978).

### 7.2.3 Other problems

Fertility control is not an effective alternative to limit populations under certain conditions (Bomford 1990). (i) When density is nearing carrying capacity of the environment and density-dependent mortality and dispersal are highest among juveniles. In this situation, only a small proportion of offspring may be recruited to the adult population, therefore even high reductions in fertility will not reduce population density if birth rates remain higher than the (low) recruitment rate. (ii) Reduced birth-rates due to sterility will be ineffective in reducing population density if other population parameters change to fully compensate, e.g. in the case of a winter food induced population minima (Bomford 1990).

A further problem with fertility control is that reproductive inhibition is a gradual method of population control, especially in long-lived species; its effect is delayed until natural mortality decreases population size. As a result damage can still occur during the delay if numbers are high, this is of particular concern when dealing with an introduced predator. In comparison, control by lethal means removes animals immediately, and therefore provides relief from damage immediately (Bomford 1990).

Generally, fertility control is best combined with mortality enhancing control methods (Balser 1964: Howard 1967: Bomford 1990: Hone 1992); mortality enhancing methods initially reduce population size and reproductive inhibition reduces population rebound. Thus, immediate and relatively inexpensive relief from damage is achieved, while population (re)growth is slowed due to reduced recruitment.

Overall, with current technology, the potential use of fertility control is limited to the relatively few situations already described. The development of new, more effective agents is essential for this method to become useful for broad-scale wildlife management.

## 8. BIOLOGICAL CONTROL

Biological control has had limited success against vertebrate pests. The introduction of the Myxoma virus to control rabbits in Australia is one of the few successful examples (Caughley 1977: Caughley and Sinclair 1994). Many invertebrate control efforts have involved the use of a predator, however, control of vertebrate pests by predators is not a realistic option (Putman 1989). This has been repeatedly demonstrated around the world where cats, weasels, stoats and numerous other predators have been introduced in attempts to control various pests and have failed (King 1984). The potential for controlling predators with predators is even less realistic. Most biological control efforts focus on the use of pathogens, such as the rabbit Myxoma virus, however, there are major difficulties associated with using pathogens to control pests. Firstly, a pathogen must be found that has never been in contact with the target species, but, which is hosted by a closely related species. Secondly, it must be ascertained that the pathogen will attack only the desired species and not spread to other animals. And thirdly, it must be accepted that the pathogen will provide only temporary control as both the pathogen and the target species will, through natural selection, soon reach an "accommodation" (Caughley 1977). The difficulty in finding a suitable pathogen, and the relatively short term effect achieved count heavily against this method of control (Caughley 1977).

The introduction of the feline parvo virus to the feral cat population on Marion Island is one of the few examples of biological control of a predator. The highly contagious virus was introduced to Marion Island in an attempt to cause an epidemic in the feral cat population (Van Rensburg *et al.* 1987). It led to a drastic reduction in the density of cats, with the population falling from an estimated 3465 to 615 in five years, after which the population stabilised, suggesting this control method was becoming ineffective. Prior to the introduction of the virus traditional control was ineffective due to the size of the population, however, the massive reduction in density following its introduction meant that traditional methods could then be effectively used (Bloomer and Bester 1992). This example illustrates that even when possible, biological control can only be a part of an integrated control program, and is not an answer in itself. Also the use of pathogens of feral animals in Australia has the danger of them crossing over into domestic populations, therefore broad-scale vaccinations of the appropriate domestic animals would be required as part of such a control program.

## 9. CONCLUSIONS

Introductions of predators into new ecosystems is invariably devastating to the indigenous fauna. On islands, cats prey heavily on birds, but may also depend on other introduced small mammals. On the Australian mainland the impact of introduced predators is less clear, but is likely to be more significant in undeveloped natural bush environments than in agricultural areas. In both islands and mainland situations, the impact of the new predator is most severe immediately after its arrival.

Control of introduced and pest predator populations involves reducing the population density to a lower, more desirable level and maintaining it at or near that level. Control is justified on the grounds of reducing the incidence of predation on livestock; reducing the potential for disease transmission; and reducing the impact on native fauna. Control methods have traditionally aimed at reducing the population density of a given pest by

increasing mortality through poisoning, trapping, shooting and denning or combinations of these methods

Mortality enhancing methods of control have the benefit of allowing immediate reductions in population density to be achieved. However, the benefits are short term due to treated populations "rebounding" as a result of increased resource availability for the surviving population.

Some traditional methods, particularly trapping and poisoning, are non-species specific, resulting in mortality in non-target animals. Non-target mortality is not condoned, but is usually accepted as not being detrimental to the species' population's; particularly in the case of eradicating populations of introduced predators from islands as the benefits to the indigenous fauna as a whole outweigh the loss of a few individuals.

Population control by inhibiting fertility has been proposed as a potentially superior method of controlling populations then increasing mortality. However fertility control has not been as successful as initially expected. Few wild animals are strictly monogamous in sexual activity, even if apparently so in social structure. Therefore the proportion of sterile individuals needs to be very high for even modest control to be effected.

Anti-fertility agents used must not affect behaviour, and preferably, when controlling introduced predators, should require only a single dose to achieve permanent sterility. As yet no such agents have been developed. The necessity of having to repeatedly dose animals places severe limitations on fertility control as a means of controlling wild animals on a broad scale.

Potentially, fertility control is best used in conjunction with mortality enhancing methods. Traditional methods can achieve rapid and effective reductions in population

density, and fertility control can then be implemented to prevent the treated population "rebounding".

Biological control methods are of very limited application in the control of introduced predator populations. This stems from two major difficulties, the first is finding a suitable pathogen that is sufficiently species specific; the second problem is the potential for a pathogen to cross over into domestic populations.

In conclusion, controlling populations is increasingly becoming an integral part of wildlife management. As a result, it is essential that more effective, humane and cost effective methods be developed. Traditional methods are labour intensive, only effective in the short term, and of limited species-specificity, but until there is a major technological break-through; either in fertility control, or in some other, perhaps as yet unknown, method of managing populations, wildlife management and pest control will continue to rely heavily on these methods. There is then, a great need to continue research into fertility control to develop agents capable of achieving single dose infertility; both on a seasonal basis, and for permanent sterilisation.

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