MOVEMENT PATTERNS AND PREY HABITS OF HOUSE CATS *FELIS CATUS* (L.) IN CANBERRA, AUSTRALIA.

by

DAVID G. BARRATT, B.Sc.

Applied Ecology Research Group

University of Canberra

PO Box 1, Belconnen ACT 2616

A thesis submitted in fulfilment of the requirements of the Degree of Master of Applied Science at the University of Canberra

JULY 1995

ACKNOWLEDGMENTS

First and foremost, my sincerest thanks to all cat owners who volunteered to supply prey records and/or allow the movements of their cat(s) to be monitored. Thanks also to the many volunteers and technical staff who helped in the often laborious and sleep depriving task of gathering radio–telemetry data, in particular, Jan Martin, Phil Tennant and Gavin Potter. Project funding was generously provided by the ACT Department of Environment, Land and Planning and the University of Canberra, Applied Ecology Research Group. Many thanks to my long–suffering supervisors Jim Hone and Arthur Georges, and also to Michelle Manning for her support, and assistance in the collation of Canberra Ornithologists Group bird data and presentation of map figures. Finally, heartfelt thanks to my wonderful family, for all those things that parents and siblings do to help, often without ever realising; and to Lauren, for her help in proof reading draft manuscripts and for her faith and friendship.

ABSTRACT

House cat movements in Canberra suburbs adjacent to grassland and forest/woodland areas were examined using radio–telemetry over 9 months. Information on the composition of vertebrate prey caught by house cats in Canberra was also collected by recording prey items deposited at cat owners' residences over 12 months.

Home range areas of 10 suburban house cats, and a colony of seven farm cats, were examined using 95% convex polygons. Nocturnal home range areas of the suburban cats varied between 0.02 and 27.93 ha (mean 7.89 ha), and were larger than diurnal home range areas (range 0.02 to 17.19 ha – mean 2.73 ha). Nocturnal home range areas of cats from the farm cat colony varied between 1.38 and 4.46 ha (mean 2.54 ha), and were also larger than diurnal home range areas (range 0.77 to 3.70 ha – mean 1.70 ha). Activity levels were greater at night than during the day, though diel activity patterns varied seasonally in response to ambient temperature. Four suburban house cats moved between 390 m and 900 m into habitat adjoining the suburb. Movements further than 100–200 m from the suburb edge were always made at night. Polygons describing the home ranges of these animals were strongly spatially biased away from the suburban environment, though the cats spent the majority of their time within the bounds of the suburb.

In addition to nocturnal and diurnal effects, home range areas, and subsequently habitat utilisation, appeared primarily determined by the density and spatial distribution of cats utilising separate food resources, and the dominance of individual cats in local social hierarchies, rather than gender or neutering effects. Home ranges of cats in the farm cat colony overlapped extensively, as did those of cats living at the same suburban residence. There was little or no overlap between the home ranges of cats from different residences. Barriers, in the form of busy roads, appeared to also significantly influence home range size and shape.

Within home range areas, house cat movements during the day appeared strongly influenced by available cover (drains, tall grass, fences and shrubs etc.), and the location of resting/sunning spots and hunting sites close to home. At night, movement patterns appeared influenced by the location of favoured hunting sites toward the outer edges of home range areas (in this study, tall grass and scrub/forest habitat, and farm buildings).

Nineteen hundred and sixty one prey items representing 67 species were reported or collected. Sixty–four percent of the prey items were introduced mammals, with native birds comprising 14%, introduced birds 10%, unidentified birds 3%, reptiles 7%, amphibians 1% and native mammals 1%. Predation appeared to be largely opportunistic with respect to spatial and temporal (daily and seasonal) prey availability and accessibility. All amphibians and 62% of mammals taken by cats not confined at night, were caught at night. In contrast, 70% of birds caught, and 90% of reptiles, were taken during the day (45% of birds between 0600 h and 1200 h, and 61% of reptiles between 1200 h and 1800 h). There was some evidence that small mammals are preferred prey of house cats.

The mean number of prey items reported per cat over 12 months – 10.2 ± 2.66 (2SE, n=138) – was significantly lower than mean predation per cat per year – 23.3 ± 6.16 (2SE, n=138) – estimated by cat owners before the prey survey began. Seventy percent of cats were observed to catch less than 10 prey items over 12 months, but for 6% of cats, more than 50 prey items were recorded. Because counts of the amount of prey caught per house cat per unit time were highly positively skewed, data assumptions and statistical parameters used to extrapolate results from the study sample of cats, to the house cat population of Canberra, had a significant effect on estimates of total predation in Canberra. The precision of the total predation estimate was low (± 25%), from a sample of 0.3% of the Canberra house cat population. The accuracy of such estimates are dependent on how representative the study cat sample is of the wider house cat population, and on the proportion of prey items not observed by cat owners.

The total amount of prey taken was not significantly influenced by cat gender, age when desexed, or cat breed. Nor did belling or the number of meals provided per day have a significant influence on predatory efficiency. Cat age and the proportion of nights spent outside explained approximately 11% of the variation in the amount of prey caught by individual cats. House cat density and distance to prey source areas (rural/grassland habitat) explained 43% of variation in predation on introduced mammals and birds.

The impact of predation beyond suburb edges is likely to be most significant on populations of small to medium sized arboreal and ground–dwelling mammals, because of their nocturnal nature, and because they appear to be preferred prey types of house cats. Impacts on diurnally active prey, such as most birds and reptiles, are likely to be confined to within 200 m of residential housing (possibly further where good cover is available). Properly enforced nocturnal confinement should restrict the range sizes of cats that roam widely and utilisation of habitat beyond suburb edges, and also reduce predation on mammals and amphibians. Night–time curfews however, are unlikely to greatly reduce predation on diurnally active species, including most birds and reptiles. Curfews are currently neither widely adopted nor effectively practiced in Canberra.

Estimates of predation by house cats, particularly extrapolated estimates, should be treated with caution. They do not necessarily reflect relative impacts on different prey types. Nor do high rates of predation prove prey populations are detrimentally effected, particularly in urban environments. Nonetheless, on a small (backyard) scale in suburban environments, and in habitat within 1 km of residential housing, including isolated private properties, predation by individual cats may threaten populations of native wildlife. Hunting by house cats is particularly undesirable in relatively undisturbed habitat because of fundamental differences in the ecological processes operating in these areas (especially isolated remnants) compared with contrived and modified suburban environments. Adverse impacts on native fauna will always be potentially greatest in undisturbed habitat adjacent to new residential developments.

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1 GENERAL INTRODUCTION

1.1 DOMESTICATION OF THE CAT

The north African wild cat *Felis sylvestris lybica* is generally believed to be the ancestor of the modern domestic cat *Felis catus* (Serpell cited in Bradshaw 1992). The process of domestication of the wild cat began in Egypt, probably around 4000 BC. The remains of *Felis sylvestris*, and other cats such as *F. chaus*, are found in Egyptian tombs of that period, though it is unclear whether these earliest remains are of domestic cats, or of animals killed for their pelts (Bradshaw 1992). Egyptian paintings and sculptures dating from about 1600 BC onwards depict cats sharing many human activities, such as eating and hunting, providing conclusive evidence of their domestic status by this time (Serpell cited in Bradshaw 1992).

The initial function of domestication is obscure, but may have been to help protect Egypt's grain–based economy from the impact of outbreaks of granivorous rodents. Alternatively, the domestication process may simply have been a consequence of the rise in the religious status of the cat in Egypt, culminating in the elevation of the cat goddess Bastet into the national deity in about 950 BC. The importance of cats in Egyptian religion at this time appears to have hindered their export as pets or as controllers of rats and mice (Bradshaw 1992). Nonetheless, by 200 BC domestic cats had reached India, and subsequently the Far East, achieving a global distribution in modern times. Domestic cats were introduced into Australia by early European settlers to the New South Wales colonies (Jones 1987), but may have also arrived from shipwrecks along the Western Australian coast or with the Macassans (Johnson 1991).

While changes such as a reduction in brain size, modification of the hormone balance, and expression of neoteny have occurred in domestic cats, domestication appears to have had less effect on the cat in behavioural terms than on any other domestic mammal (Bradshaw 1992). The persistence of feral cat colonies, genetically almost identical to house cats, in a variety of non–urban environments is evidence that association with man has little altered the cat's ability to survive as a wild predator. Feral cat populations ranging in density from less than one, to 2000 per square kilometre, have become successfully established around the world in a range of habitats including urban and remote locations, from sub–antarctic to tropical climates (Liberg and Sandell 1988).

The ecology of domestic cats living in these varied habitats have been increasingly studied since the second World War. This study is primarily focused on the spatial movement patterns, habitat utilisation, temporal activity patterns and predatory behaviour of house cats. For clarity, the terms used to define different types of cats in this thesis are outlined below, based on the definitions of Liberg and Sandell (1988). The term 'domestic cat' refers to all categories of *Felis catus*. House cats live in close association with a household which assumes responsibility for feeding them. A farm cat is a house cat living on an agricultural farm. A suburban cat refers to a house cat living at a suburban residence. Finally, feral cats are domestic cats not attached to a particular household. This does not mean that they cannot live close to humans on a more anonymous basis. A feral cat can subsist either entirely on its own, hunting and scavenging like any wild carnivore, or by being fed unwittingly by humans from garbage bins or at garbage dumps, or by handouts from 'cat lovers'.

1.2 PREDATION BY FERAL CATS

In Australia, feral cats occur in habitats ranging from the arid zone to coastal eucalypt forests (Fitzgerald 1988). Numerous studies have been conducted on the diet of feral cats in areas remote from human settlement (e.g., Coman and Brunner 1972, Triggs *et al.* 1984, Jones and Coman 1981, Bayley 1978, Strong and Low 1983, Maddock 1983). This work has revealed these cats prey upon a wide range of native Australian fauna, including most ground dwelling and arboreal marsupials, lizards, frogs, bats, and many passerine and ground–dwelling bird species. Introduced species, such as the rabbit

Oryctolagus cuniculius are also important prey items of feral cats in most Australian habitats except forests.

Fewer studies from Australia and overseas have attempted to measure the impact of predation by feral cats on prey populations (see Fitzgerald 1988). The impact of carnivores (red foxes *Vulpes vulpes* and feral cats) on rabbit populations on a 300 km^2 nature reserve in semi–arid Australia was tested using predator–removal experiments (Newsome *et al.* 1989). It was found that foxes and cats did control rabbit populations, but only after rabbit numbers had collapsed during drought, i.e., the predatory control was environmentally modulated (Newsome *et al.* 1989). The conclusion that carnivores can limit rabbit populations once rabbit numbers have been reduced by some external agency, was the same as that found in a similar study conducted in New Zealand (Gibb *et al.* 1978), and also by Elton (1953) in relation to farmyard cats and Norway rats *Rattus norvegicus*. Similarly, in a study of both feral and farm cat predation on rabbits and rodents in rural Sweden, Liberg (1984a) concluded that cats by themselves were not limiting any of their prey.

Studies by Oliver Pearson (1966, 1971) and Erlinge *et al.* (1983, 1984) showed vole (*Microtus* spp.) populations were effected differently by predator assemblages (including feral cats) depending on their relative abundance and preference as prey items. Where voles were the most abundant and most preferred prey, alternative prey such as gophers *Thomomys bottae*, brush rabbits *Sylvilagus bachmani* and wood rats *Neotoma fuscipes* allowed the predators to continue to hunt their preferred prey even as the vole population reached extremely low densities, subsequently dictating the timing and amplitude of vole population cycles (Pearson 1966, 1971). Where voles were secondary in abundance and dietary preference, an abundant primary prey source (European rabbits *Oryctolagus cuniculus*) allowed predator numbers to be buoyed to such an extent that annual predation on voles was of the same magnitude as annual production, and consequently vole populations remained fairly stable between years and did not fluctuate cyclically (Erlinge *et al.* 1983, 1984).

On oceanic islands, the introduction of cats has most affected bird species, but impacts are rarely well documented. In many cases bird populations were not well described before cats were established and the possible role of other factors in shifting bird abundances are treated inadequately (Fitzgerald 1988). Extinctions of species endemic to a particular island and the elimination of island populations of more widespread species have occurred following the establishment of cat populations on a number of islands (Fitzgerald 1988). An often quoted example of extinction is the Stephens Island wren *Traversia lyalli* from Stephens Island off the New Zealand coast, that was discovered, and exterminated, by the lighthouse keeper's cat in 1894 (Fitzgerald 1988).

Fitzgerald and Karl (1979) however, argue that feral cats in the forests of New Zealand may suppress populations of other more damaging predators, such as rats, and thus allow denser populations of birds than would exist without them. On Lord Howe Island off the Australian east coast, black rats *Rattus rattus* exterminated five endemic passerine bird species following their introduction in 1919 (Ebenhard 1988). On western Mauna Kea in Hawaii, black rats are not a significant predator of endemic birds because of differences in microhabitat preference between endemic birds and rats, and because predation by feral cats and mongooses limits black rat populations (Amarasekare 1994).

The feral cat population on western Mauna Kea is itself limited by physical factors associated with high elevations and consequently is unable to respond to high densities of another of its prey species, mice *Mus domesticus*. Under these conditions, instead of allowing the cat population to reach levels detrimental to endemic birds, the mice, as an abundant and predictable food source, are thought to reduce the effect of predation by cats on endemic birds (Amarasekare 1994). Similarly, on Dassen Island off South Africa, Apps (1984) found that feral cats did not seriously threaten local seabird populations as they primarily ate rabbits and seabird carcasses. The cats controlled the number of rabbits such that seabird nesting habitat was not threatened by overgrazing.

The sole removal of either rabbits or cats could therefore be detrimental to the seabird colonies. Conversely, on Macquarie Island, the introduction of rabbits apparently allowed the number of feral cats to increase to the extent that a population of red–fronted parakeets *Cyanoramphus novaezelandiae erythrotis*, with which the cats had previously coexisted for over 60 years, was exterminated (Taylor 1979).

In summary, feral cats have documented impacts on wildlife. However, the impact of controlling feral cats usually depends upon the complex interplay of cats as predators of both introduced and native species which also prey on or compete with on–another. Single species control of cats may not be desirable in many circumstances.

1.3 PREDATION BY HOUSE AND FARM CATS

Since the mid 1980s, the question of impact by house cats on wildlife in suburbs and towns, and in parks and nature reserves adjoining these areas, has received increasing attention (Churcher and Lawton 1987, May 1988, Fitzgerald 1988, Paton 1991). The provision of food on a regular basis, often on demand, could well be expected to extinguish predatory behaviour in house cats by removing the need for them to hunt to satisfy nutritional requirements. However, patterns of predatory behaviour, practised from an early age by kittens, are used to considerable effect by many adult farm and suburban house cats (see Fitzgerald 1988), often in spite of ample food provision (Churcher and Lawton 1987, Trueman 1990, Paton 1991). In respect of this behaviour, the majority of farmers in the UK keep several cats whose primary function is supposedly to control rodents (Macdonald *et al.* 1987 in Bradshaw 1992).

People in rural and urban communities in Europe and north America have long attempted to use predatory behaviour retained in farm cats to their advantage by providing milk and scraps to attract cats to human dwellings and farm buildings to control rats and mice (see Darwin 1872). The effectiveness of this technique was examined by Elton (1953) in a study of farm cats in rural England during the second

World War. From observational data, Elton concluded that cats supplied with approximately half a pint of milk per day (about a third of their daily food requirement) could only keep buildings free of Norway rats once existing infestations were eliminated by other means (gassing, poison baits and trapping). This impact was usually restricted to areas within about 50 m of the buildings where the cats dwelt. In Maryland USA, Davis (1957) showed that while cats were not be able to eradicate Norway rats from farm buildings, they did have some effect on seasonal population changes. Cats were installed at rat infested farm buildings and provided with supplementary food. With the cats present, the rat population declined earlier in Autumn than it had in previous years, and increased later in spring, after the cats switched to preying on young pigeons (Davis 1957).

Many cat owners though, are distressed by the hunting success of even pampered household pets, and speculation within the scientific community of the consequences of predation by house cats on local, regional and even continental populations of small mammals, reptiles and birds, has increased since the mid 1980s (Churcher and Lawton 1987, May 1988, Trueman 1990, Paton 1991). Unfortunately, impacts on prey populations and community structure are difficult to quantify. Mead (1982) examined the fate of banded birds in Britain and discovered that for six species more than 25% of recoveries were of birds caught by cats. All six species were ground or low vegetation feeders regularly occurring in gardens. However, birds in rural and suburban parts of Britain have co–existed with cats for hundreds of generations and may now be under less pressure from cats than they were in the past from assorted 'natural' predators (Mead 1982). As stated by Fitzgerald (1988), while the relative abundance of some bird species in Britain may have been greater in the absence of cats, no–one appears to have been able to demonstrate this experimentally.

In a comprehensive study of predation by house cats in an English village, Churcher and Lawton (1987) examined prey items brought home by approximately 70 house cats over 12 months. Fifteen species of mammals, predominantly wood mice, field and bank voles and common shrews, and 22 bird species were identified among the prey items. The authors proffered no suggestion as to the impact this predation may have had on small mammal populations, having no data on the local abundance of these species. However, following a survey of house sparrow *Passer domesticus* densities, it was suggested that at least 30% of sparrow deaths in the village were probably due to domestic cats, comprising about one–third of all the sparrows in the village at the start of the breeding season. This estimate of predation was considered conservative as it was highly unlikely that all prey items were recorded. House cats were concluded to be a significant, perhaps even the most important, source of mortality for house sparrows in the village (Churcher and Lawton 1987).

In Australia, a similar survey of prey caught by domestic cats was carried out by 200 cat owners in southern Tasmania over 3 months in winter. The impact of this predation on prey populations was not measured. However, it was noted that of the marsupial prey species, eastern barred bandicoots *Perameles gunni*, which were the most common of the marsupial prey items (n=4), were reported to be listed as vulnerable on the Tasmanian mainland (Smith 1991). Two bird prey items were identified as swift parrots *Lathamus discolor*, a species regarded as vulnerable (Smith 1991). No lizard species on the Tasmanian mainland are listed as endangered, vulnerable, or rare (Smith 1991).

Paton (1991) estimated that house cats in suburban areas of Adelaide caught between 10 and 20 birds per hectare per year from the results of a postal questionnaire asking cat owners in and around Adelaide to estimate annual predation by their pets. It was reported that this represented approximately 50% of the standing crop of birds in suburban Adelaide given typical bird densities of between 10 and 30 birds per hectare. Honeyeaters were the most frequently taken group of native birds. Paton suggested that honeyeater populations may be declining in remnant habitat adjacent to or surrounded by suburbs as a result of birds being attracted to suburban gardens by the presence of a wide range of nectar producing plants, and then cropped unsustainably by domestic cats (Paton 1991). As these birds play an important role in the pollination and seed production of many native plants, local reductions in their numbers may have significant wider ecological impacts. This theory however was not tested. Paton (1991) also found that bells attached to collars did not prevent cats from catching prey.

1.4 TERRITORIAL BEHAVIOUR AND HOME RANGE SIZES OF DOMESTIC CATS

Sociality, including territorial overlap, sharing of food resources and co–operative rearing of kittens by related female cats, has been much studied (Macdonald and Apps 1978, Dards 1978, Tabor 1981, Kerby and Macdonald 1988, Liberg and Sandell 1988, Leyhausen 1988). Until recently it was generally assumed that the domestic cat was essentially a solitary creature, that only tolerated the close proximity of its con–specifics for mating and while rearing offspring (Jones and Coman 1982, see also Bradshaw 1992). It is now apparent that social structure in groups of domestic cats is common and is not merely an artefact of the conditions under which house cats are kept (Bradshaw 1992). Rather, social structure is clearly present in groups that are barely tolerant of human company (Macdonald and Apps 1978, Dards 1978, Tabor 1981, Bradshaw 1992). Whether sociality in the domestic cat has been inherited from its ancestors or has arisen secondarily as a by–product of domestication remains uncertain. Irrespective, understanding the nature and extent of social behaviour in domestic cats is of importance in predicting home range size, shape and overlap of cats under different conditions, including house cats in suburban environments.

Home range sizes of feral cats living in habitats ranging from Mediterranean cities to sub–antarctic islands vary by three orders of magnitude from 0.1 to nearly 200 ha in females and up to approximately 600 ha in males (see Liberg and Sandell 1988 for summary of home range studies). Female home range size has been shown to be directly determined by food abundance and distribution (Liberg and Sandell 1988). The size of home ranges of dominant males appears determined by female density, and even more so, by female distribution (Liberg and Sandell 1988), though the size of subordinate male ranges may be determined by food availability. Male ranges are on average three times larger than female ranges (Liberg and Sandell 1988). Home ranges of group–living females overlap extensively within a group but little with those of females from other groups (Liberg and Sandell 1988, Bradshaw 1992) and territories, particularly core areas, may be fiercely defended (Leyhauson 1988). Male home ranges overlap extensively, especially during the mating season (Liberg and Sandell 1988), and fighting is for supremacy and rank rather than territory (Leyhauson 1988).

The movement patterns and home ranges of well–provisioned suburban cats have scarcely been studied. The small amount of work which has been done (Chipman cited in Bradshaw 1992, Bradshaw 1992, Das 1993) suggests the average home range size of solitary suburban cats (less than 1 ha) lies at the lower end of the distribution of home range sizes of domestic cats. Home ranges of neutered suburban males may also be expected to show less overlap than observed for feral male cats, presumably being based on food resource distribution rather than the distribution of breeding females. On the other hand, considerable spatial overlap in the ranges of mutually intolerant individuals has been observed to be achieved by temporal differentiation in the use of spatially shared habitats (Leyhauson 1988, Bradshaw 1992). Control is by sight over some distance and by scenting conspicuous landmarks along well–travelled trails (Leyhauson 1988).

1.5 STUDY RATIONALE

Community concern over the impact of predation by house cats on native wildlife in Australia was increasing when this study commenced. One Melbourne metropolitan Wildlife Shelter had reported received 364 victims of cat attacks between January 1990 and May 1991 (Seebeck *et al.* 1991). Of these, 272 were mammals and 92 were birds. Of the mammals, 242 were common ringtail possums *Pseudocheirus peregrinus*. On two days in February 1991, 39 common ringtail possums were received. All had to be destroyed. Reports in the popular press, based on the work by Paton (1991), were suggesting that many hundreds of millions of vertebrate prey, particularly native animals, were being destroyed every year by house cats (including those house cats in suburban and urban environments) and that this predation posed a serious threat to populations of native Australian wildlife on a national level (e.g., Greenwood 1993). These predictions however, were based on cat owner's estimates of annual predation by their pets rather than actual numbers of prey collected over at least one year of monitoring, as was the case for the study by Churcher and Lawton (1987) in the UK. In addition, wildlife losses were reported by taxonomic class (birds, mammals, reptiles amphibians), and little attempt appeared to be made to reliably ascertain the impact (if any) of predation on specific populations of introduced and native prey.

Similar predictions of the threat posed by house cats to wildlife populations in the UK (May 1988), based on extrapolated data from Churcher and Lawton's (1987) study in Felmersham, met with criticism for failing to consider differences in predation by cats in different environments, and not relating predation data to the abundance and population dynamics of prey species (Fitzgerald 1990). Many local governments in Australia, the Australian Capital Territory (ACT) Government being no exception, were under increasing pressure to examine in some detail the effect of house cats on populations of native wildlife within their jurisdictions, and to consider taking action to reduce predation via such measures as compulsory curfewing, belling, and the restriction of cats within the borders of their owners' property (ACT Legislative Assembly 1993).

Predation by house cats in the ACT had not been quantified prior to this study. Prey selection by house cats in Australia in different seasons and at different times of the day and night had not been investigated. Variation in predatory efficiency between individual cats and the importance of environmental factors, cat management practices and physical cat attributes in explaining this variation was unknown. Also, the precision and accuracy of total predation estimates calculated from data collected by cat owners monitoring prey items caught by their cats over a period of time, or from estimates of predation by their cats per week, month or year had not been examined.

In addition to predation by house cats in suburban environments, concerns had been raised regarding the movement of house cats into 'natural' environments adjoining residential areas, particularly remnant native habitat patches, and their potential impact on faunal populations in these areas (Osborne and Williams 1991). Regular movements of both feral cats and house cats between urban areas and nature reserves along approximately 90 km of urban–reserve interface in Canberra was suspected (Osborne and Williams 1991), but no quantitative research describing the temporal and spatial extent of this movement had been done. Indeed, no significant quantitative information on diurnal and nocturnal movements, and factors affecting movements, of house cats living on residential suburb edges in Australia was available.

1.6 STUDY AIMS AND SIGNIFICANCE

The primary aims of this research were:

(i) to compare nocturnal and diurnal movements, home range sizes and habitat utilisation of house cats living in close proximity to a suburb edge,

(ii) to quantify daily activity patterns of house cats living in close proximity to a suburb edge,

(ii) to quantify the species composition of prey caught by house cats in Canberra, particularly the proportion of native to introduced prey items, and examine prey preference by cats,

(iii) to identify which factors relating to the suburban environment, physical cat attributes, and house cat management have the greatest impact on the type and amount of prey caught by suburban cats, and examine the amount of variation in predatory efficiency between individual cats explained by these factors, and,

(iv) to examine the accuracy and precision of estimates of predation per cat over 12 months, and extrapolated total predation estimates for the entire Canberra house cat population, using the methods adopted in this and other studies .

Assessing the effects of cats on prey populations is difficult as predation by cats is just one of a suite of factors influencing prey populations and its effects cannot be easily isolated from those of other factors. Controlled experiments designed to monitor prey response following predator removals are extremely difficult to conduct in suburban environments with domestic animals. The logistic constraints to studying domestic cats in suburban and nature reserve interface environments in Canberra at the time the study began meant that an experimental study design to assess the impact of domestic cats on wildlife was not feasible. However, it was expected the data collected could be used to promote discussion of the comparative ecological effects of predation by house cats in modified environments and in undisturbed habitat. It was also intended that the data be used in association with published information on local prey abundance, distribution and ecology to help qualitatively predict the ecological effects of predation by house cats in the Canberra region.

2 GENERAL METHODS

2.1 PREDATION BY HOUSE CATS

2.1.1 Description of Canberra suburbs and adjoining environments

Canberra (35° 17'S, 149° 13'E) is an inland city situated approximately 600 m above sea level and 144 km from the south–east Australian coast in the ACT (Figure 2.1). Summers are warm to hot with maximum temperatures averaging 28°C. Winters are cold with maximum temperatures of 11°C on average. Frosts occur on 100 days per year on average and snow falls usually 1 to 3 times each year. Mean annual temperature is 12.7°C. Average monthly rainfall is highest in spring (October 69 mm) and lowest in winter (June 38 mm), but is generally fairly evenly distributed throughout the year. Average annual rainfall is 628 mm.

Canberra is a relatively young city, the older suburbs being between 60 and 80 years old. Its population in 1993 was 299 000 (ACT Commissioner for the Environment 1994). The city is somewhat unusual in Australia by virtue of its spacious, well maintained gardens and parks which were included as part of the original design of Canberra. Much of suburban Canberra is situated on land previously naturally without trees. The local region was mostly a combination of native and improved grasslands and partially cleared woodland when suburbs were first erected. When plans were made for the construction of the national capital, tree planting was accepted as one of the necessities of the design of Canberra. By the late 1970's, almost fifty years later, over 10 million trees and shrubs had been planted (Gibson 1978).

About 200 different species or cultivars are currently recorded as growing in Canberra's streets (ACT Commissioner for the Environment 1994). Edward (1979) and Pryor and Banks (1991) list the species of trees planted along streets in all residential areas of Canberra. There is a marked difference in the species composition of trees and shrubs planted in old compared to new suburbs. The older suburbs are dominated by exotic trees and shrubs which were more popular than native species at the time these suburbs were built. The proportion of exotic to indigenous vegetation decreases as suburb age decreases in both house and garden and street vegetation, reflecting changing attitudes toward native flora in Australia. A similar trend is evident in city and suburban parkland areas. In the new suburb of Gungahlin, about 50 000 plants of native species and 5 000 plants of exotic species had been used in public landscape planting by July 1993 (ACT Commissioner for the Environment 1994).

As a result of this plant diversity, the city's vegetation now provides shelter and food for a varied range of wildlife and especially birds (Murphy 1979, Fraser 1981, Munyenyembe 1985, Taylor and Canberra Ornithologists Group 1992). The well vegetated suburban areas share avifauna with nearby high altitude wet sclerophyll forest and alpine habitats by way of seasonal altitudinal migrations (Taylor and Canberra Ornithologists Group 1992). As part of its policy to promulgate the "Garden City" ethos inherent in the landscape designs of Walter Burley Griffin and T. C. Weston, the ACT Government continues to provide free plants to new home buyers, and about 150 000 native trees and shrubs were issued in this way in 1993 (ACT Commissioner for the Environment 1994).

The original plans for Canberra included the concept of a permanent agricultural green belt encircling the city and limiting its size. The outer suburbs of Canberra are consequently bounded by a combination of rural land, CNP reserves, and exotic pine (generally *Pinus radiata*) plantations. The agricultural leases are primarily used for sheep and cattle grazing with significant areas near urban settlement used for horse agistment. These lands have been degraded to varying degrees by overgrazing and tree clearance, though the number of trees on farms in the ACT is now increasing (ACT Commissioner for the Environment 1994). The CNP reserves contain remnants of three poorly protected low–altitude vegetation associations; Open Forest (Red Stringy Bark *Eucalyptus macrorhyncha* — Scribbly Gum *E. rossii*), Woodland (Yellow Box *E.*

melliodora — Blakely's Red Gum *E. blakelyi*), and Lowland Native Grassland (Tall Spear Grass *Stipa bigenculata* — Kangaroo Grass *Themeda triandra* — Wallaby Grass *Danthonia spp.* — Redleg Grass *Bothriochloa macra*). In general however, these communities are degraded and substantially altered versions of those that existed at the time of European settlement (Munyenyembe 1985). Much of the remnant open forest and woodland communities on Black Mountain, Mount Ainslie, Mount Majura, Bruce Ridge and Aranda Bushland are regenerated from 19th and early 20th century clearing practices. The CNP contains a significant proportion of exotic plant species (ACT Commissioner for the Environment 1994). Hills such as Mount Taylor, Red Hill and parts of the Aranda Bushland have only had grazing leases withdrawn in the 1980's and 1990's, while Mount Painter remains largely devoid of tree vegetation because grazing in this area is ongoing. Nevertheless, the amount and quality of native habitat in many CNP reserves is improving and can be expected to continue to do so under current management policies and initiatives.

2.1.2 Methods Used to Collect Cat Prey Data

The predatory habits of domestic cats have usually been studied in two ways: by examining scats (e.g., Dilks 1979; Fitzgerald and Karl 1979; Triggs *et al.* 1984), or by identifying the gut contents of animals trapped or shot as part of a pest control program (e.g., Coman and Brunner 1972, Bayley 1978, Jones and Coman 1981, Catling 1988). A third technique, which is more suitable for use with house cats, involves surveying items of prey deposited at or near the residence of the cat owner. The method has been employed by a number of workers (Bradt 1949, Davis 1957, George 1974, Warner 1985, Churcher and Lawton 1987, Paton 1991), the only qualification to the technique being that deposited prey items are assumed to be representative of the cats' total catches.

Homes bordering the CNP in central and inner north Canberra (i.e., suburbs adjoining the Pinnacle, Aranda Bushland, Red Hill, Gossan Hill, and Mt. Ainslie CNP reserve units) were surveyed for house cat densities by doorknocking and letterbox drops. Residents were asked if they owned or cared for a cat or cats. Cat owners were then asked if they had ever known their cat(s) to catch vertebrate prey items, and if so, approximately how many per week, month or year they estimated their cat(s) normally caught. People who suspected their cat(s) caught at least one vertebrate prey item per year were then supplied with more information about the nature of the study and asked if they would agree to participate further by collecting and/or recording prey items caught by their pet(s) for one year (see APPENDIX I). Those willing to participate were subsequently given a questionnaire (or questionnaires) to complete in which they provided information about their cat(s) and cat management practices. Each questionnaire was number coded for cross–referencing with cat names, and acted as a registration form for each cat (see APPENDIX II).

Next, participating households were provided with a supply of polyethylene bags and asked to bag the remains of any animal caught by their cat(s). Bags were collected weekly, or at other times depending on the predatory activity of each cat. Owners were asked to store prey items in a cool dry place (if possible, in a freezer). Data sheets displaying each cat's ID number were also provided to record catches observed by the owner, but for which there were no remains (see APPENDIX II).

In addition to participants recruited to the study via letterbox and door–knocking campaigns in selected north Canberra suburbs, members of the Canberra Ornithologists Group, Canberra Field Naturalists and the ACT Herpetological Association were invited to contribute to the study by recording catches made by their cats on supplied data sheets (see APPENDIX II). An invitation to interested members of the wider community to be similarly involved was made through local radio and print media, and information and registration forms were made available at the University of Canberra Open Day in April 1993, and from local environmental organisation shopfronts and two veterinary surgeries. People responding to these calls for volunteers were provided with a folder of materials containing a registration questionnaire, reply paid envelope and sets of data sheets, for each cat they owned. An I.D. number on each questionnaire corresponded with a number on each page of the associated set of data sheets. Participants were asked to complete and return the questionnaire(s) (which again acted as a registration document) and to begin recording catches on the data sheets. A mailing address was provided for the return of completed data sheets. Additional reply paid envelopes were distributed at the conclusion of the data collection period to aid in the return of data sheets.

Prey items were only collected from participants recruited to the study from the letterbox drop and doorknocking campaigns. However, all other participants were asked to contact the University for help with identifying prey items. The distribution of homes which provided data for at least one season of the study in Canberra is shown in Figure 2.1. Canberra Nature Park reserve units are shown as hatched areas in Figure 2.1. Closely spaced hatching represents reserve units containing predominantly open–forest/woodland habitat, and wider spaced hatching represents units with predominantly grassland habitat.

Collection of prey data began at the start of May 1993 and was concluded at the end of April 1994. Participants were sent quarterly newsletters during this period to keep them informed of the study's progress and to maintain enthusiasm in collecting data. During the course of the study numerous participants discontinued data collection for various reasons. New recruitments were achieved by enlisting interested members of the community who contacted the University sporadically throughout the course of the study. Participation was also bolstered by a letterbox drop of information and registration forms in September 1993 to a number of suburbs in the area where radio–telemetry work was conducted (see next section).

The methods used to collect data on the predatory habits of house cats in this study are based on the work of Churcher and Lawton (1987) and Paton (1991). The continuous

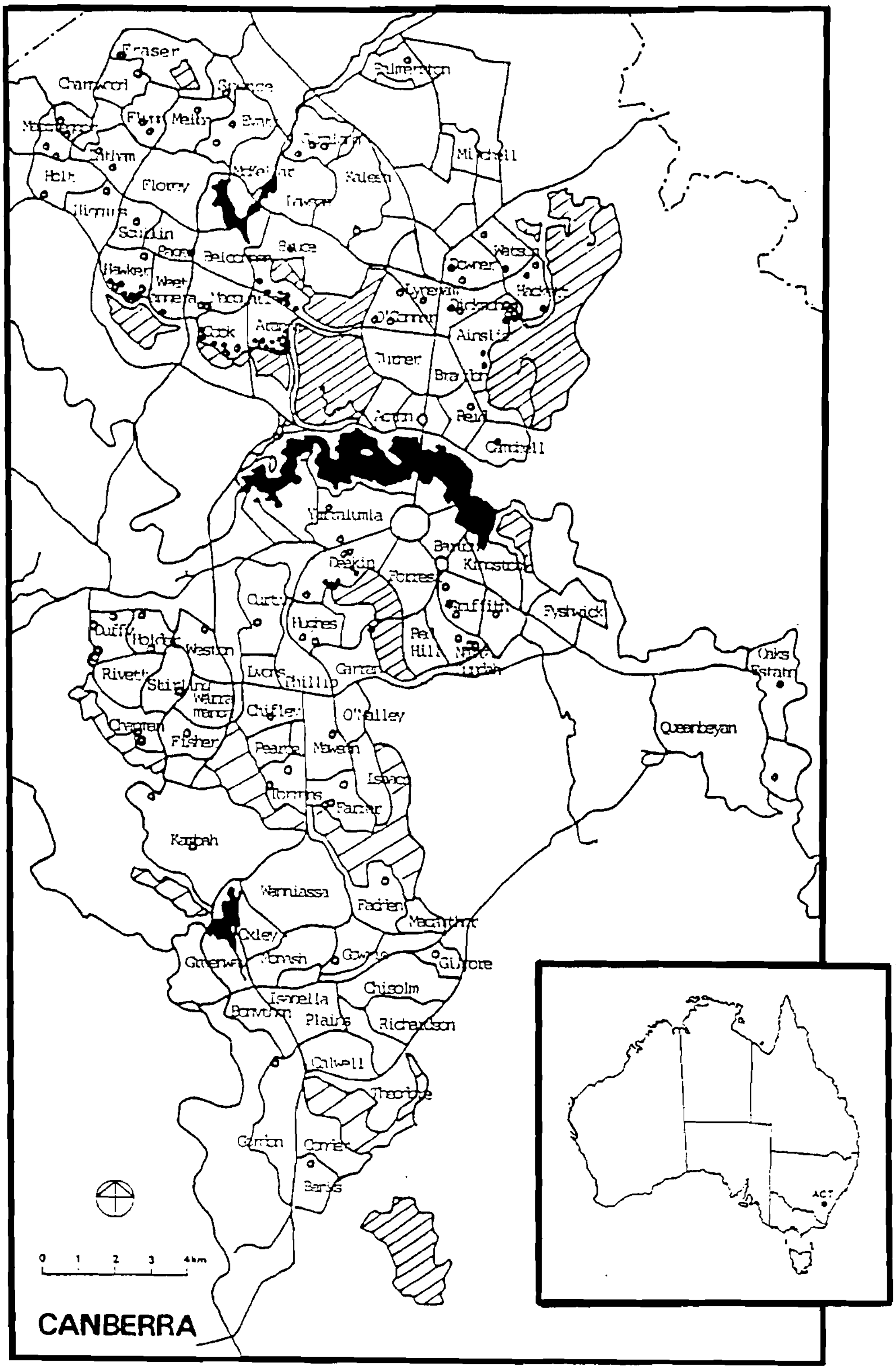


Figure 2.1 Map of Canberra showing the distribution of homes from which data on prey caught by cats was provided for at least one season of the study. Closed circles indicate homes where prey items were collected by the author. Open circles indicate homes where catches were recorded on data sheets by the cat owner.

collection of prey data over 12 months, and the collection of prey items directly from suburban residences made the study the first of its kind in Australia.

2.2 HOME RANGE, HABITAT UTILISATION AND DAILY ACTIVITY PATTERNS

2.2.1 Recruitment of cats for monitoring

Information on activity patterns, home ranges and habitat utilisation by domestic cats living near a suburban – rural/reserve interface were gathered using radio–telemetry. Potential involvement in this aspect of the study was mentioned to all cat owners recruited to collect and/or record prey items, who also lived close to a suburban–rural/reserve interface. Ideally, a study site where a number of participating homes were located in close proximity to one another would allow several cats to be monitored simultaneously on foot. The best study site in this regard was identified and is described in detail below. All participating cat owners in the selected area were interested in investigating the movements of their pets but many restrained their cats for significant periods of the night or day by locking them inside. Cats whose movements were unimpeded by their owners were selected for radio–tracking in preference to restricted animals.

A colony of domestic farm cats living at a farmhouse abutting the residential suburban edge were also incorporated into the study with their owner's permission. The cats were kept as mousers by one of the farm managers and were fed once each day in the early evening near the centre of a group of farm buildings including a hay shed, shearing shed, farm homestead and a number of other smaller equipment sheds and machinery garages. The homestead and farm buildings, around which the cat's activity was centred (referred to in Chapter 3 as the 'farm core'), were only separated from residential houses by an arterial road (see Figure 2.2). It was considered these animals would contribute valuable information to the study by virtue of the fact that none of them had been desexed, while only one intact (i.e., not neutered) cat, a tom, had been recruited from the adjoining suburb.

Unlike the domestic cats from surrounding residential homes, the farm cats had never been handled and were approachable to within a few metres only. In order to attach radio collars therefore, the cats had to be trapped and sedated. Trapping was carried out at the cat's feeding site using three wire cage traps. Feed bowls were placed inside the cages and the trap doors wired open for several nights. Once the cats had become used to feeding inside the cages they were trapped over two consecutive nights by remotely triggering the trap door mechanisms using cotton lines. After gently crushing the animals against the back of the cage with a folded piece of heavy material, they were given a 0.5 ml intra–muscular injection of Xylazine, then collared, caged overnight and released the following morning.

A trapping campaign was also conducted in the nature reserve and rural land adjoining the suburban radio–telemetry study site immediately prior to the commencement of radio–tracking, in an attempt to trap and collar any feral cats in the area. Between six and 12 wire cage baited–hook possum traps were placed approximately 300m from the suburb edge for four nights each week over four weeks. The traps were baited with sardines in oil wrapped in gauze. Procedures were approved by the University of Canberra Animal Ethics Committee.

2.2.2 Description of radio–telemetry study area

The radio–telemetry study area was located on the outer edge of the north Canberra suburb of Hawker (Figure 2.2). The suburb is approximately 20 years old and the density of houses in the outer suburban area is approximately 8 per hectare. The suburb edge runs in a north–west to south–east direction through the study area. Land adjoining the suburb predominantly slopes gently away from the houses in a south–westerly direction. A remnant Red Stringy bark *Eucalyptus macrorhyncha* –

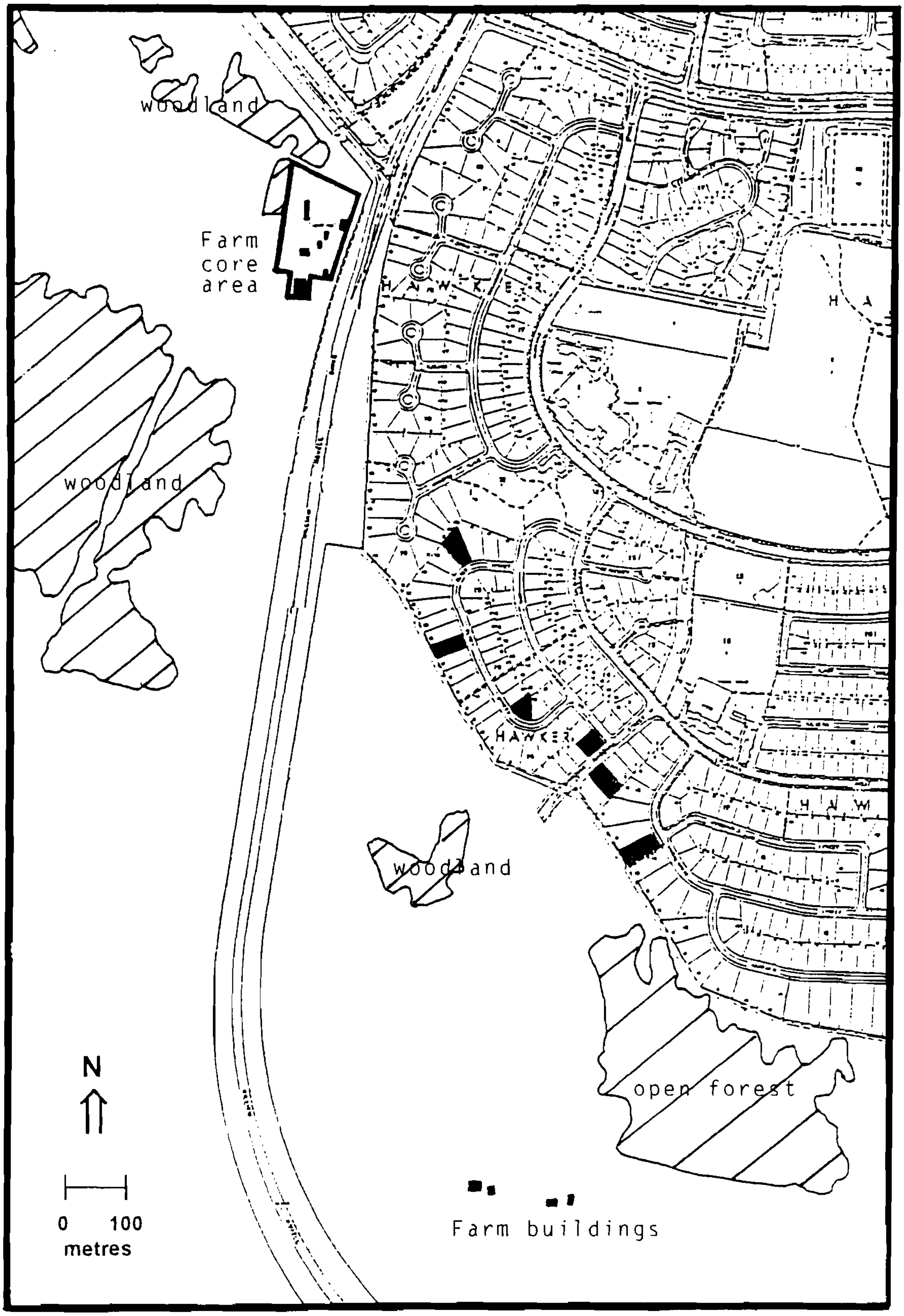


Figure 2.2 Map of the radio telemetry study area. The location of residential properties where radio–collared cats lived are shown in red, and the 'core' area of the farm inhabited by the farm cat colony (see text) is also indicated.

Scribbly gum *E. rossii* open forest community abuts the suburb at the south–eastern end of the study area, and is bounded on its southern side by a poorly drained modified grassland recently replanted with eucalypt saplings. The rest of the land adjoining the suburb in the study area is cleared rural land characterised by grazed open woodland habitat with small grazed remnant woodland and open forest patches. The domestic stock carried are predominantly sheep and horses. A 20 to 50 m grassy nature strip dominated by the introduced grass species *Phalaris aquatica* (mown once by the ACT Government during the study in summer) separates the suburb from adjoining rural/reserve land. A three lane arterial road runs north–south through the western part of the study area. The road is bounded by a six metre embankment, shielding it from view of the residential homes on the suburb edge. The embankment and associated drainage line are ungrazed and unmown and support a thick cover of tall grass (predominantly *Phalaris aquatica*) and occasional small trees. A farm homestead and farm buildings are situated on the southern edge of the study area.

The core area, including the homestead and associated farm buildings, of the farm at which the radio–collared farm cats in this study were located, is shown abutting residential homes in the north–west of the study area in Figure 2.2. Habitat on this farm consisted of numerous small inner paddocks containing animal yards and farm buildings, surrounded by larger paddocks of grazed open woodland and patches of grazed open forest. Two small, generally ungrazed, paddocks containing medium scrub habitat surrounded a large Canberra water reservoir immediately to the west of the inner farm paddocks.

2.2.3. Radio–telemetry methods

Studies of the activity and movement of between 4 and 25 feral and domestic farm cats (Liberg 1980, Macdonald and Apps 1978, Warner 1985, Langham and Porter 1991) and between 2 and 12 domestic urban cats (Bradshaw 1992, Das 1993) have been successfully conducted using radio–telemetry. Fixes were obtained by both triangulation techniques using fixed tower antennae and/or antennae mounted on vehicles (Warner 1985, Langham and Porter 1991), and by visual location of animals using hand held yagi antenna and tracking on foot (Liberg 1980, Macdonald and Apps 1978, Langham and Porter 1991, Bradshaw 1992, Das 1993). In this study, tracking was carried out on foot using a Sirtrack three element hand–held yagi antenna and Telonics TR4 receiver. Volunteer help with radio–tracking was provided by students from the University of Canberra. The location of an animal was ascertained either by direct visual contact or by approximating its position to within 10m by triangulation from 2 or 3 points. Observers wore a Petzel halogen headlamp at night to help visually locate cats and to aid in movement through unlit habitat beyond the suburb edge.

Fourteen radio–collars designed specifically for use on domestic cats were purchased from Sirtrack electronics. The collars consisted of a 30g transmitter encased in dental acrylic and moulded onto a standard buckle–up leather domestic cat collar, with a 20 cm rubber encased whip aerial. Transmitting frequencies ranged between 150.020 and 150.028 Megahertz, separated by 20 Kilohertz intervals. A pulse was emitted 40 times per minute and the battery life of the transmitters was approximately 16 months. The total collar weight represented between approximately 0.75% and 3% of the body weights of the cats in the study.

The radio–telemetry study area was divided into two field sites because of the distance between radio–collared animals located at suburban residences and the colony of cats living at the farmhouse (Figure 2.2). These two areas were subsequently referred to as the 'suburb site' and the 'farm site'. Fieldwork was organised with respect to the two areas.

Radio collars were rotated among the suburban cats as more cats were available to be tracked than there were radio collars. As radio–tracking progressed, collars were preferentially assigned to cats whose home ranges continued to increase with each tracking period.

A series of 1:2500 orthophoto maps covering both farm and suburban sites were divided into 625 m^2 (1 cm x 1 cm) grid cells. Cat locations were resolved to the centre of the appropriate quadrant within each grid cell. The minimum distance between observation was therefore 12.5 m. Grid references were recorded on data sheets as well as information on the type of habitat at that location and whether the cat was resting or active. Cats were located hourly to obtain information on activity and movement patterns. After initially attempting to track animals continuously over a number of days it was decided to work in four or six hour shifts separated by at least 12 hrs such that 24 observations representing each hour of the clock were collected per cat per week. In many studies of feral cats, radio fixes have been made predominantly during the day (Liberg 1980, Jones and Coman 1982, Turner and Mertens 1986, Fitzgerald and Karl 1986). However, as stated by Laundre *et al.* (1987) and Langham and Porter (1991), night fixes are essential to describe the home range of a nocturnally active animal. Palomares and Delibes (1992) also point out that data may be biased if it is not representative (by random or systematic sampling) of all parts of the 24 hr cycle, with interval lengths between consecutive observations dependent upon total activity levels and temporal activity patterns of the animal. Tracking shifts in this study were systematically rotated to obtain fixes at all hours of the 24 hr cycle. Data was collected over six weeks in each of spring 1993, summer 1993/94 and autumn 1994.

3 HOME RANGE SIZE AND HABITAT UTILISATION

3.1 INTRODUCTION

Quantitative studies of the home range size and movement patterns of house cats are limited to work done by Liberg (1980, 1984b) and Warner (1985) on farm cats in Sweden and the mid–west United States respectively, Chipman (cited in Bradshaw 1992), on urban house cats in Manchester, and more recently, a brief study by Bradshaw (1992) working on suburban cats in London, and work by Das (1993) investigating suburban cats in Melbourne. Average range sizes of farm cats were calculated to be between 50 ha (Liberg 1984b) and 112 ha (Warner 1985) for females (number of cats observed = 15 and 7 respectively), and between 228 ha (Warner 1985) and 380 ha (Liberg 1984b) for males (number of cats observed = 4 and 11 respectively). In contrast, Bradshaw (1992) found the range sizes of two suburban house cats, one male and one female (both neutered), to be less than one hectare (0.27 and 0.45 ha respectively). On the basis of this result and observations of other cats in the area, Bradshaw (1992) suggested that home ranges of less than one hectare could be expected for neutered house cats with no nutritional reason to hunt. The number of male and female cats in Bradshaw's study area meant that exclusive territories could be maintained within sexes, so long as male and female territories overlapped. It was suggested that further spatial overlap, while maintaining exclusive territories, might be achieved by 'time sharing' overlapping areas (Bradshaw 1992).

The home ranges of 66 female urban house cats (64 of which were desexed) studied by Chipman (cited in Bradshaw 1992) in Manchester, UK were generally smaller than the home ranges of the female suburban house cat monitored by Bradshaw (1992), the maximum recorded home range being 0.12 ha. Cat densities between the two studies were similar (5–7 cats per hectare). Differences in home range sizes may have been due to Chipman not using radio–telemetry to locate cats in inaccessible parts of their ranges (Bradshaw 1992). An additional 52 castrated male cats in Chipman's 25 ha study area had home range sizes similar to those of females except for one male which had not been neutered until it was four years old. This cat's home range was suggested to have 'frozen' at this point (approximately 1 ha in size). Seventeen entire males had home ranges of up to 6.1 ha. The largest ranges were held by males about nine years old, increasing from approximately 0.5 ha used by young adult males, and decreasing with old age (Chipman cited in Bradshaw 1992).

Das (1993) reported that the nocturnal home ranges of 13 house cats (five neutered females, seven neutered males and one entire male) ranged between 0.19 and 2.16 ha. The degree of spatial and temporal overlap in home ranges was greatest among cats from the same home. Home range size and shape were influenced by food resources (location of open bins), physical barriers such as roads, and individual personality which was suggested to be a function of the age at which the cat was desexed and the relationship between the cat and its owner (Das 1993). Gender was not a significant factor, which was attributed to the fact that most cats in the study area were desexed (Das 1993).

The studies by Bradshaw (1992) and Das (1993) were both conducted in suburban environments abutting parkland areas. The male cat in Bradshaw's study moved into parkland adjoining the suburban study site, but did not make disproportionate spatial use of this area. Bradshaw (1992) states elsewhere however, that suburban cats may actively exploit areas containing no cat residents, such as patches of urban woodland, for hunting. In the study by Das (1993), male house cats were observed to utilise parkland near their homes but females did not. Range sizes of pet cats estimated by residents living in, or adjacent to, bushland habitat in southern Tasmania were larger than those estimated by cat owners living in areas with no bushland (Trueman 1990).

The objective of this chapter was to examine diurnal and nocturnal home range sizes and habitat utilisation of house cats living on a suburban boundary. Many of the hills in and around Canberra are managed as part of what is known as the Canberra Nature Park

(CNP). Some of this area contains valuable remnants of open forest, woodland and native grassland (Osborne and Williams 1991), and a diverse and interesting flora and fauna has been identified in parts of the CNP (Ingwersen *et al.* 1974, Kukolic 1990, Jones 1992, Osborne and Mckergow 1993). Information on the movements of house cats living on suburban edges would help identify areas within which faunal populations are currently at risk of direct predation effects from house cats, and habitats within which populations may come under threat in the future with respect to suburban planning designs. Variation between nocturnal and diurnal home range size and habitat utilisation by free–ranging suburban house cats has not been studied.

3.2 MATERIALS AND METHODS

The software package Home Range (Ackerman *et al.* 1990) was used to analyse radio telemetry data collected using the methods outlined in Chapter 2. Locational data in 7 of 17 nocturnal and 12 of 17 diurnal datasets were indicated to be temporally auto–correlated using statistical tests developed by Swihart and Slade (1985b, 1986). However, Lair (1987:1099) suggested using a shorter "biological time to independence", since an animal can choose not to move in a time interval. Lair's suggestion is based on the rule of thumb reiterated by White and Garrott (1990) that two locations can be considered statistically independent if sufficient time has elapsed for the animal to move from any point in its home range to any other point. Field observations in the present study indicated that all cats were capable of moving from one end of their home range to the other in the one hour interval between consecutive locations during tracking shifts. White and Garrott (1990) suggest that if a representative sample has been taken, then the observations can be assumed to be independent relative to the time frame of the study and associated analyses. A representative sample may be achieved by taking a random sample whereby each instant in time throughout the relevant time frame has an equal chance of being sampled. "In practice, a systematic sample of time might be taken that would be a representative sample" (White and Garrott 1990:148). The systematic sampling design in the present study (see Chapter 2) ensured each hour of the 24 hour cycle had an equal chance of being sampled.

Home range estimates were calculated using minimum convex polygon, harmonic mean, bivariate elipse and weighted bivariate elipse techniques. Although the parametric bivariate elipse methods have the advantage of being able to provide estimates of precision with their home range calculations, thus allowing statistical comparison of home range estimates, the assumption of bivariate normally distributed data was rarely met in the present study, and use of these two techniques was eventually abandoned. The harmonic mean technique has no assumptions with regard to underlying data distributions, but the sample size required is large ($n>100$) because the underlying distribution must be estimated from the data, rather than fitting an assumed parametric distribution (Ackerman *et al.* 1990). The number of independent nocturnal or diurnal observations collected in this study for seven of 17 cats was less than 100. In addition, the harmonic mean technique was overly sensitive to scale parameters, as has been identified previously (Spencer and Barrett 1984, Worton 1987). As a consequence, this technique poorly described the spatial utilisation patterns of most cats by including large areas never visited by an animal, or excluding areas such as linear transit routes between more heavily utilised areas, such that several discrete home range outlines were mapped for one animal.

The minimum convex polygon technique is best suited to data distributed under a bivariate uniform distribution (White and Garrott 1990). More than half the data sets analysed approximated this distribution according to the Cramer–von Mises test statistic (Samuel and Garton 1985). In most cases the polygons produced did not obviously include significant areas not utilised by animals, and home range estimates calculated using minimum convex polygons were consistently lower than those calculated using the harmonic mean technique. The problem of increasing home range size with increasing sample size caused by the effect of outliers could be partially addressed by calculating the home range as a 95% convex polygon (see Ackerman *et al.* 1990 for details).

Home range is defined as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943:351). The inadequacies in this definition are that a time frame is not specified, and the lack of objective definition of what is "normal" (White and Garrott 1990). White and Garrott (1990) suggest the use of 95% of an animal's locations is an arbitrary but adequate objective repeatable method of defining home range and has since been used in studies on domestic cats (Bradshaw 1992, Das 1993).

The algorithm developed to produce 95% convex polygons however, can give spurious estimates for unusually shaped home ranges such as along the inside of a river curve (White and Garrott 1990). The validity of the home range estimates produced by each of the techniques described above therefore, was ultimately tested by overlaying convex polygons, bivariate ellipses and harmonic contour outputs on the data points used to calculate them and visually assessing the spatial fit of each home range outline to the data. On this basis, the minimum convex polygon technique was felt to provide the most accurate and appropriate estimate of home ranges for the data collected, in spite of the disadvantages with the technique described above (see White and Garrott 1990 for greater detail). The minimum convex polygon method requires moderate sample sizes (20 – 50 independent observations) though some authors have found larger sample sizes (100 – 200 observations) reduce problems with accuracy and precision (Swihart and Slade 1985a, Ackerman *et al.* 1990). Range sizes calculated from minimum convex polygons using all data points (100% MCP) are referred to in the results section as 'maximum range' sizes. Ninety–five percent minimum convex polygon estimates are referred to as 'home range' areas.

Straight–line distances to the furthest nocturnal and diurnal radio–location from 'home' for each cat were estimated on a 1:2500 orthophoto map sheet. Home was defined as the cat owner's house for suburban cats, and the farm building at which each cat spent the majority of its time resting for farm cats. Differences between nocturnal and diurnal home ranges, and nocturnal and diurnal distances moved from home (maximums) were tested using paired t–tests or their non–parametric equivalents. The effect of gender on home range size and maximum distances moved from home was tested using t–tests or their non–parametric equivalent.

The age, gender, sexual status, and age when neutered where applicable, of each cat radio–collared during the study is shown in Table 3.1. The ages of the farm cats were not known precisely, but were estimated by the farm manager. Quantitative analyses of cat age and neutering age effects were not conducted because of the small total sample size.

Spatial home range overlap between cats was examined visually by plotting minimum convex polygons of home range areas of each cat on 1:2500 orthophoto map sheets. The significance of home range overlap between individuals was not analysed statistically. Differences in the distribution of nocturnal and diurnal locations among broad habitat types were tested using Chi–square analysis. A description of habitat was recorded with each radio–location record.

3.3 RESULTS

Eight cats whose movements were unimpeded by their owners and two cats that were confined inside from late evening (~10 pm) until early morning (~6 am) were recruited from the suburban radio–telemetry site with their owners permission. In addition, seven cats living at the farmhouse abutting the residential suburb edge, were radio–collared with their owners permission (see Figure 2.3). The density of cat owning households within the suburban area was calculated to be approximately 2.7 per hectare and the density of house cats was approximately 4 per hectare.

Table 3.1 Gender, age and sexual status of radio–collared cats

Cat Name or ID	Gender	Age (yrs)	Sexual Status	Age Desexed (mths)
SUBURB				
Blossom	female	5	desexed	7
Tiddles	female	7	desexed	20
Merry	female	2	desexed	6
Gismette	female	1	desexed	5
Gismo	male	1	desexed	5
Jasper	male	3	entire	N/A
Pippin	male	2	desexed	6
Mitzie	male	6	desexed	~ 6
Horse	male	10	desexed	unknown
Simba	male	1	desexed	6
FARM				
Female A	female	~1	entire	N/A
Female B	female	~3	entire	N/A
Female C	female	~1	entire	N/A
Female D	female	~1	entire	N/A
Female E	female	~1	entire	N/A
Male A	male	~1	entire	N/A
Male B	male	~1	entire	N/A

The trapping campaign conducted on land abutting the suburban radio–telemetry site resulted in the capture of only two cats over 149 trap nights. Both animals turned out to be domestic pets. One cat, a desexed male, was already known as its owner had previously agreed to having the animal involved in the radio–tracking study. The second cat, an entire (i.e., not desexed) male, was unknown and not wearing a pet collar or any other identification. A radio–collar was fitted to this cat and the animal then released. It was subsequently tracked to a residence close to the suburb edge over a 12 hour period. The cat's owner agreed to allow monitoring of the cat's movements to continue.

Between 46 and 466 locations were recorded per cat over the entire tracking period. The number of radio–locations recorded for each cat varied because of the loss of one suburban cat and two farm cats in road traffic accidents during the study, the occasional inability to locate animals, and the rotation of collars from inactive animals with static home range sizes to more active animals with expanding home ranges.

3.3.1 Home Range Size

Mean nocturnal and diurnal range sizes for male and female farm and suburban cats estimated using minimum convex polygons are shown in Table 3.2. Also shown are means of the straight–line distances to the furthest nocturnal or diurnal radio–location from home for each cat. Nocturnal home ranges were significantly larger than diurnal home ranges (Wilcoxon Sgn Rnk; S=45 DF=16 P=0.018). However, distances to the furthest radio–location from home at night were not significantly different to distances to the furthest diurnal radio–location (Wilcoxon Sgn Rnk; S=28.5 DF=16 P=0.186).

Variation in home range size between individuals in the farm cat colony was relatively small (1.38 – 4.46 ha at night; 0.77 – 3.70 ha during the day). Variation in maximum distance moved from home was also relatively small particularly at night (160 – 350 m at night; 110 – 730 m during the day). Cat gender had no effect on home range size of

Table 3.2 Nocturnal and diurnal home range areas and straight–line distances to furthest locations from home.

CAT LOCATION	n	MCP	Diurnal Observations: Range ± SD (Ha)	Diurnal Observations: Maximum Distance (m)	Nocturnal Observations: Range ± SD (Ha)	Nocturnal Observations: Maximum Distance (m)
FARM						
Male	2	100% 95%	2.39 ± 0.96 1.34 ± 0.43	195 ± 85	7.44 ± 0.04 3.03 ± 1.44	275 ± 5
Female	5	100% 95%	6.96 ± 8.33 1.84 ± 0.98	340 ± 205	5.44 ± 2.46 2.34 ± 0.82	290 ± 68
All Farm Cats	**7**	**100%** **95%**	**5.65 ± 7.35** **1.70 ± 0.89**	**299 ± 191**	**6.01 ± 2.27** **2.54 ± 1.08**	**286 ± 58**
SUBURB						
Male	1	100% 95%	39.90 17.19	900	43.56 20.54	940
Desexed Male	5	100% 95%	2.07 ± 3.06 0.97 ± 1.70	148 ± 127	8.57 ± 12.59 6.00 ± 8.45	278 ± 246
Desexed female	4	100% 95%	1.62 ± 1.84 1.31 ± 1.93	255 ± 332	7.38 ± 11.99 7.08 ± 12.04	275 ± 334
All Suburb Cats	**10**	**100%** **95%**	**5.57 ± 11.67** **2.73 ± 5.12**	**266 ± 315**	**11.59 ± 15.83** **7.89 ± 10.57**	**343 ± 338**

farm cats at night (Wilcoxon Rnk Sum; Z=0.590 DF=6 P=0.561) or during the day (Wilcoxon Rnk Sum; Z=0.194 DF=6 P=0.847). Equally, gender had no effect on maximum distance moved from home at night (Wilcoxon Rnk Sum; Z=–0.968 DF=6 P=0.333) or during the day (Wilcoxon Rnk Sum; Z=–0.782 DF=6 P=0.434).

In contrast to the farm cats, there was more than an order of magnitude difference in home range size between suburban cats (0.02 – 27.93 ha at night; 0.02 – 17.19 ha during the day). Variation in maximum distances moved from home was also large (30 – 940 m at night; 20 – 900 m during the day). There was no significant difference between home range sizes of desexed males and desexed females at night (Wilcoxon Rnk Sum; Z=–0.320 DF=8 P=0.749) or during the day (Wilcoxon Rnk Sum; Z=0.107 DF=8 P=0.915). Equally, no significant difference in maximum distances moved from home was found between desexed males and desexed females, either at night (Wilcoxon Rnk Sum; Z=–0.642 DF=8 P=0.521) or during the day (Wilcoxon Rnk Sum; Z=–0.642 DF=8 P=0.521).

The nocturnal home range of the one entire (not desexed) suburban male, Jasper, was relatively large (20.54 ha). However, two desexed suburban cats, one male (Simba) and one female (Tiddles), had nocturnal home ranges of a similar size (22.16 ha and 27.93 ha respectively). Straight–line distances to the furthest locations (nocturnal or diurnal) from home for each of these cats (Jasper, Tiddles and Simba) were 940 m, 850 m and 720 m respectively.

3.3.2 Home Range Overlap

Nocturnal and diurnal home ranges for all cats are shown in Figures 3.1 and 3.2. The home ranges of related suburban cats living at the same residence overlapped completely (Gismo and Gismette; Tiddles and Blossom). Unrelated cats living at the same residence (Tiddles and Jasper; Merry and Pippin) had completely overlapping core areas (house and yard), and were amicable to one another in these areas, but tended to have non–overlapping outer home range areas (Figures 3.1 and 3.2). The home ranges of all farm cats also overlapped completely around feeding and sleeping sites (farm buildings). Groups of 1 to 3 cats monopolised different farm buildings or other cover as resting and hiding sites. There was no spatial overlap of home ranges between radio–collared female suburban cats living at separate residences (Figures 3.1 and 3.2).

Spatial overlap of home ranges of males from separate suburban residences was evident (Figures 3.1 and 3.2). To some extent this result was a function of the incorporation of non–utilised areas by the minimum convex polygon home range estimation technique. Radio–collared males from separate homes were never observed in sight of one another and appeared to avoid each other's core areas (house and yard). These cats possibly also avoided one another in shared territory by way of the detail of their movements in these areas spatially, and by time sharing. For example, utilisation of shared territory along the arterial road embankment and drainage line by Gismo (desexed male) and Jasper (male) appeared temporally disparate, with Gismo generally active in this area in the early evening and Jasper in the late evening and during the day. These two cats were observed hunting in the tall grass road embankment habitat approximately 400 m from one another on one occasion during the day.

Overlapping ranges of males and females from separate homes was also evident (Figures 3.1 and 3.2), but again the degree to which these cats were amicable to one another or avoided each other through the spatial detail and timing of their movements was unclear. Contact between cats from different residences, radio–collared or otherwise, was rarely observed.

3.3.3 Habitat Utilisation – Suburban Cats

With the exception of Tiddles (desexed female), the suburban cats spent the majority of their time (between 70 and 98% of locations) within their own home or yard

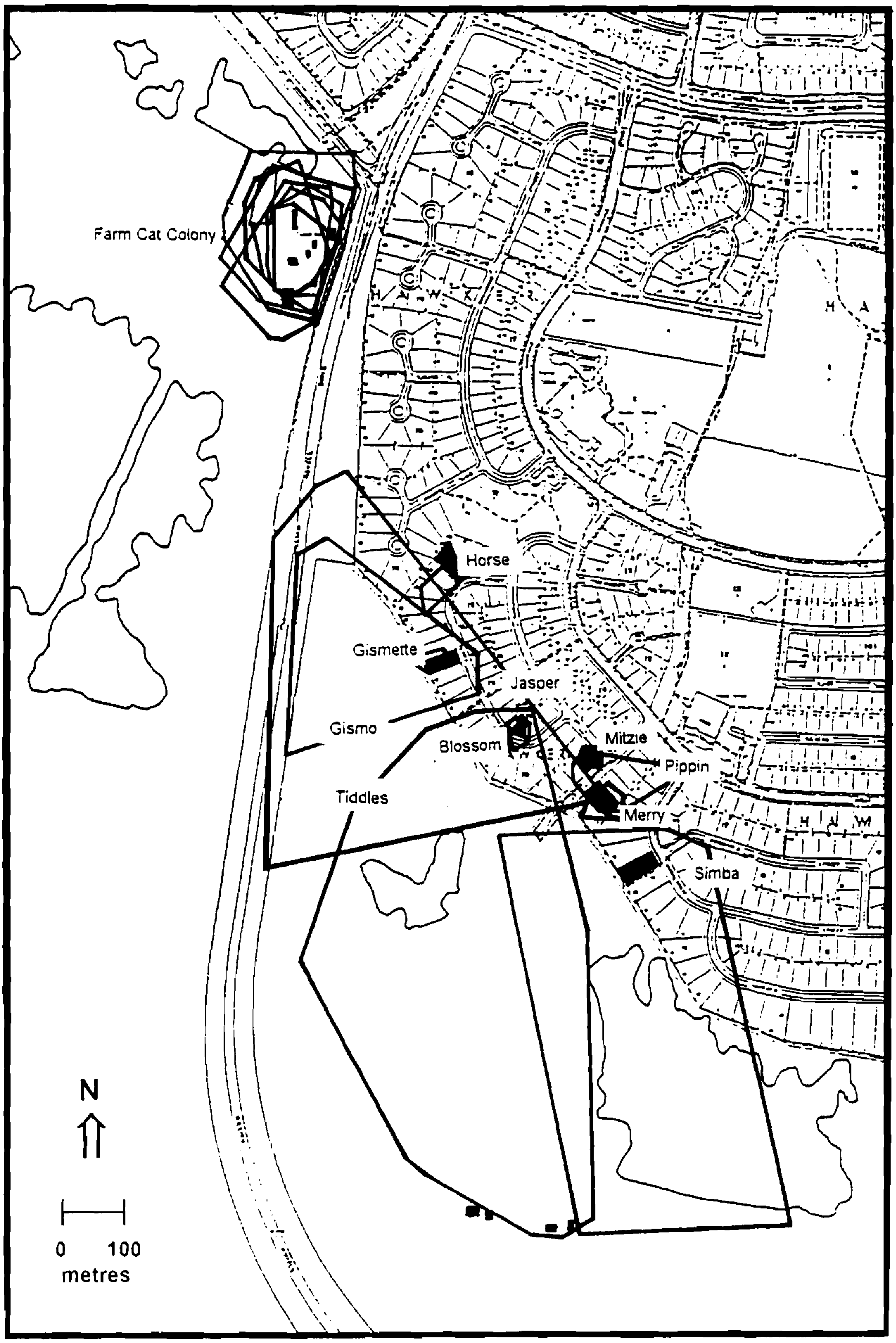


Figure 3.1 Nocturnal home ranges of farm and suburban house cats, estimated using 95% minimum convex polygons.

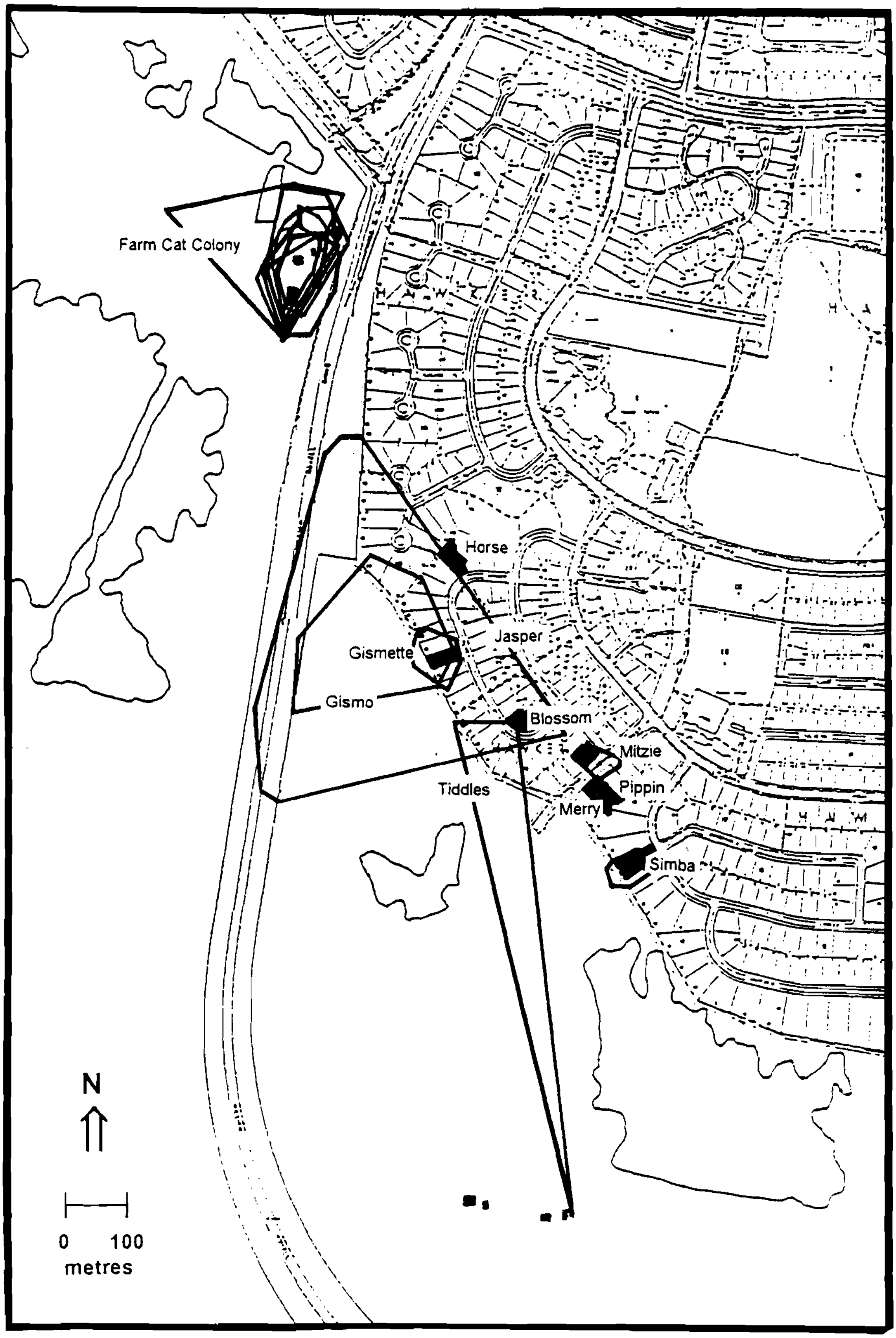


Figure 3.2 Diurnal home ranges of farm and suburban house cats, estimated using 95% minimum convex polygons.

environment (Table 3.3). Six of 10 suburban cats moved beyond the suburb edge. Four of the cats that utilised areas beyond the suburb edge moved significant distances (>100 m) into the non–suburban habitat. All four had home ranges significantly spatially biased away from the suburban environment into the adjoining habitat (approximately 70 – 90% of their home range area – see Figures 3.1 and 3.2), though they spent the majority of their time at home or within the suburban environment (82 – 91% of locations – Table 3.3).

Comparison of the proportion of time (number of locations) spent in the home or yard environment at night and during the day is shown in Table 3.4. Gismo and Gismette spent significantly more time at home at night than during the day (Table 3.4). Of the remaining cats, four utilised the home/yard environment more during the day than at night, and four showed no significant difference in nocturnal and diurnal use of the home/yard environment (Table 3.4).

Comparison of nocturnal and diurnal utilisation of the rural/reserve habitat by those cats that moved significant distances (> 100 m) beyond the suburb edge is shown in Table 3.5. Tiddles (desexed female) and Simba (desexed male) utilised areas beyond the suburb edge significantly more at night than during the day (Table 3.5), and only moved significant distances (> 100 m) into the rural/reserve habitat at night (see Figures 3.1 and 3.2). The small proportion of diurnal locations beyond the suburb edge for Simba were mostly in the tall grass habitat of the nature strip located immediately behind the residential houses. Tiddles however, occasionally remained all day in the farm buildings at the southern boundary of the study area. Jasper (male), spent significantly more time beyond the suburban edge during the day than at night (Table 3.5). This result was entirely due to the use of a linear configuration of cover (the arterial road embankment) by this cat during the day. Jasper would occasionally spend entire days, and even two or three days at a time, hidden in drain culvit entrances and the tall grass of the road embankment and drainage line bordering the arterial road running into the suburb from the south, or moving in the drain system beneath the embankment. The

Table 3.3 Habitat Utilisation by suburban cats. The total number of locations (n) and the proportion locations occurring in each habitat type are shown.

		Habitat Utilisation (% n)		
Cat	n	Home/yard	Suburb	Rural/reserve
Tiddles	270	35.9	45.9	18.2
Gismo	145	69.7	20.0	10.3
Simba	333	70.3	12.0	17.7
Jasper	451	77.4	13.8	8.8
Gismette	371	78.7	19.7	1.6
Pippin	196	83.2	16.8	0
Merry	199	83.9	14.1	2.0
Horse	46	91.3	8.7	0
Mitzie	121	92.6	7.4	0
Blossom	120	97.5	2.5	0
MEAN ± 2SE		78.1 ± 2.7	16.1 ± 2.3	5.8 ± 1.7

Table 3.4 Comparison of nocturnal and diurnal utilisation of the home/yard environment by suburban cats. The total number of nocturnal and diurnal locations (n) and the proportion of nocturnal and diurnal locations in the home/yard environment are shown.

	Diurnal Observations		Nocturnal Observations			
Cat	n	% home/yard	n	% home/yard	**Difference**	
Blossom	51	98.0	69	97.1	**– 0.9**	**ns**
Gismette	242	69.8	129	94.6	**+ 24.8**	**
Gismo	100	54.0	45	84.4	**+ 30.4**	**
Horse	33	93.9	13	84.6	**– 9.3**	**ns**
Jasper	246	72.0	205	64.4	**– 7.6**	**ns**
Merry	117	94.0	82	69.5	**– 24.5**	**
Mitzie	52	88.5	69	95.7	**+ 7.2**	**ns**
Pippin	114	92.1	82	69.5	**– 22.6**	**
Simba	196	92.9	137	38.0	**– 54.9**	**
Tiddles	150	59.3	120	6.7	**– 52.6**	**
MEAN ± 2SE		81.5 ± 2.5		70.5 ± 3.3		

Chi–square Test * P<0.05 ** P<0.01

amount of time spent by Gismo in non–suburban habitat was equally divided between night and day (Table 3.5) primarily because of the crepuscular nature of his activity peaks.

Three suburban cats (Gismo, Gismette and Jasper) made occasional use of drains both within and beyond the suburban environment. Just over six percent (n=9) of locations for Gismo were underground and nine percent (n=40) for Jasper. On one occasion, Jasper moved more than 500 m within the drain system beneath the arterial road embankment running through the study area. As already mentioned, Jasper often rested during the day hidden in thick tall grass near culvit entrances in the road embankment, and the drainage system provided an easy escape route when disturbed. Seventeen percent (n=75) of all observations of Jasper were in the road embankment habitat or associated drain system, amounting to 93.8 % of observations beyond the suburb edge for this cat. One radio location made near a culvit entrance was approximately 940 m from his home. Movements between home and the road embankment habitat were always made at night. The proportion of time Gismo spent in the road embankment habitat was similar to Jasper. Gismette (desexed female) was found underground once, near the entrance to a drain in the street servicing her owner's home.

On the opposite side of the study area, 54.2% (n=32) of locations beyond the suburb edge for Simba were within the CNP nature reserve, mostly in open forest habitat (including one location in a tree), and occasionally in marshy grassland habitat just beyond the forest edge. A further 20.3% (n=12) of time spent by Simba beyond the suburb edge was on the grazed rural land, 22.1% (n=13) in the tall grass habitat of the nature strip at the back of his owner's home, and 3.4% (n=2) in or around farm buildings on the southern edge of the study area approximately 700 m from his home. Tiddles also utilised these farm buildings, but to a greater extent, spending 40.8% (n=20) of time spent beyond the suburb edge hunting in and around the buildings at night, or hiding within them during the day. The remaining observations for this cat beyond the suburb

Table 3.5 Comparison of nocturnal and diurnal utilisation of the rural/reserve environment by suburban cats. Analysis of utilisation of this environment type was only conducted with respect to those cats that spent a significant proportion of their time (more than six locations) in habitat beyond the suburb edge. The total number of nocturnal and diurnal locations (n) and the proportion of nocturnal and diurnal locations in the rural/reserve environment are shown.

	Diurnal Observations		Nocturnal Observations			
Cat	n	% rural/reserve	n	% rural/reserve	**Difference**	
Gismo	100	19.0	24	20.8	**+ 1.8**	**ns**
Jasper	246	21.1	205	13.7	**– 7.4**	*
Tiddles	150	6.7	120	32.5	**+ 25.8**	**
Simba	196	3.1	137	38.7	**+ 35.6**	**
MEAN ± 2SE		12.5 ± 2.8		26.4 ± 3.1		

Chi–square Test * $P<0.05$ ** $P<0.01$

edge were in the grazed woodland habitat between the farm buildings and the suburban environment at night.

3.3.4 Habitat Utilisation – Farm Cat Colony

All cats in the farm colony spent the vast majority of their time (88 – 97 % of locations) in and around the farm buildings and small paddocks and yards immediately surrounding the farm homestead (Table 3.6). This area was described as the 'core' of the farm (see Figure 2.3). The rest of their time was spent in the paddocks beyond the farm core, fairly evenly divided between relatively open grazed paddocks and some small patches of normally ungrazed scrub along the arterial road embankment and surrounding the large water reservoir to the north west of the farm buildings (Table 3.6).

At no time during the study were any of the farm cats located in the suburban environment abutting the farm to the north and east. One cat was located on one night in scrub on the suburban side of the road bordering the farm to the north, and two other cats were killed by traffic on the arterial road separating the farm from the suburb immediately to the east of the farm homestead.

All farm cats spent the majority of their time during the day in farm buildings and other cover (such as a large pile of dead timber approximately 50m to the south of the shearing shed) presumably to avoid people and farm dogs, and also to avoid high daytime temperatures in late spring and summer. Locations beyond the farm core comprised less than 4% of diurnal observations for six of the seven farm cats (Table 3.7). Female A was observed hunting in rabbit warrens up to 900 m from the farm core during the day in summer while raising a litter of kittens. Seventeen percent of all radio locations beyond the farm core for female A were in rabbit warrens. In general however, utilisation of habitats beyond the farm core was significantly greater at night than during the day, accounting for up to 24% of nocturnal observations (Table 3.7).

Table 3.6 Habitat utilisation by farm cats. The total number of locations (n) and the proportion of locations occurring in each habitat type are shown.

		Habitat	Utilisation	(% n)
Cat	n	Farm buildings/yards	Scrub paddocks	Grazed paddocks
Female A	463	88.7	6.5	4.8
Female B	465	90.9	6.2	2.9
Female C	466	96.4	1.5	2.1
Female D	465	92.7	0.6	6.7
Female E	175	96.5	0.6	2.9
Male A	447	88.1	5.1	6.8
Male B	464	95.0	2.8	2.2
MEAN ± 2SE		92.6 ± 1.4	3.3 ± 1.2	4.1 ± 1.0

Table 3.7 Comparison of nocturnal and diurnal utilisation of paddocks beyond the farm core area by farm cats. The total number of nocturnal and diurnal locations (n) and the proportion of nocturnal and diurnal locations beyond the farm core area are shown.

	Diurnal Observations		Nocturnal Observations			
Cat	n	% Paddocks	n	% Paddocks	**Difference**	
Female A	261	8.4	202	14.8	**+ 6.4**	*
Female B	259	2.7	206	17.0	**+ 14.3**	**
Female C	259	3.5	207	3.9	**+ 0.4**	**ns**
Female D	259	1.9	206	14.1	**+ 12.2**	**
Female E	97	3.1	78	3.8	**+ 0.7**	**ns**
Male A	258	2.3	189	23.8	**+ 21.5**	**
Male B	258	2.7	206	7.8	**+ 5.1**	*
MEAN ± 2SE		3.5 ± 1.1		12.2 ± 2.0		

Chi–square Test * P<0.05 ** P<0.01

All but one of the farm cats were located in trees at least once, usually in the farm core area. Two cats, Female B and Male A, made considerable use (57.1%, n=24, and 33.3%, n=17, of observations beyond the farm core area respectively) of the scrub and tall grass road embankment habitat at night. Male A was also twice located underground in drains on the property. Female D was twice located at night in scattered forest approximately 300 m to the south of the farm core.

3.4 DISCUSSION

The home range size of domestic cats has been estimated from daytime observations only (generally radio–fixes) in numerous studies (Liberg 1980, Jones and Coman 1982, Turner and Mertens 1986, Fitzgerald and Karl 1986, Bradshaw 1992). Both diurnal and nocturnal observations, or nocturnal observations only, have been used to calculate home range sizes in other studies (Corbett 1979, Warner 1985, Konecny 1987, Langham and Porter 1991, Das 1993). The present study and the work by Langham and Porter (1991) on feral cats in rural New Zealand appear to be the only research on domestic cats where differences in nocturnal and diurnal home range sizes has specifically been examined. In both cases nocturnal home ranges were larger than diurnal home ranges. The diurnal home range area of one female farm cat in the present study was significantly larger than its nocturnal home range. This cat was occasionally located in rabbit warrens some distance from the farm buildings during daylight while raising a litter. It was assumed she was preying on rabbits to supplement her diet of domestic food. Similar behaviour by female feral cats denning in barns in rural New Zealand was suggested by Langham and Porter (1991).

The maximum distance cats were observed from home was not significantly different between night and day. Many cats occasionally hid during the day in cover (farm buildings, houses, tall grass, drains, rabbit warrens) some distance from their owner's homes. Movements to these resting (or possibly preferred hunting) sites however, were almost always made at night, unless they could be reached predominantly without breaking cover.

As shown in Table 3.8, home range areas for the farm cats in the present study were significantly smaller than those of farm colony cats in other studies (Liberg 1984b, Warner 1985) but generally larger than previously documented for suburban or urban house cats (Chipman cited in Bradshaw 1992, Bradshaw 1992, Das 1993). Home range sizes of suburban cats in the present study were highly variable. For four cats, home range sizes of between 7 and 28 ha were around an order of magnitude greater than the home ranges of four other suburban cats monitored. They were also up to an order of magnitude larger than the home range sizes of many urban and suburban house cats studied by Chipman (cited in Bradshaw 1992), Bradshaw (1992) and Das (1993), and up to 28 times greater than the one hectare prediction of Bradshaw (1992) for neutered suburban cats with no non–domestic nutritional requirements. Distances moved from home of up to 900 m were also many times larger than observed for other suburban or urban house cats (Chipman cited in Bradshaw 1992, Bradshaw 1992, Das 1993), and for many of the cats in the present study.

There are several factors that do not adequately explain the relatively large movements and home range areas of some suburban house cats in the present study. Firstly, they do not appear to be a function of the use of nocturnal observations in calculating home range size, as the proportion of nocturnal to diurnal locations was approximately the same for all cats in the present study, and the relatively small home ranges estimated by Das (1993) were based on nocturnal data. Secondly, the large home ranges were not due to the distribution and/or density of prey, at least not directly for nutritional reasons, as all cats were fed by their owners at least once a day. Thirdly, differences in home range size were not entirely due to gender. Finally, large home ranges were not exclusive to cats that had not been neutered. The specific effects of neutering on cat movements, home range size and territorial behaviour would be best demonstrated by conducting controlled experiments. However, Bradshaw (1992) states the behaviour of

Table 3.8 Comparison of densities and home range sizes of house cats in different environments from this and previous studies.

Environs and Sociality	Cat Density	Mean Home Range (ha) ± SD		Source
		Female (n)	Male (n)	
Rural (Colony and solitary)	0.3–0.7	50 ± 41 (15)	350 ± 223 (5) 380 ± 367 (6)	Liberg (1984b)
Rural (Colony?)	0.63	112 ± 21 (7)	228 ± 100 (4)	Warner (1985)
Urban (Solitary)	6.6	up to 0.12 (66)	up to 6.1 (17)	Chipman cited in Bradshaw (1992)
Suburban (Solitary)	4.5	0.45 (1)	0.27 (1)	Bradshaw (1992)
Suburban (Solitary)	NA	0.28 ± 0.15 (5)	0.53 ± 0.16 (8)	Das (1993)
Suburb Edge (Colony)	~ 3.5	2.34 ± 0.82 (5)	3.03 ± 1.44 (2)	This study
Suburb Edge (Solitary)	~ 4	7.08 ± 12.04 (4)	8.44 ± 9.41 (6)	This study

female cats does not appear to be greatly altered after neutering. Interestingly, the desexed female in the present study that had a nocturnal home range of approximately 28 ha – an order of magnitude larger than the largest of the home ranges of the remaining desexed females – was the only animal in the study that had been neutered as an adult.

The extent to which the behaviour of male cats is changed by neutering has been suggested to depend to a large extent on the timing of castration (Bradshaw 1992). The home ranges of castrated free–ranging male house cats in an urban environment in Manchester were only marginally larger than neutered female cats (Chipman cited in Bradshaw 1992). One castrated male that ranged more widely had been neutered after puberty (Chipman cited in Bradshaw 1992). However, two of the three male suburban cats that roamed relatively widely (home ranges greater than six hectares) in the present study were neutered before puberty at approximately five to six months of age. The third male had not been desexed.

The effect of cat age on home range area was not examined quantitatively as most of the cats monitored were quite young (less than five years old). It is likely though, that old cats have relatively small home ranges. Certainly, the range of Horse, a 12 year old male, was relatively small. However, Mitzie, a six year old male, also had a small range. Leyhauson (1988) suggests more dominant, aggressive house cats tend to maintain larger ranges than subordinate cats, though subordinate animals, particularly females, may still fiercely defend core territories. In feral farm cat communities in Hebrides, Scotland, male, adult and dominant cats had larger home ranges than female, young and subordinate cats (Corbett 1979). Similar results, with respect to the existence of social hierarchies and the home range areas of dominant versus subordinate individuals, have been reported for house cats (Chipman cited in Bradshaw 1992, Bradshaw 1992).

Theory emerging from relatively recent work on house cat behaviour (see Turner and Bateson 1988, Bradshaw 1992), suggests home range sizes and shapes are primarily determined by con–specifics. Competition between house cats for foraging space has been observed when a new cat is introduced into an area with established cat territories (Bradshaw 1992). Liberg and Sandell (1988) suggest territoriality observed between females from separate feral cat colonies or groups (see also Leyhauson 1988) should also be observed between solitary female house cats which, like feral cat groups, have defendable, predictable food patches – their primary homes. Home range size should therefore be more closely correlated with the density of cat owning houses than with the density of cats *per se*. Home ranges of female cats from separate houses in the present study did not overlap. Not all female cats in the study area were monitored. However, none of the radio–collared females had home range areas which included properties with one or more resident female cat(s). It appears therefore, that in the present study the presence of habitat uninhabited by house cats, and with apparently no resident feral cats, allowed the more adventurous of the suburban house cats to significantly expand their ranges into these areas, i.e., the rural/reserve land.

Why the cats in the study by Bradshaw (1992) study did not utilise adjoining parkland habitat to a greater extent is unclear, though the study duration was only three weeks, and only two cats were monitored. In addition, diurnal locations only were used in the home range analyses (Bradshaw 1992). Utilisation of an area of parkland adjoining suburban homes by male house cats in the study by Das (1993) was abbreviated by the presence of a feral cat whose home range encompassed much of the park. The home ranges of house cats that utilised the park habitat abutted the home range of the feral cat. Movements of cats into and within the park did not appear to be influenced by the presence of foxes (Das 1993). In the present study, foxes were seen in habitat included in the home ranges of some cats, particularly the thick grass of the road embankment. The foxes appeared to use this habitat as emergency cover when foraging in the adjoining grazed paddocks. On one occasion during daylight, a fox was seen within metres of where the male cat, Jasper, was lying in thick, tall grass above a culvit entrance on the eastern side of the arterial road embankment.

For the farm cat colony, theory suggests that given their abundant and predictable food resource (daily provision of approximately one kilogram of tinned and dry cat food), and kinship between many individuals, these cats would have extensively overlapping home ranges (Liberg and Sandell 1988, Kerby and Macdonald 1988, Leyhauson 1988, Bradshaw 1992). This was indeed the case. In addition, home range sizes were similar for all cats, males and females. The males in the colony had no need to expand their ranges in search of receptive females as all five females within the colony were able to breed and all were unrelated to one or other of the two male cats. Bradshaw (1992) suggests it may not pay male cats to attempt to mate with females from more than one group, either because other groups of females are too far away, or because they are too well defended. "Under these circumstances male home ranges may not be any larger than females, and this has been found in two studies, under the very high population density of a Japanese fishing village, and the very patchy distribution of cats on Swiss farms" (Bradshaw 1992:147). Yearling male cats living in cat colonies usually disperse under increasing attack from older males. The two males at the farm colony in the present study were both approximately one year old when the study commenced (as apparently were all but one of the females), but no older males were present.

With no territorial pressure from within the farm colony and all cats being of a similar age, home range sizes of the farm cats appeared primarily determined by the location of habitats in which the cats hunted at night (such as the tall grass habitat on the banks of the water reservoir and in the scrub paddocks surrounding the reservoir, along the arterial road embankment, in the buildings and yards scattered around the farm core, and the open forest to the south of the farm core), and during the day by resting and sunning spots, as well as hunting sites such as the active rabbit warrens to the west of the farm core. The farm cats made no use of the suburban habitat immediately to the north and east of the farm core, presumably because of territorial pressure from suburban cats in this area and because of the barrier in the form of the busy arterial road.

Regarding temporal utilisation of available habitats by suburban cats, the majority of their time, both at night and during the day, was spent in the home or yard of their owner, except for one cat that preferred to spend many of its days resting in the gardens or under–house areas of neighbouring houses, and nights roaming in the suburban environment or beyond the suburb edge. All the farm cats spent the majority of their time within the farm core area. Utilisation of habitat beyond the suburb edge by suburban cats, and beyond the farm core by farm cats, was largely nocturnal and to a lesser extent crepuscular, though cats occasionally sought refuge during the day in cover beyond the suburb edge and farm core area.

Within home range areas, house cat movements during the day appeared strongly influenced by available cover (including drains, tall grass, fences and shrubs etc.), and the location of resting and sunning spots and hunting sites close to home, and at night by the location of favoured hunting sites toward the outer edges of their home range areas, such as farm buildings, tall grass, and scrub and forest habitats. Dogs and antagonistic people appeared to also influence the spatial movement patterns of house cats. Configurations of cover such as the tall grass road embankment habitat in the present study are likely to be particularly attractive to cats as they provide a means of moving under cover during daylight as well as being good hunting sites, particularly for rodents. The significance of sunning spots, hunting sites and configurations of cover have been implicated elsewhere as important in determining the spatial movements and fine scale habitat use by house cats (Liberg 1980, Warner 1985).

In summary, the size of home ranges of farm cats in the present study varied between approximately one and four hectares, while home range sizes among the suburban cats were highly variable (0.02 – 28 ha), in some cases being an order of magnitude larger than reported for house cats in urban and suburban environments elsewhere (Chipman cited in Bradshaw 1992, Bradshaw 1992, Das 1993). Nocturnal ranges were generally larger than diurnal ranges. Four of 10 radio–collared suburban cats moved between 390 m and 900 m into habitat adjoining the suburban environment. Two of the four cats that roamed widely were desexed males and one was a desexed female. There is evidence that the shape and size of home ranges was primarily determined by con–specifics with respect to food resources (i.e., shared or not shared), the density and spatial distribution of cat owning residences, and the dominance of cats with respect to local social hierarchies (determined by cat age and personality), rather than gender or neutering effects. Other factors which appeared to be important in determining spatial movement patterns, and consequently habitat utilisation by house cats, were configurations of cover, such as fences, hedges, tall grass and drains, barriers such as the arterial road, and threatening or disturbing influences such as dogs and antagonistic people. In respect of these influences, farm cats made no use of suburban environments, and suburban cats which utilised habitat beyond the suburb edge had home range areas significantly spatially biased toward these non–suburban areas. Large movements only occurred at night or under heavy cover (e.g., in drains), and utilisation of habitat beyond the suburb edge was predominantly nocturnal.

4 ACTIVITY PATTERNS

4.1 INTRODUCTION

The assumed ancestor of the domestic cat *Felis sylvestris lybica* is mainly nocturnal (Guggisberg 1975). However, studies on semi–dependent farm cats indicate a shift to diurnal activity (George 1974, Panaman 1981). Panaman (1981), and Turner and Meister (1988), suggest increased diurnal activity in semi–dependent domestic cats is related to daytime provision of food by people. George (1974) found his own house cats mainly hunted around mid–day in winter, shifting towards dawn and dusk in spring. Several studies on feral cats have reported activity is greater around sunset and sunrise than at other times (Jones and Coman 1982, Izawa 1983, Konecny 1987). Studying feral cats on rural land in New Zealand, Langham (1992) found that although activity increased at dusk as reported by others (Fennell 1975, Jones and Coman 1982, Izawa 1983, Konecny 1987), there was a tendency for distances moved to decrease towards dawn.

Activity peaks in felids have been related to peaks in prey activity (Schaller 1972, Laundre and Keller 1981, Zielinski *et al.* 1983). Studying free–ranging domestic and feral cats in Brooklyn, Haspel and Calhoon (1993) reported a bi–modal activity pattern with peaks at 0100 h and at sunrise. The lack of a sunset peak in activity was attributed to a lack of dependence on prey for food and avoidance of human activity peaks by cats. Ambient temperature, humidity, precipitation and hour accounted for 32.6% of feral cat activity (Haspel and Calhoon 1993). Churcher and Lawton (1987) similarly found rain suppressed house cat activity. Many workers (George 1974, Fennell 1975, Jones and Coman 1982, Izawa 1983, Liberg 1984a, Haspel and Calhoon 1993, Langham 1992) have identified seasonal changes in nocturnal and diurnal activity, with increases in nocturnal activity toward mid–summer and decreases toward mid–winter, and increases in diurnal activity towards mid–winter and decreases toward mid summer. These changes were suggested or shown to be related to ambient temperature in all studies.

An exception was found for feral cats living around farm buildings in New Zealand where females were active during the day in spring and summer when nursing kittens (Langham 1992). Langham also found cats living in habitats with heavy vegetation cover were more active in general, and during the day in particular, than cats living near more open habitat such as grazed pasture around barns because of disturbance associated with human activity.

Diel activity patterns of free–ranging suburban house cats do not appear to have been examined. The objectives of this chapter were to quantify nocturnal and diurnal movement and activity patterns of house cats in different seasons and to examine the relationship between ambient temperature and activity of house cats.

4.2 MATERIALS AND METHODS

Information on cat activity was gathered during radio–telemetry work. Each time a cat was located during a tracking shift, its location was considered with respect to its location in the previous hour. If the cat had moved from its previous location, it was noted on the telemetry data sheets as 'active' for that hour. If the cat had not moved from its previous location, i.e., was still in the same 156 m^2 quadrant, it was noted as 'inactive'. Generally, if cats were inside their owner's house they were described as 'inactive'. For the first observation of each shift, a decision as to whether a cat was active or inactive with respect to the previous hour was made on the basis of each animal's behaviour and location.

Hourly activity data for each cat was pooled for seasonal analysis of 24 hr activity patterns because the number of observations recorded per cat for each hour of the 24 hr cycle within a season was small (maximum of six). Although habitat use differed temporally between cats (see Chapter 3), activity patterns were similar among farm cats and among suburban cats. Analyses of activity patterns were consequently conducted with respect to the two telemetry field sites (farm and suburb).

The proportion of active observations in each hour of the 24 hr cycle were plotted as percentages by site and season. The proportion of all nocturnal and diurnal observations in each season which were active was also calculated for each cat. Diurnal and nocturnal mean percentage activity in each season was then calculated using the results for each cat as observations (n). Differences in nocturnal and diurnal mean percentage activity between seasons were tested using one–way Analysis of Variance or its non–parametric equivalent (Kruskal–Wallis Test).

Records of maximum and minimum temperatures for Canberra over the radio–tracking period were obtained from the Bureau of Meteorology. For each day of tracking, the proportion of active observations in the six hours from midnight to 0600 h were plotted against minimum daily temperature, and the proportion of active observations in the six hours from midday to 1800 h were plotted against maximum daily temperature. The relationship between activity and temperature was tested using correlation analysis.

Movement activity (mean distance moved between consecutive observations) was automatically calculated for each cat as part of the home range analysis output (Ackerman *et al.* 1990). Differences between nocturnal and diurnal rates of movement were tested using Wilcoxon Sign Rank tests. The effect of cat gender on movement rate was tested using Wilcoxon Rank Sum tests.

4.3 RESULTS

4.3.1 Nocturnal and Diurnal Movement

Mean distance moved (in metres) between consecutive nocturnal and diurnal observations for male and female domestic suburban and farm colony cats is shown in Table 4.1. Movement between consecutive observations was significantly greater at night than during the day (Wilcoxon Sgn Rnk S=62.5 DF=16 P=0.002).

Table 4.1 Mean distance moved (m) between consecutive observations (n=No. of cats).

		Nocturnal	Diurnal
	n	metres ± SD	metres ± SD
FARM CATS			
Male	2	48.3 ± 10.7	23.1 ± 3.1
Female	5	55.4 ± 10.4	34.0 ± 7.5
All Farm Cats	**7**	**53.4 ± 10.9**	**30.9 ± 8.2**
SUBURBAN CATS			
Male	1	113.8	58.5
Desexed Male	5	56.0 ± 45.6	22.2 ± 20.5
Desexed female	4	57.1 ± 75.0	19.5 ± 7.7
All Suburban Cats	**10**	**62.2 ± 59.9**	**24.7 ± 19.1**

Cat gender had no effect on rates of movement of farm cats (Wilcoxon Rnk Sum; Z=0.194 DF=6 P=0.847 – nocturnal locations; Wilcoxon Rnk Sum; Z= –1.36 DF=6 P=0.175 – diurnal locations). Variation in mean distance moved between consecutive observations was relatively small between individuals in the farm cat colony, compared with suburban cats (Table 4.1). Among the suburban cats, no significant difference was found between movement rates of desexed males and desexed females (Wilcoxon Rnk Sum; Z= –0.320 DF=8 P=0.749 – nocturnal locations; Wilcoxon Rnk Sum; Z= –0.107 DF=8 P=0.915 – diurnal locations). The mean distance moved between consecutive nocturnal locations for the only entire (i.e., not desexed) suburban male was relatively large (113.8 m). However, three desexed suburban cats, two males and one female, had similar nocturnal movement rates (100.1 m, 119.7 m and 186.6 m respectively).

4.3.2 Seasonal Differences in Nocturnal and Diurnal Activity

Nocturnal activity (mean percent active nocturnal observations) of farm cats was significantly greater in summer than in spring or autumn (F=6.57 DF=2,16 P=0.008; Sidak F–Test P<0.05), and diurnal activity (mean percent active nocturnal observations) was significantly greater in autumn than in summer (F=5.22 DF=2, 16 P=0.018; Sidak F–Test P<0.05) (Table 4.2). Seasonal differences in mean nocturnal and diurnal activity of suburban cats were not significant (P>0.05).

4.3.3 Seasonal Differences in Diel Activity Patterns

Diel activity patterns for suburban and farm cats in spring, summer and autumn are shown in Figure 4.1. Farm cat activity was bi–modal in spring with a major peak just after dusk (1900 h – 92.6% of observations active) and a minor peak just before dawn. Activity was lowest around 1000 h when only 12.9% of observations were recorded as active. Suburban cat activity in spring was basically uni–modal reaching a maximum at midnight (80% of observations active) and was lowest around 1300 h (7.1% of observations active).

Table 4.2 Mean percentage diurnal and nocturnal observations recorded as 'active' in spring, summer and autumn (n=No. of cats).

		Mean Percentage Observations 'Active' ± SD	
	n	Diurnal	Nocturnal
FARM CATS			
Spring	7	36.4 ± 10.6	50.1 ± 8.7
Summer	6	28.4 ± 10.7	69.8 ± 10.5
Autumn	6	46.7 ± 7.8	50.5 ± 13.4
SUBURBAN CATS			
Spring	9	17.3 ± 16.9	32.6 ± 18.0
Summer	4	23.6 ± 10.8	64.3 ± 22.6
Autumn	6	29.4 ± 12.7	45.5 ± 22.5

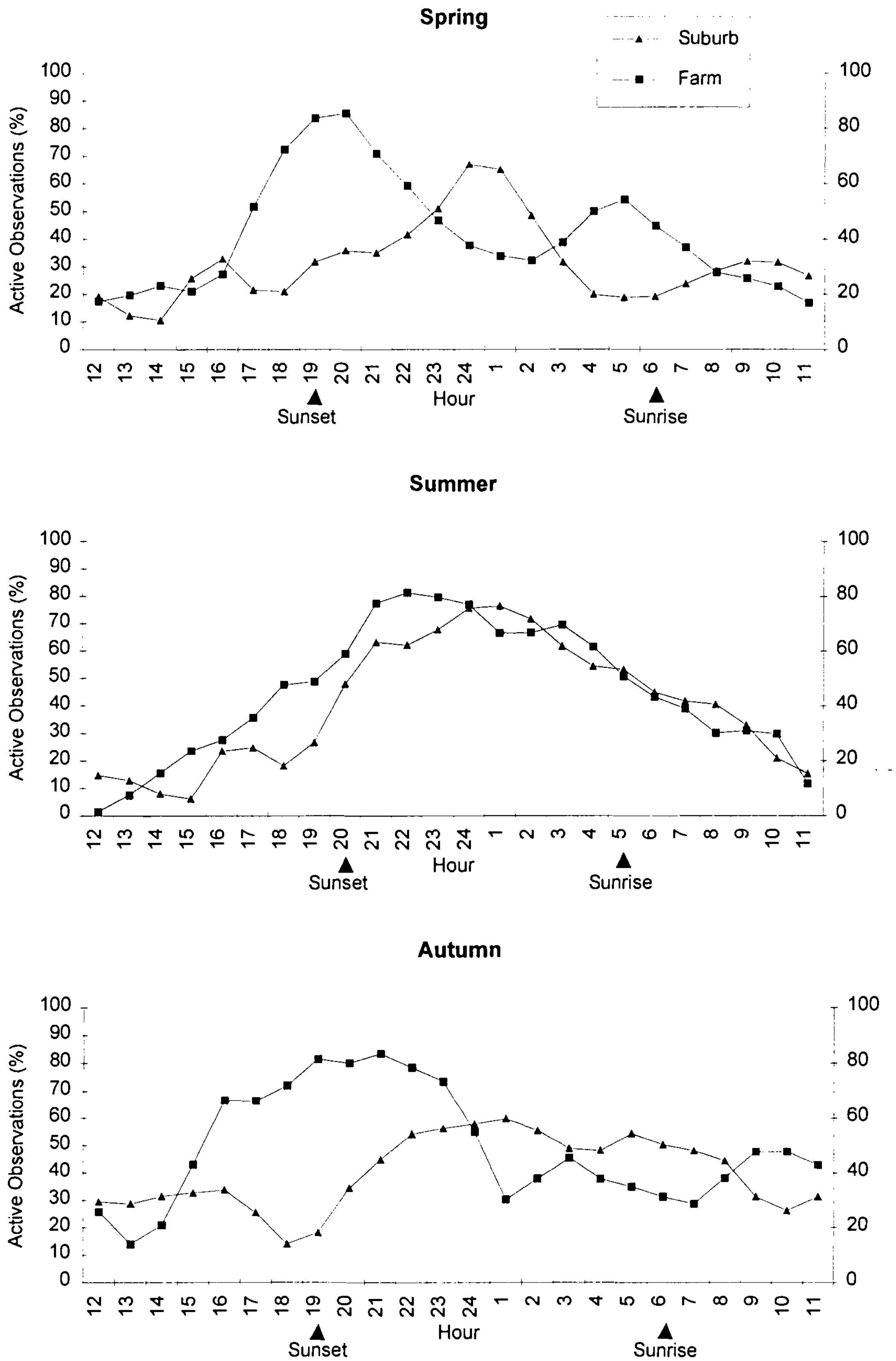


Figure 4.1 Diel activity patterns of suburban and farm cats in spring, summer and autumn. Lines have been smoothed by plotting the average of consecutive observations.

Both suburban and farm cat activity was uni–modal in summer, but maximum activity for suburban cats was recorded at midnight (82.6% of observations active), three hours later than farm cats (83.3% of observations active at 2100 h). Minimum diurnal activity was lower in summer than in spring and autumn. No active observations were recorded for farm cats between 1100 h and midday in summer (Figure 4.1). Suburban cat activity was lowest in the mid–afternoon (5.3% of observations active at 1400 h).

Farm cat activity was greatest around 2100 h (86.7 % of observations active) in autumn as in summer, but unlike summer, a smaller peak in the mid–morning (~ 0900 h) was also recorded. Farm cat activity was lowest at midday when 11.1% of observations were active. The nocturnal peak in activity for suburban cats in autumn (60% of observations active at midnight) was relatively low compared to other seasons, and to the farm cat activity peak in autumn (Figure 4.1). Activity was lowest at 1800 h (5.8% of observations active). There was a dip in activity around 1800 h which can also be seen, though less conspicuously, in spring and summer (Figure 4.1).

Activity patterns calculated from data pooled over all three seasons are shown in Figure 4.2. Activity levels between the hours of 3 am and 4 pm are similar for suburban and farm cats. The activity peak for farm cats however, is earlier in the evening (2000 h) than for suburban cats (12 midnight). The dip in activity levels of suburban cats around 1800 h is again evident.

4.3.4 Activity and Ambient Temperature

Afternoon activity (proportion of all observations of all cats recorded as active between midday and 1800 h) was negatively correlated ($r=-0.475$, $P=0.0006$) with coinciding maximum daily temperatures between October 1993 and June 1994 (Figure 4.3). Early morning activity (proportion of all observations of all cats recorded as active between midnight and 0600 h) was positively correlated ($r=0.480$, $P=0.0013$) with coinciding minimum daily temperatures over the same period (Figure 4.4). At high temperatures

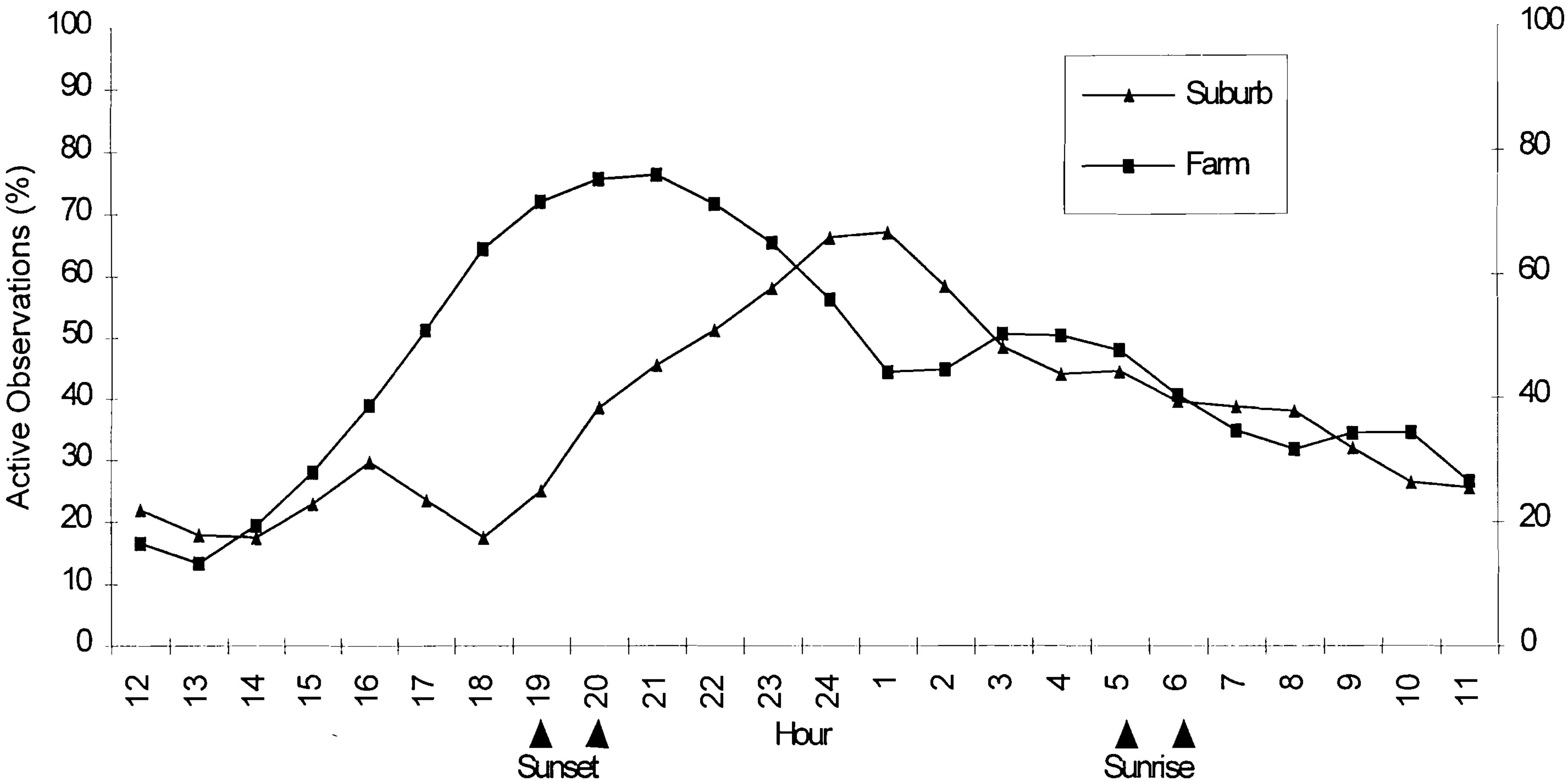


Figure 4.2 Activity patterns over the 24 hr cycle for suburban cats and farm cats using combined spring summer and autumn data. Lines have been smoothed by plotting the average of consecutive observations.

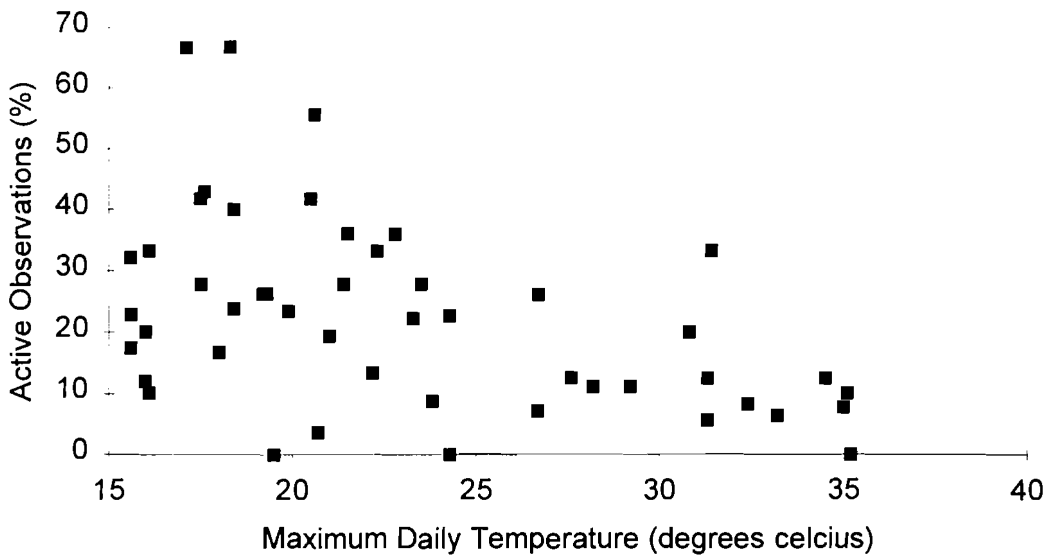


Figure 4.3 Active observations between midday and 1800 h, shown as a percentage of all observations taken during this period, plotted against maximum daily temperature.

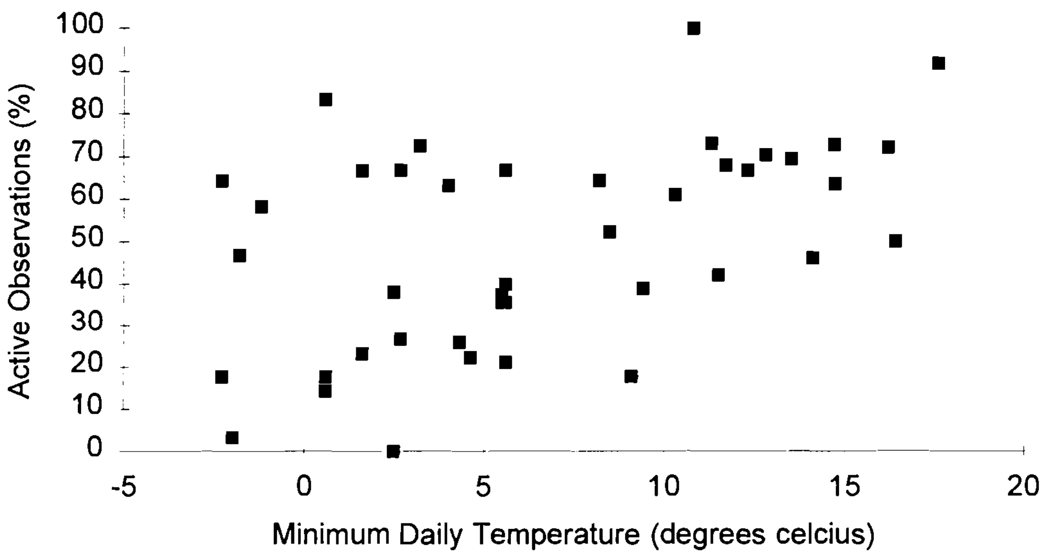


Figure 4.4 Active observations between midnight and 0600 h, shown as a percentage of all observations taken during this period, plotted against minimum daily temperature.

both activity levels and variation in activity levels between different days were low, while at low temperatures activity levels were often low but variation in activity levels between different days was high.

4.4 DISCUSSION

Cat movements (in total and per hour) were significantly larger at night than during the day (see also Chapter 3). Langham (1992) found distances moved by feral cats were greater at night than during the day, though there were some exceptions. For instance, female cats denning in barns increased their diurnal movements in spring and summer when rearing kittens (Langham 1992). Increased diurnal movement by a female farm cat while rearing kittens during summer was also observed in the present study.

Activity (defined as the proportion of all observations when cats were active, rather than the mean distance moved between consecutive observations) was generally greatest at night for both farm and suburban cats. This result was most pronounced in summer and less apparent in spring and autumn. Farm cat activity in spring and autumn was more crepuscular than nocturnal, and greatest around sunset. Seasonal shifts in activity patterns from diurnal to crepuscular to nocturnal are suggested to be a function of ambient temperature (George 1974, Izawa 1983). In support of this theory, the results of this study show cat activity is negatively correlated with maximum daytime temperature and positively correlated with minimum night–time temperature.

Several workers have reported activity peaks for cats around sunset and sunrise (George 1974, Jones and Coman 1982, Izawa 1983, Konecny 1987). Langham (1992) observed a peak in activity at dusk but not at dawn for barn denning feral cats, similar to the result in the present study for farm cats during autumn. The lack of a sunrise peak in activity for farm cats in autumn is probably a consequence of low night–time temperatures.

Diurnal activity was greater in autumn than summer for farm cats. Suburban cat activity showed a similar trend, though differences in diurnal activity between seasons were not statistically significant because of variation in total activity among suburban cats. Also, activity patterns were unable to be recorded for all suburban cats in all seasons and inter–seasonal comparisons were confounded as a result. Diel activity patterns of farm cats appeared more closely related to ambient temperature than was the case for suburban cats. Disturbances and interactions involving people, unrelated cats, dogs and traffic had a greater influence on the activity patterns of the suburban cats compared with the farm cats.

Overall, farm cat activity was greatest immediately after sunset. There was a time lag between this peak and the suburban cat activity peak at around midnight. A similarly delayed peak in nocturnal activity was observed for feral urban cats living in New York (Haspel and Calhoon 1993). Haspel and Calhoon suggest sunset peaks in activity patterns of domestic cats reported in numerous studies (George 1974, Jones and Coman 1982, Izawa 1983, Konecny 1987) are synchronised with prey activity. The absence of this peak in the study by Haspel and Calhoon (1993) was attributed to cats avoiding peaks in human activity and to a lack of dependence on prey for food.

The absence of an early evening peak in the activity patterns of suburban house cats in the present study may have been because the suburban cats were more independent of prey for food than the farm cats. However, the phenomenon appears to also be related to the activity patterns of people but in a different, almost opposite manner to that described by Haspel and Calhoon (1993). Suburban house cats in this study tended to spend the hours around sunset and immediately after dusk inside their owner's homes, either willingly or forcibly interacting with their owner and owner's family. The movement of suburban cats from outside to within the home to be fed and handled is indicated by the dip in activity levels around 1800 h and the lower levels of activity in the early to mid–evening compared to the farm cats (Figure 4.2).

In summary, cats were significantly more active at night than during the day. Nocturnal peaks in activity were most pronounced in summer. Farm cat activity in spring and autumn was more crepuscular than nocturnal, and greatest around sunset. The absence of post–sunset peaks in the activity patterns of suburban house cats is thought to have been due to a lesser dependence on prey for food compared with farm cats, and to cat–human social interaction patterns. Diurnal activity of farm cats was greater in autumn than summer. Seasonal changes in diurnal and nocturnal activity levels are suggested to be primarily a function of ambient temperature. Disturbances and interactions involving people, unrelated cats, dogs and traffic etc, also influence the activity patterns of suburban cats.

5 PREY COMPOSITION AND PREFERENCE

5.1 INTRODUCTION

Quantitative studies of the diet of both farm cats and feral cats have shown they are versatile, generalist predators, exploiting a wide range of prey, and able to switch readily from one prey type to another (Davis 1957, Coman and Brunner 1972, George 1974, Triggs *et al.* 1984, Jones and Coman 1981, Bayley 1978, Gibb *et al.* 1978, Fitzgerald and Karl 1979, Taylor 1979, Strong and Low 1983, Maddock 1983, Apps 1984, Liberg 1984a, Fitzgerald 1988, Ebenhard 1988, Newsome *et al.* 1989, Amarasekare 1994). Mammalian prey (voles, mice, rats, rabbits, hares and hamsters) is of greatest importance to free–ranging farm cats and feral cats in Europe and North America, with a lesser but consistent predation on birds (Elton 1953, Davis 1957, Liberg 1984a, Fitzgerald 1988). The contribution of reptiles to the diet of feral cats differs greatly between continents. The number of reptile species eaten is related to latitude, climate and species diversity (Fitzgerald 1988).

Studies of predation by suburban house cats are less numerous (Mead 1982, Churcher and Lawton 1987, Trueman 1990, Paton 1991). Churcher and Lawton (1987) reported 15 species of mammals, predominantly wood mice, field and bank voles and common shrews, comprised 65% of the prey items caught by house cats in an English village over one year. The remaining 35% of identified prey items were birds. From a survey of prey caught by the pets of 200 cat owners in southern Tasmania over 3 months in winter, Trueman (1990) reported 45.1% of prey were mammals, 44.2% were birds and 10.7% were reptiles. No amphibians were recorded. Of the mammals, 93.3% were introduced species. Twenty–three percent of bird prey were introduced species and 63.3% were native species (13.7% not identified). Fifty–five percent of all prey items were introduced species.

The work of Davis (1957) and more recently others (Mead 1982, Churcher and Lawton 1987, Trueman 1990, Paton 1991), has shown house cats will readily prey upon many bird species in addition to small mammals. Passerine species are generally the most common group of birds eaten. Honeyeaters were the most frequently taken group of native birds by house cats in suburban areas of Adelaide (Paton 1991).

Little attempt has so far been made to analyse the relative proportions of different faunal species or groups taken by house cats with respect to the relative availability of these prey types in the local environment. An important aspect of any study of the ecology of a predatory species is to ascertain whether the predator actively selects one prey type over another. A resource such as a prey species is said to be "preferred" when the proportion of that prey type killed by a predator is higher than its proportion in the available environment (Begon *et al.* 1990). Many authors have described resources as "avoided" if the reverse is true (see Alldridge and Ratti 1986, White and Garrott 1990).

Hess and Swartz (1940) were among the first to give greater definition to resource preference or avoidance by developing food preference ratings for trout feeding on bottom insects, which they termed Forage Ratios. Preference rating or ratio values are generated by dividing the percentage utilisation of a resource component by the percentage availability of the component in the total accessible environment. Subsequent work on utilisation–availability data included the development of so–called utilisation indices (Ivlev 1961, Jacobs 1974, Strauss 1979, Pepin 1986, Viljoen 1989) as a means of measuring resource preference or avoidance. Utilisation indices have an advantage over preference ratios in that selection values lie between definite positive and negative limits, usually 1 and –1, centring on zero as a reference point.

Both preference ratios and utilisation indices, however, provide no statistical means of testing results from a null hypothesis of neutrality. A 'neutral' result means a resource is utilised randomly, that is, utilised in proportion to its relative abundance in the available environment. To this end, numerous workers have carried the analysis of utilisation –

availability data a step further by developing means to analyse the significance of apparent preference or avoidance of resources using a statistical test (see Alldridge and Ratti 1986). One of these techniques, developed by Neu *et al.* (1974) and clarified by Randall Byers *et al.* (1984), has been employed here.

The overall aim of this chapter was to examine predation by house cats with respect to published information on the temporal and spatial abundance and distribution of faunal groups in the ACT and the Canberra region in particular. Specific objectives were to i) quantify the composition, age, size and gender of prey taken by domestic cats over one year, ii) ascertain whether house cats show a preference for particular bird species, iii) quantify seasonal differences in the composition, age and gender of prey taken, and iv) examine the type and amount of prey caught at different times of the night and day. George (1974) reported his own neutered house cats (n=3) caught 49.8% of their prey during the day, 20.1% at dawn or dusk and 30.1% during the night. However, the timing of predation with respect to different prey types in Australia does not appear to have been quantified, despite calls from environmental organisations for night–time cat curfews to reduce impact on native wildlife.

5.2 MATERIALS AND METHODS

Participants collecting prey items or the remains of prey in polyethylene bags were supplied with labels to record the date and estimated time of the catch, the cat's name and/or ID number and the cat owners opinion as to the identification of prey remains. Catches that could not be definitely attributed to a particular cat where a number of cats were living at the same residence, were distributed among the cats at the completion of data collection in accordance with the proportion of observed catches per cat. Prey items collected from study participants were, where possible, described in terms of age (adult or juvenile), size (body length in cm) and gender. Where it was not possible to identify prey remains, the species was recorded as unknown. Normally however, prey remains could be identified to at least the taxonomic class level. Data sheets distributed to participants keeping their own prey records, rather than having prey collected, provided space on which to describe catches with respect to the date and approximate time of the catch, common prey name, prey age (adult or juvenile), prey sex, and general comments (see Appendix 5). Field texts such as Simpson and Day (1984) for birds and Hyett and Shaw (1980) for mammals were used to help identify collected prey remains, in addition to local expertise and reference to previously collected prey specimens.

The technique for analysis of utilisation–availability data employed here was first described by Neu *et al.* (1974) and uses a chi–square test of the hypothesis that animals use forage or prey species in proportion to their availability to the animal, a multinomial distribution (Ostle 1963:124). If a statistically significant difference is found between the utilisation and availability of, in this case, prey types, the data may be further investigated using Bonferroni confidence intervals to determine which species are preferred. Krausman (1978) used the technique to evaluate forage preferences of deer in relation to availability. The procedure involves comparing the observed number of instances of utilisation with the expected number of occurrences based upon known availability. The methodology used to gather utilisation data in this study, i.e., identification of prey items caught by domestic cats over one year to at least the taxonomic class level, is described in the general methods section (Chapter 2).

To examine preference by domestic cats for particular bird species, the relative abundance of common species in the bird prey sample was calculated after removing all records of prey items unidentified at the genus level. The relative abundance of the same bird species in suburban Canberra during the prey data collection period was calculated from the Canberra Ornithologists Group Garden Bird Survey records for the year beginning June 1993 and ending June 1994. The Garden Bird Survey data were derived from standard charts on which participants record observations on a weekly basis at sites throughout suburban Canberra (see Figure 5.1 for 1993/1994 sites). Observers record the maximum number of each species seen at any one time during a week within a radius of 100m of their home or workplace. A detailed description of the

Garden Bird Survey has been made by Hermes (1981). A measure of abundance is calculated as the average number of individuals of a species recorded at a site for each week over a full year. It is obtained by adding all weekly observations of a species and dividing the sum by the total number of weeks during which observations were made. For example if abundance = 5.1 then on average, 5.1 individuals of that species were recorded each week, at each site, over the full year.

Variation in predation within prey classes between seasons and between prey classes within seasons was tested using factorial and one–way analyses of variance on log–transformed seasonally grouped mammal, bird and reptile data. Changes in prey composition, gender and age ratios between seasons were examined using log–linear modelling and Chi–square analyses (using Yates correction factor where appropriate).

Spatial variation in prey species composition with regard to the habitat related variables Suburb Age (approximate age of the suburb in which cats were living), Distance From Suburb Edge (the distance from the cat owners home to the nearest suburban – rural/reserve interface), and Adjoining Habitat Type (the type of habitat – rural/grassland or woodland/forest – adjoining the suburb edge nearest the cat owners home), was analysed using log–linear modelling techniques. The age of suburbs was derived from Department of Environment Land and Planning records and from Munyenyembe (1985). The continuous variables Suburb Age and Distance From Suburb Edge were broken into categories that accommodated curvilinear trends in the prey data and ensured reasonable sample sizes within each category.

Variation in the frequency of capture of different prey types at different times of the day and night by unconfined cats was tested using log–linear modelling and Chi–square analysis.

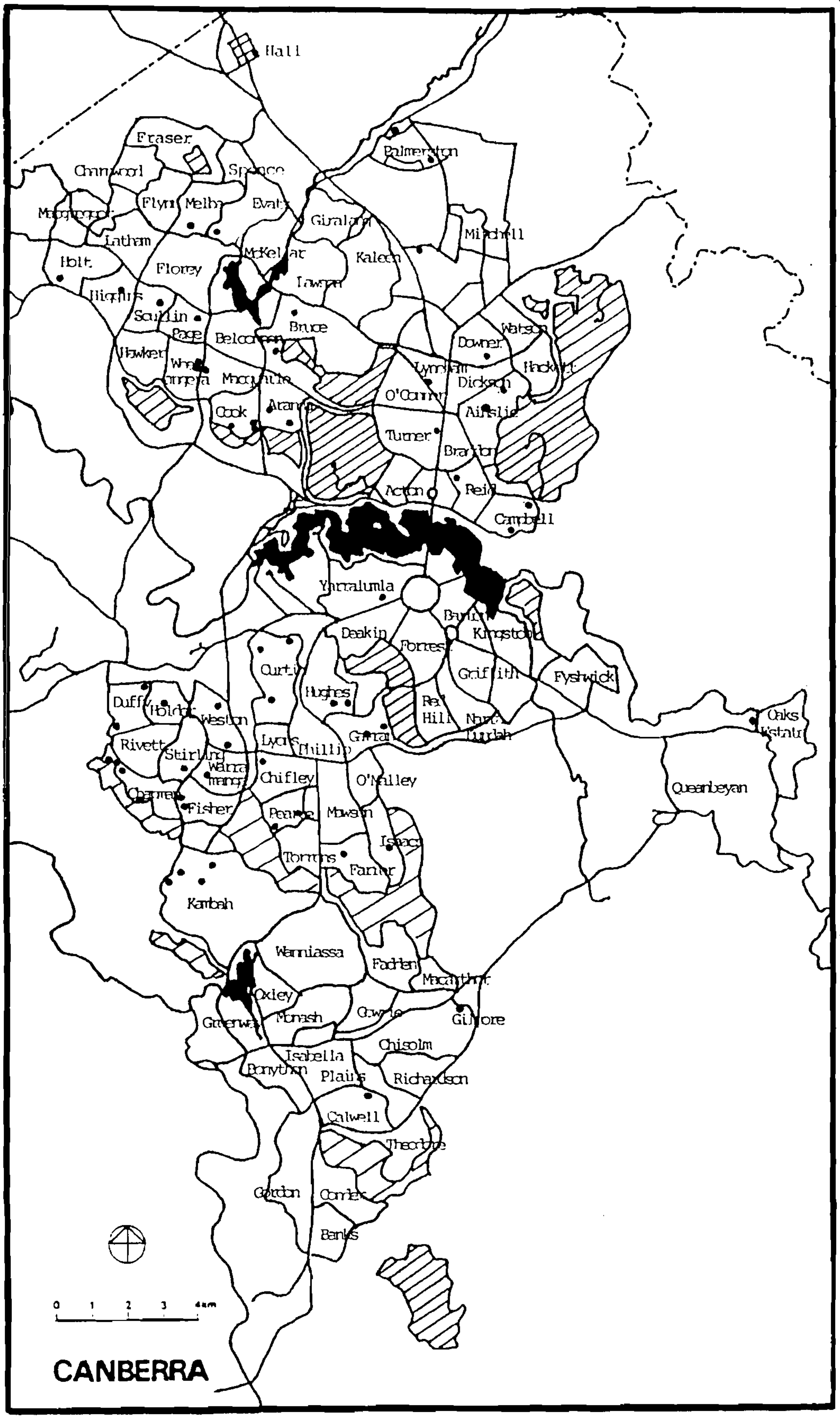


Figure 5.1 Map of Canberra showing 1993/94 Canberra Ornithologist Group Garden Bird Survey sites.

5.3 RESULTS

5.3.1 Prey Species Composition

214 cats from 143 homes in 61 suburbs contributed data for at least one season of the study. The number of cats monitored in each month ranged from a low of 174 in June to a high of 197 in September. Reliable predation records over the entire year were received for 138 cats. The total number of prey items recorded in each month and average per cat are shown in Figure 5.2. The upward trend in the average number of prey items recorded per cat per month at the study's conclusion, toward the peak at the same time the previous year, is encouraging as it suggests that the data reflect trends in cat predatory activity rather than the degree of co–operation and observation effort of cat owners.

A total of 1961 prey items were recorded over the 12 months of the study. Twenty–six percent of all prey items were collected from cat owners and identified, aged, sexed and measured in the laboratory. Forty–seven bird species, 10 mammal, seven reptile, two amphibian and one fish species were recorded (Table 5.1, see also APPENDIX V). Eight mammal, 106 bird, 108 reptile and 15 amphibian prey items could not be identified at the species level. Two other prey items were unidentified at the taxonomic class level. The number of species recorded therefore likely underestimates the total number of species caught. In addition, sixty bird and eight mammal prey items could not be distinguished as either introduced or native animals.

The observed number of species caught per cat ranged from 0 to 14. Most cats (81.9%) were observed to catch less than 5 prey species over the 12 month study period, though for 2.9% of cats, more than 10 prey species were recorded. The mean number of prey species recorded per cat ± 2SE was 2.8 ± 0.45 and the median was 2.

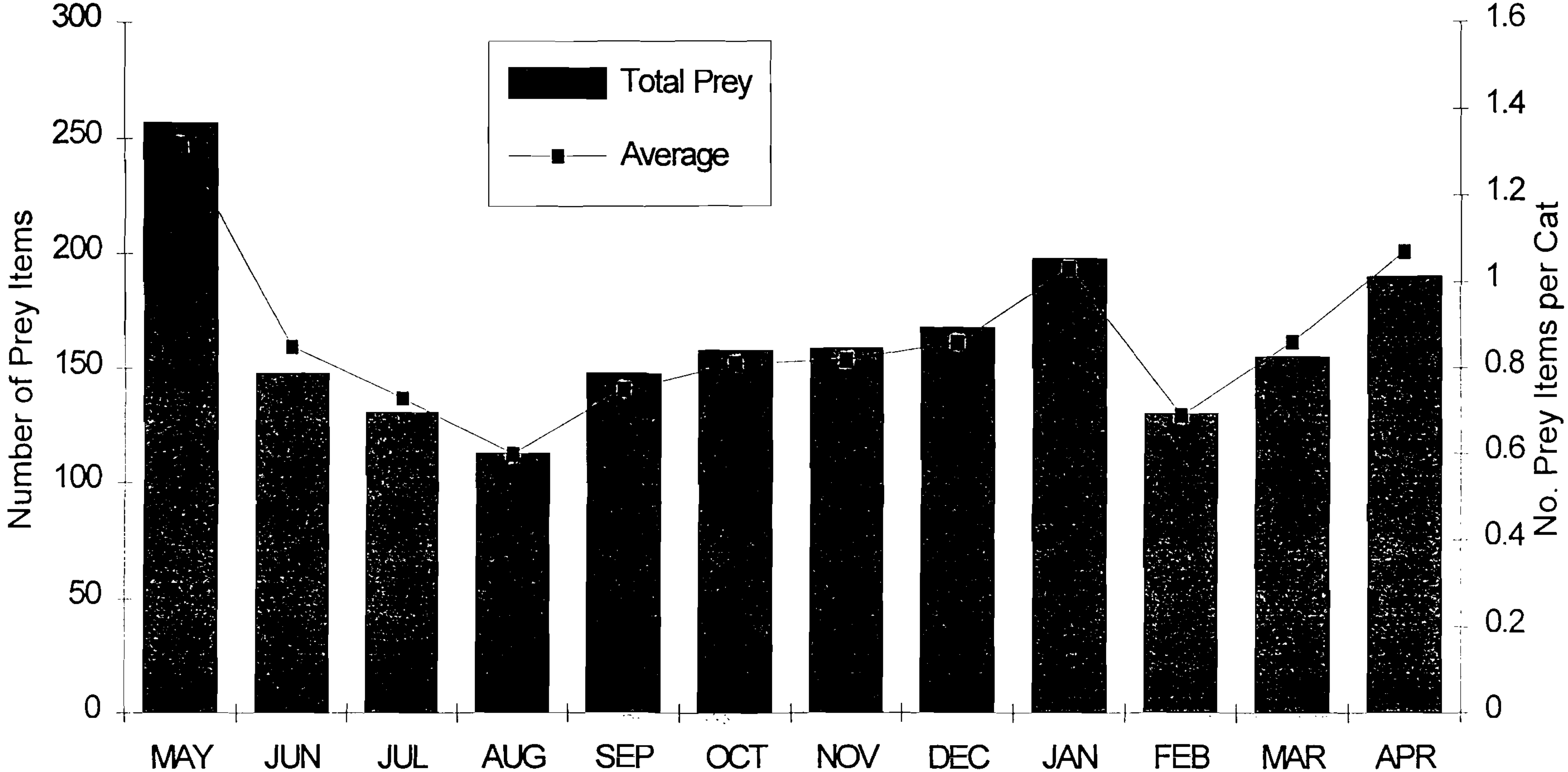


Figure 5.2 Total and average number of prey items recorded per month

Of the 67 identified prey species, house mice *Mus domesticus* comprised more than half of all recorded prey items (Table 5.1). Black rats *Rattus rattus* were the next most common prey species. Other introduced mammals included rabbits *Oryctolagus cuniculus*, as well as two guinea pigs *Cavia porcellus* and a brown rat *Rattus norvegicus*. Included among the native mammals were four sugar gliders *Petaurus breviceps*, two juvenile common brushtail possums *Trichosurus vulpecula*, five bats (species unknown), two water–rats *Hydromys chrysogaster,* and one bush rat *Rattus fuscipes.* There were also two unconfirmed reports of ground–dwelling marsupials being taken by house cats. These were not included in the data–set.

Birds comprised only 27% (n=529) of the total prey items. This relatively small proportion, however, included 47 species, 41 of which were native. House sparrows *Passer domesticus* (n=104), silvereyes *Zosterops lateralis* (n=62), common starlings *Sturnus vulgaris* (n=50), blackbirds *Turdus merula* (n=34) and crimson rosellas *Platycercus elegans* (n=23–30) were the most common prey. Seven birds described as rosellas were not identified as eastern or crimson rosella species. Other species well represented among the bird prey items were superb fairy–wrens *Malurus cyaneus* (n=14), magpie larks *Grallina cyanoleuca* (n=13), eastern rosellas *Platycercus eximius* (n=10–17), yellow–faced honeyeaters *Lichenostomus chrysops* and unspecified honeyeaters (n=4–11), red wattle–birds *Anthochaera carunculata* (n=11) and golden whistlers *Pachycephala pectoralis* (n=9). Native and exotic species accounted for 58.2% (n=273) and 41.8% (n=196) of identifiable birds caught respectively.

Reptiles and amphibians comprised 7% and 1% of prey items respectively. Twenty–two of 131 reptile prey items recorded were described as 'lizards', 86 items were described as 'skinks' and three items were described as 'geckos'. Species identified included seven jacky lizards *Amphibolurus muricatus*, five juvenile eastern brown snakes *Pseudonaja textilis*, four blue–tongue lizards *Tiliqua scincoides*, three striped skinks *Ctenotus robustus*, and a bearded dragon *Pogona barbata.* Amphibian prey species were mostly recorded as 'unknown' by study participants, but five Peron's tree

Table 5.1 Frequency and composition of prey items caught by 214 house cats in Canberra over the 12 month prey data collection period from May 1993 to May 1994.

Prey Class	Status and Species	Sample (n)	%	Species (n)
Mammals	Introduced			
	Mus domesticus	1095	55.84	1
	Rattus rattus	143	7.29	1
	Oryctolagus cuniculus	10	0.51	1
	Other	3	0.15	2
	Native	14	0.71	5
	Unknown	8	0.41	
	Sub–Total	**1273**	**64.92**	**10**
Birds				
	Native	273	13.92	41
	Introduced	196	10.00	6
	Unknown	60	3.06	
	Sub–Total	**529**	**26.98**	**47**
Reptiles		**131**	**6.68**	**7**
Amphibians		**22**	**1.12**	**2**
Fish	Introduced	**4**	**0.20**	**1**
Unknown		**2**	**0.10**	
TOTAL		**1961**		**67**

frogs *Litoria peronii*, and a banjo frog *Limnodynastes dumerilii*, were identified. Four goldfish *Carassius auratus* were also reported.

5.3.2 Bird Prey Preference

The relative abundance of the most common bird species recorded in the prey sample and the relative abundance of these same species in the gardens of suburban Canberra are shown in Table 5.2. For the purposes of this analysis, prey items of cats which were described as 'rosella' (n=7) were divided between eastern and crimson rosella species in approximately the same ratio as catches positively identified as one or other of the species. Unknown honeyeaters (n=7) were included in the analysis as yellow–faced honeyeaters.

The proportion of house sparrows and blackbirds recorded as prey was significantly greater than the estimated relative abundance of these two introduced species in the local environment. Conversely, the proportion of common starlings recorded as prey was significantly less than the estimated abundance of this species in suburban gardens relative to the other bird prey types shown (Table 5.2). Differences between utilisation (predation by cats) and availability (in suburban gardens) were non–significant for all native bird species tested.

Trends in abundance between 1984 and 1994 of the two bird species preferred as prey by house cats given their relative abundance in suburban gardens, namely house sparrows and blackbirds, and the two most commonly taken native bird species, namely silvereyes and crimson rosellas, are shown in Figure 5.3. Numbers of house sparrows are apparently decreasing in suburban gardens in Canberra. However, the other preferred bird prey species of house cats, blackbirds, appear to be increasing in abundance. Numbers of the two most common native bird prey species, silvereyes and crimson rosellas, also appear to be stable or increasing in suburban gardens, in spite of an estimated annual cull by house cats of more than 10 000 crimson rosellas and more

Table 5.2 The relative abundance of the most common bird species recorded in the prey sample compared with the relative abundance of these same species in the gardens of suburban Canberra.

		Relative Abundance (%)			
SPECIES	n	Cat Prey Sample	Canberra Gardens	95% CI (Prey Sample)	RESULT
House Sparrow	104	29.9	17.5	22.6 – 37.1	Preferred
Silvereye	62	17.8	15.4	11.7 – 23.9	Neutral
Starling	50	14.4	35.5	8.8 – 19.9	Avoided
Blackbird	34	9.8	5.0	5.1 – 14.5	Preferred
Crimson Rosella	28	8.0	7.9	3.7 – 12.4	Neutral
Superb Fairy–wren	14	4.0	2.3	0.9 – 7.1	Neutral
Magpie Lark	13	3.7	5.5	0.7 – 6.7	Neutral
Eastern Rosella	12	3.4	3.9	0.6 – 6.3	Neutral
Red Wattlebird	11	3.2	4.5	0.4 – 5.9	Neutral
Yellow–Faced Honeyeater	11	3.2	2.1	0.4 – 5.9	Neutral
Golden Whistler	9	2.6	0.5	0.1 – 5.1	Neutral

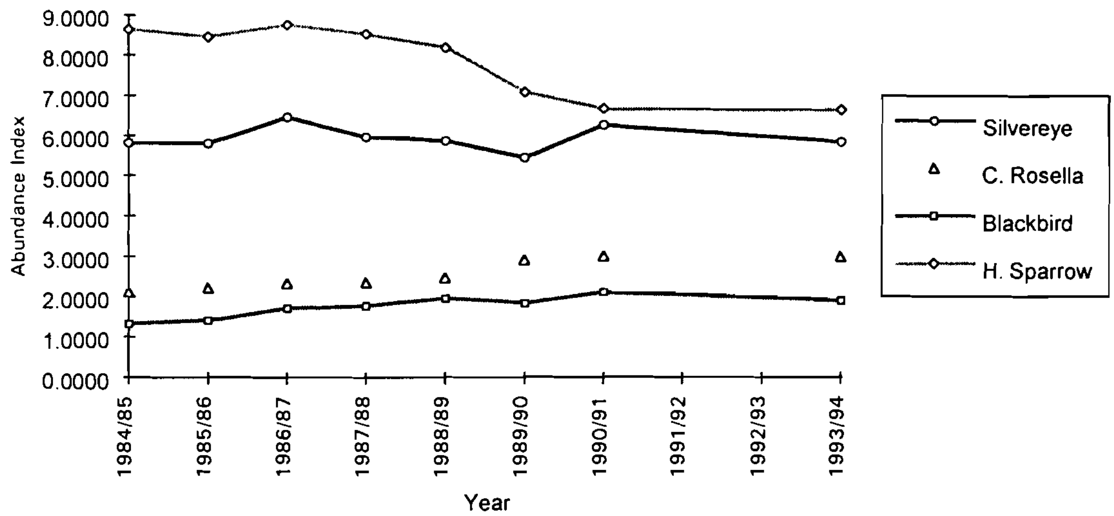


Figure 5.3 Temporal trends in abundance of preferred bird prey species of house cats (house sparrows and blackbirds), and the two most commonly taken native bird species (silvereyes and crimson rosellas).

Table 5.3 Abundance of common bird prey of house cats (other than those shown in Figure 5.3) in suburban gardens in Canberra between 1984 and 1994.

	ABUNDANCE INDEX *									
SPECIES	**84/85**	**85/86**	**86/87**	**87/88**	**88/89**	**89/90**	**90/91**	**91/92**	**92/93**	**93/94**
C. Starling	13.10	12.57	11.06	12.02	10.20	8.83	11.10	N/A	N/A	13.42
Y–F. Honeyeater	3.69	3.97	3.46	4.34	1.92	1.86	2.20	N/A	N/A	0.78
R.Wattlebird	1.62	1.70	1.53	1.92	1.57	1.93	2.02	N/A	N/A	1.69
Magpie Lark	1.65	1.74	1.67	1.60	1.46	1.77	2.00	N/A	N/A	2.07
E. Rosella	1.48	1.61	1.49	1.50	1.25	1.42	1.63	N/A	N/A	1.46
S. Fairy–Wren	0.68	0.67	0.55	0.53	0.61	0.75	0.73	N/A	N/A	0.85
G. Whistler	0.09	0.11	0.17	0.14	0.13	0.15	0.20	N/A	N/A	0.18

* Taken from Canberra Ornithologist Group Garden Bird Survey records.

than 20 000 silvereyes, calculated by multiplying the average number of birds caught per cat in this study by the Canberra house cat population (estimated by REARK Research 1994). Of the other bird species recorded among the most common prey of house cats, magpie larks, superb fairy–wrens and golden whistlers appear to be increasing in abundance in suburban Canberra. A declining trend in numbers of yellow–faced honeyeaters is evident from 1988 onwards, while abundances of common starlings, eastern rosellas and red wattlebirds fluctuate between years but are approximately the same at the end of the 10 year period as at the beginning (Table 5.3).

5.3.3 Seasonal Variation in Species, Gender and Age Composition of Prey

The average number of mammals, birds, reptiles and amphibians caught per cat per month is shown in Figure 5.4. Mammals comprised the greatest proportion of total prey items in all months except November and December when birds were the most abundant prey type. Reptiles and amphibians were the third and fourth most important prey types respectively in all months. As shown in Figure 5.5, predation on mammals (98% of which were introduced and 86% house mice), was greater in autumn than in spring or summer (Sidak F–Test, $P<0.05$). In contrast, predation on birds and reptiles was greater in spring and summer than in winter (Sidak F–Tests, $P<0.05$).

Seventeen of 22 amphibian prey items were recorded in summer. The remaining five records were collected in late spring and early autumn.

Predation on mammals was significantly greater than predation on birds in autumn and winter (Sidak F–Tests, $P<0.05$), but not significantly different in spring and summer (Sidak F–Tests, $P>0.05$). Predation on birds was significantly greater than predation on reptiles in all seasons (Sidak F–Tests, $P<0.05$).

The relative importance (percent total bird prey) of native and introduced bird prey is shown by month and season in Figures 5.6 and 5.7. The proportion of total bird prey

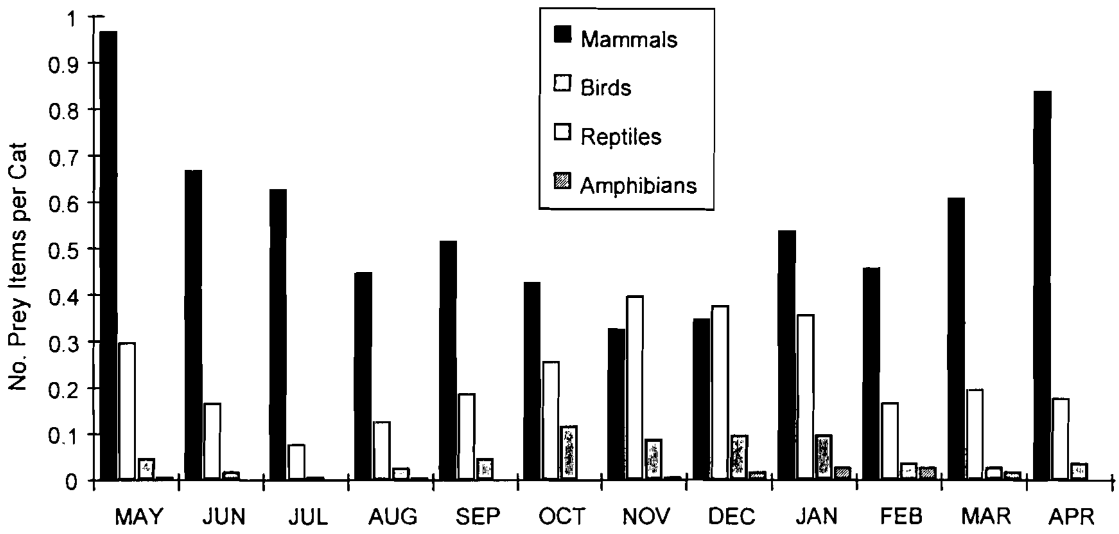


Figure 5.4 Average number of mammal, bird, reptile and amphibian prey items recorded per cat per month.

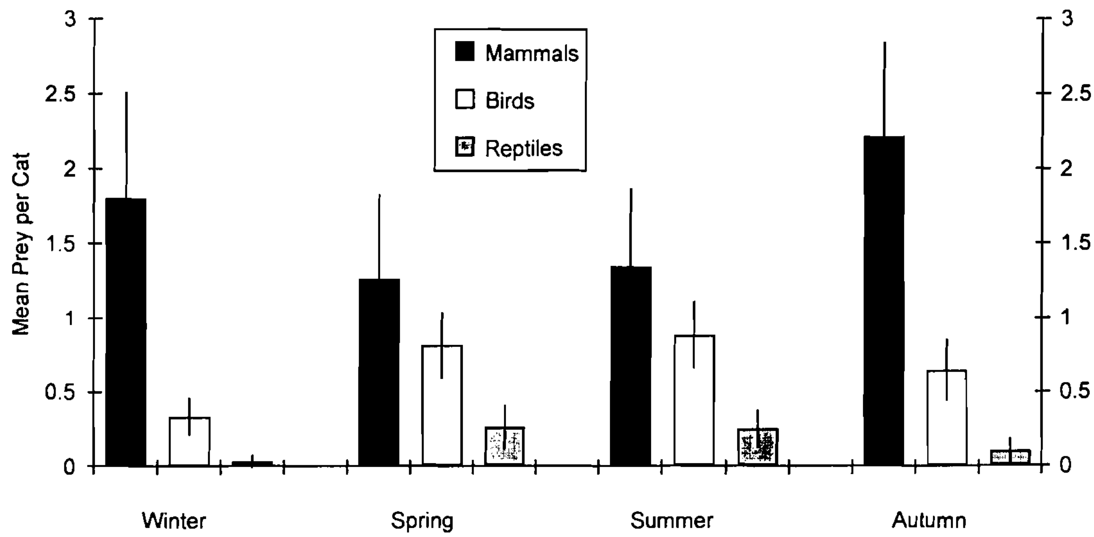


Figure 5.5 Seasonal variation in the mean amount of prey caught per cat (± 2SE) by taxonomic prey classes.

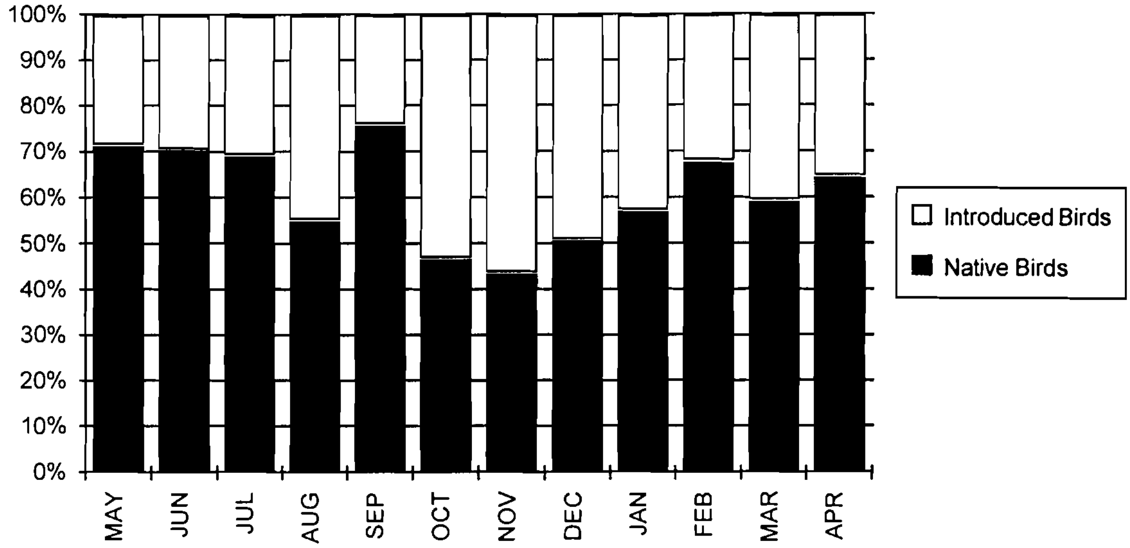


Figure 5.6 Proportion of native to introduced bird prey items recorded each month.

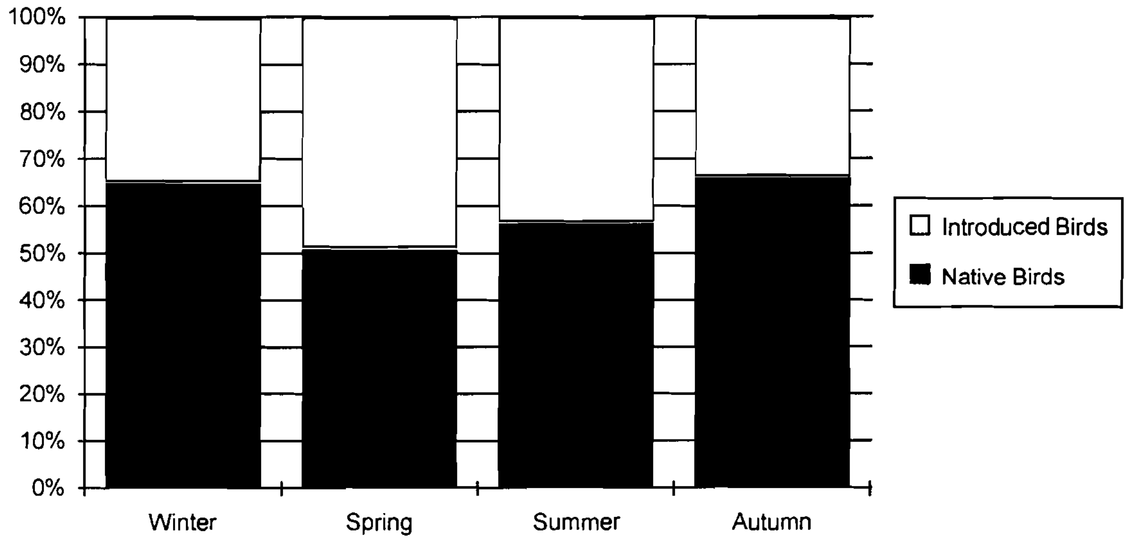


Figure 5.7 Proportion of native to introduced bird prey items recorded each season.

comprised by native species was generally greater than introduced species at all times except late spring (October, November). Log–linear analysis of seasonally grouped data showed no significant association between the type of birds caught (native or introduced) and season (G=6.19 DF=3 P=0.1027).

Gender ratios for bird and rodent prey items are shown by season in Table 5.4. The proportion of male to female rodent prey was not significantly different from 1.0 in all seasons except winter when the number of female rodents caught was significantly greater than males (χ^2=4.33 DF=1 P<0.05). In contrast, the number of male birds caught in winter was significantly greater than females (χ^2=5.88 DF=1 P<0.02). The ratio of male to female prey recorded over 12 months was not significantly different from 1.0 for both bird and rodent prey (P>0.05).

The proportion of rodent and bird prey items comprised by juveniles or sub–adults is shown by season in Table 5.5. Predation on juveniles was significantly associated with season for both mammals (G=17.80 DF=3 P=0.0005) and birds (G=10.43 DF=3 P=0.015). The proportion of juvenile mammals caught in spring, summer and autumn was approximately double the proportion caught in winter. The proportion of juvenile birds caught in spring and summer was approximately twice that of winter, and also nearly double the proportion caught in autumn (Table 5.5).

5.3.4 Spatial Variation in Prey Species Composition

Prey composition was examined with respect to suburb age, and distance from cat owner's homes to the nearest non–suburban habitat. An interaction effect between the type of nearest non–suburban habitat (rural/grassland or woodland/open–forest) and the distance from cat owner's homes to these habitats was evident with respect to predation on reptiles (G=9.02 DF=3 P=0.0110), birds (G=62.33 DF=3 P<0.0001) and introduced mammals (G=109.30 DF=3 P<0.0001). Analyses of the effect of distance from cat owner's homes to the nearest non–suburban habitat on prey composition were

Table 5.4 Gender ratios among rodents and birds recorded as prey items of house cats by season.

Season	Rodents Male/Female Ratio	n	Birds Male/Female Ratio	n
Autumn	0.97	67	0.92	25
Winter	0.53 *	52	4.68 *	17
Spring	1.40	72	1.67	24
Summer	1.28	73	0.57	22
Year	1.03	264	1.26	88

Chi–square Test * $P<0.05$

Table 5.5 Proportions of total rodent and bird prey items identified as juvenile or sub–adult by season.

Season	Rodents Proportion Juveniles	n	Birds Proportion Juveniles	n
Autumn	32.3	285	18.4	87
Winter	16.5	224	16.3	49
Spring	29.2	185	33.3	105
Summer	31.1	199	33.9	109
Year	27.4	893	27.4	350

subsequently conducted by non–suburban habitat type (rural/grassland or woodland/open–forest). No interaction effect between the type of nearest non–suburban habitat and the age of the suburb within which the cat owner's home was located was apparent. Three way interaction effects between suburb age, distance to non–suburban habitat, and non–suburban habitat type, could not be analysed owing to small sample sizes within some categories.

The relative abundance of introduced mammal, introduced bird, native bird and reptile prey items is shown against distance from cat owner's homes to rural/grassland or woodland/open–forest habitat in Figures 5.8 and 5.9. The influence of the type of adjoining habitat on distance effects is immediately apparent. In suburbs adjoining rural/grassland habitat, the relative abundance of introduced mammals (87% of which were house mice) in the prey sample increased sharply from interior suburban areas toward suburb edges ($G=94.61$ $DF=3$ $P<0.0001$). In contrast, the proportion of recorded prey comprised by birds decreased toward suburb edges adjoining rural/grassland habitat ($G=109.83$ $DF=3$ $P<0.0001$). The trend was similar for both native and introduced bird prey species. Reptiles comprised only a minor proportion of the prey sample within each distance category but were most prevalent within 50 m of rural/grassland habitat.

In contrast to suburban areas adjoining rural/grassland habitat, native prey items (reptiles and native birds) made up approximately half of all bird, introduced mammal, and reptile prey caught by house cats living within 50 m of woodland/open–forest habitat. Twenty–three percent of all prey (including native mammals and amphibians) taken in this area were reptiles. The relative abundance of reptile prey items, declined rapidly with distance into the suburban environment from woodland/open–forest habitat ($G=14.49$ $DF=3$ $P=0.0007$). The proportion of the prey sample comprised by birds was relatively high close to woodland/open–forest habitat and in interior suburban areas, but lower at intermediate distances ($G=13.47$ $DF=3$ $P=0.0037$). The proportion of native to introduced bird prey items declined from 89% within 50 m of woodland/forest

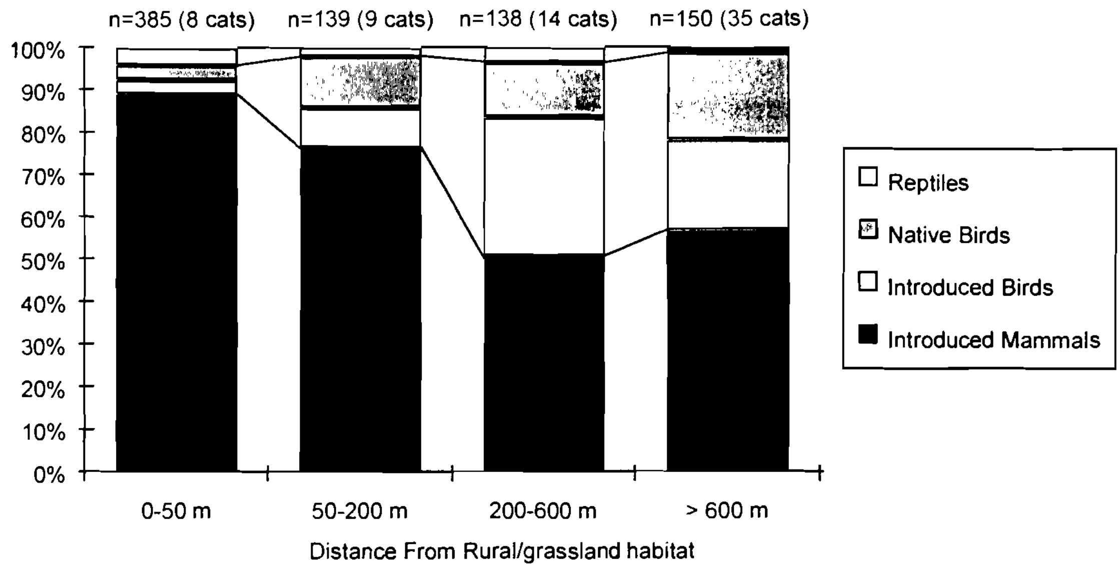


Figure 5.8 Relative frequency of birds and reptiles and introduced mammals in the prey sample with respect to distance from rural/grassland habitat adjoining suburban areas.

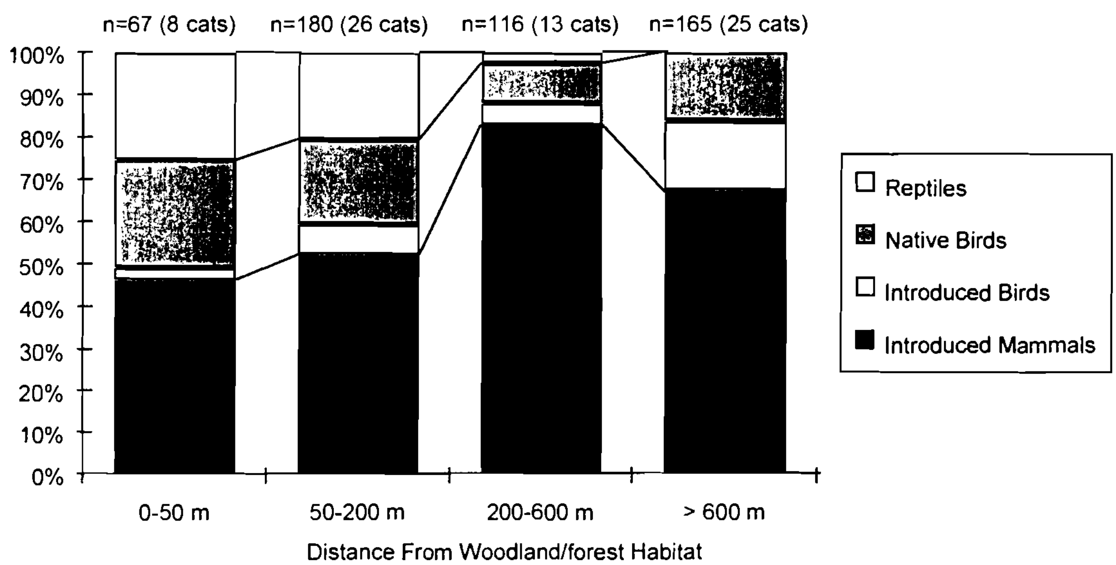


Figure 5.9 Relative frequency of birds and reptiles and introduced mammals in the prey sample with respect to distance from woodland/forest habitat adjoining suburban areas.

habitat to 50% at distances greater than 600m into the suburban environment (G=10.72 DF=3 P=0.0134). The relative abundance of introduced mammal prey items increased as the relative abundance of native prey items decreased with distance from woodland/open–forest habitat (G=43.21 DF=3 P<0.0001).

The relative abundance of introduced mammal, introduced bird, native bird and reptile prey items is shown with respect to suburb age in Figure 5.10. The proportion of the prey sample comprised by introduced mammals was greater in young and mature suburbs than in old suburbs (G=11.36 DF=2 P=0.0034). The relative abundance of reptile prey items was highest in old suburbs (G=23.87 DF=2 P<0.0001). The relative abundance of birds in the prey sample was similar in all suburb age classes. However, the proportion of native to introduced birds was greatest in mature suburbs (G=11.38 DF=2 P=0.0034).

All four sugar gliders recorded as prey items were caught in suburbs of 22 years of age or older, within 50 m of woodland/open–forest habitat. The two juvenile brushtail possums recorded were caught in a 25 year old suburb. Approximately 80% of amphibian prey items were caught in mature suburbs within 200 m of the suburb edge.

5.3.5 Diel Predation Patterns

Table 5.6 shows the diel distribution of frequency of catches made by cats not confined by their owners during the day or at night (n=124). Predation frequencies in each six hour interval were tested against an expected ratio of 1:1:1:1, under the null hypothesis that predation is uniform throughout the day and night. Frequency distributions were significantly different from the expected uniform ratio for bird (χ^2=69.55 DF=3 P<0.001), mammal (χ^2=71.83 DF=3 P<0.001), and reptilian prey (χ^2=55.46 DF=3 P<0.001). Prey composition varied depending on the time of day (G=136.79 DF=6 P<0.0001). Predation on mammals was greatest in the evening while predation on birds was greatest between 0600 h and mid–day. An afternoon maximum in predation on

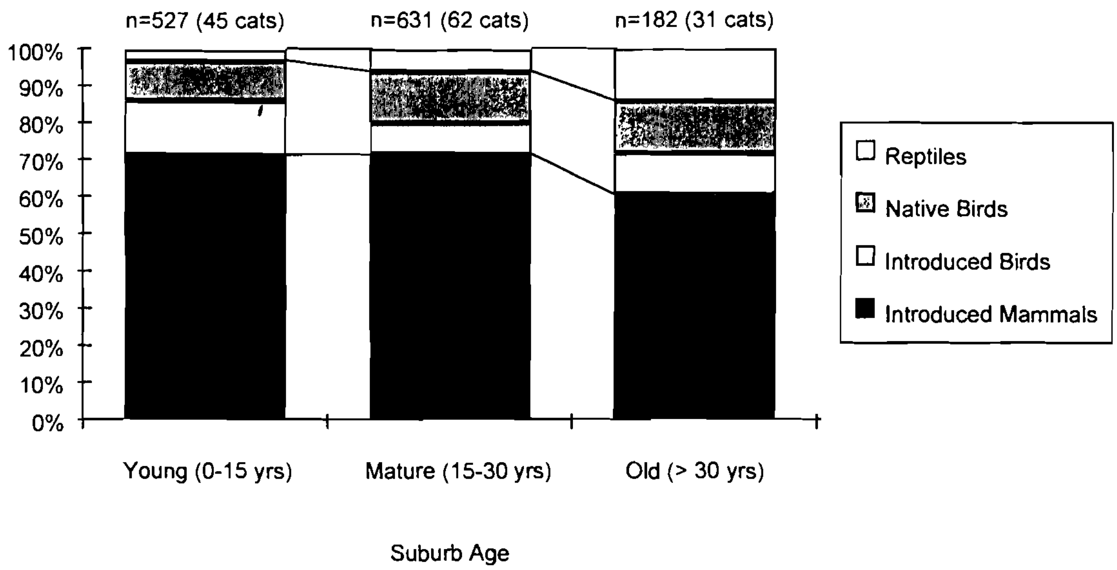


Figure 5.10 Relative frequency of birds, reptiles and introduced mammals in the prey sample with respect to suburb age.

Table 5.6 Frequency distribution over the 24 hr cycle of vertebrate prey items caught by free–ranging house cats (n=124).

	Number of prey caught			
	Nocturnal		Diurnal	
PREY CLASS	1800–2400 h	2400–0600 h	0600–1200 h	1200–1800 h
Mammal	288	181	146	145
Bird	22	54	115	66
Reptile	6	1	20	42
Amphibian	15	1	0	0

reptiles was apparent. Fifteen of 16 amphibian prey recorded were caught between mid–night and 0600 h.

5.4 DISCUSSION

The results show small mammals are the most common prey items of house cats in Canberra, particularly during autumn and winter, comprising some 65% of prey taken over one year. Small ground–dwelling mammals have comprised similar proportions of total prey taken by house cats in the northern hemisphere. Churcher and Lawton (1987) found mammals, predominantly voles, shrews and mice, accounted for 65% of prey taken by house cats in an English village over one year. The percentage occurrence by volume of mammals in the stomachs of 80 feral cats in Victoria was 88% compared with 3.5% for birds and 1.2% for lizards and frogs (Coman and Brunner 1972). In Tasmania, Trueman (1990) found mammals comprised 45% of prey caught by house cats, compared with 44% for birds. The relatively low proportion of mammal prey items in Trueman's study, compared with the findings of Churcher and Lawton (1987) and the present study, may be due to differences in the proportion of cats from each study living in inner suburban areas, or close to bushland habitat, as opposed to rural/grassland habitats. The effect of spatial environmental attributes on the composition of prey caught by house cats is further discussed below.

The large number of prey items recorded in the first month of the present study may be attributed to an unusually high abundance of house mice *Mus domesticus* (a common prey item) in suburban Canberra during autumn 1993. Accurate data on the relative abundance of wildlife in suburban Canberra by taxonomic class is not available. However, the density of birds per hectare in north Canberra suburbs was estimated from the results of a two year study of factors influencing bird density and species richness in suburban Canberra (Munyenyembe 1985) to be approximately 58. The density of introduced rodents in suburban areas subsequently required to give a neutral preference result given the relative proportion of rodent to bird classes in the prey sample in this study is approximately 136 rodents per hectare. Although densities of rodents in suburban environments in Australia have not been accurately measured, as an annual average this estimate appears very high, indicating house cats may be showing a preference for small mammal prey.

The results support the view of Leyhausen (1979), Churcher and Lawton (1987), Fitzgerald (1988) and Bradshaw (1992) that cats are primarily predators of small mammals and that this preference does not differ from one part of the world to another, though the most common types of mammal species taken may vary. Turner and Meister (1988) and Bradshaw (1992) suggest the preferred sit–and–wait hunting strategy of cats indicates a specialisation in hunting behaviour for capturing small burrowing rodents. The behavioural characteristic to wait just prior to pouncing often results in birds flying away without ever having noticed the cat. As a consequence, many cats soon give up hunting birds altogether (Turner and Meister 1988).

In summarising the work of others, Turner and Meister (1988) suggest kittens which have experience of particular prey species are more adept at handling and killing these species as adults, and do not easily generalise the skill to other species. Kittens whose mothers only carry in mice, rarely become rat killers (Leyhausen cited in Turner and Meister 1988). These cats however, may simply be fearful of the larger prey (Caro cited in Turner and Meister 1988). In the present study, the proportion of juveniles to adults among black rats recorded in the prey sample (42.9%) was almost double the proportion of juvenile to adult house mice (23.7%). Only one of 10 rabbits reported was described as adult.

Fourteen native mammals were reported comprising approximately one percent of the total prey sample. Trueman (1990) reported 6.7% of the mammal prey items recorded over one winter by the owners of house cats in Tasmania were native species. Both results likely reflect the relative availability of native mammal prey in each study area. Few mammal surveys have been conducted in Canberra Nature Park reserves. However, small native ground–dwelling and arboreal mammals (with the exception of brushtail possums) in the Canberra region are thought to be quite low in abundance and diversity and patchily distributed, relative to introduced species (black rats and house mice) which are widespread and common (National Capital Development Commission 1984, Kukolic 1990). Coman and Brunner (1972) found native mammals comprised 44% of the diet of feral cats in forest habitat in Victoria, but in agricultural habitats no native mammals were recorded as prey items.

The amount of bird prey recorded in the present study was less than half the amount of mammal prey. This result supports the findings of a review of the importance of major prey groups in the diet of feral cats, that birds are a less common prey type than mammals (Fitzgerald 1988). Native birds were more common prey items (58% of bird prey) than introduced birds, in contrast to mammals where introduced species dominated the prey sample. Trueman (1990) also found native species comprised the majority of the total sample of bird prey of house cats in Tasmania (63% of bird prey).

Nine introduced bird species occur in the ACT (Taylor and Canberra Ornithologists Group 1992). Six of these (common starlings, house sparrows, blackbirds, common mynas *Acridotheres tristis*, feral pigeons *Columba liva* and European goldfinches *Carduelis carduelis)* comprised approximately 38% of total bird numbers in suburban areas in 1984 (Munyenyembe 1985). Of the total bird prey of domestic cats in this study, introduced bird species accounted for 42%. Given increases in the relative abundance of blackbirds and common mynas in suburban Canberra in recent years (Taylor and Canberra Ornithologists Group 1992) the proportion of introduced to native birds in Canberra today may well be approaching 42%.

Based on bird abundance data from the Canberra Ornithologists Group Garden Bird Survey data for 1993/1994, house sparrows and blackbirds appear to be preferred prey of house cats in Canberra. House sparrows were the most common bird prey caught by house cats in the English village of Felmersham, though the abundance of this species relative to other bird species in the village was not reported (Churcher and Lawton 1987). Churcher and Lawton (1987) stated that the garrulity and quarrelsomeness of house sparrows made them easy to survey in the relative calm of early morning. It may be these attributes and the tendency of these birds to feed on human food scraps on or close to the ground which make them particularly easy prey for house cats. Taylor and the Canberra Ornithologists Group (1992) state that blackbirds require well watered lawns on which to feed and take cover, and nest in dense shrubs. This behaviour is likely to make them highly susceptible to predation by house cats. Taylor and the Canberra Ornithologists Group (1992) also suggest blackbird broods suffer high rates of predation, generally by pied currawongs. Fifty–eight percent (n=19) of blackbird prey able to be identified as adult or juvenile, were juveniles, compared with 40% for starlings and 18% for house sparrows.

In contrast to house sparrows and blackbirds, starlings were the only commonly caught bird species taken in amounts significantly lower than expected on the basis of their abundance in suburban garden environments in Canberra. Starlings nest in tree hollows, generally high in tall canopy trees (Simpson and Day 1984), and in gaps under eaves and roofs. They roost in large trees, or trees with dense cover such as pine trees, or in reedbeds surrounding water (Taylor and Canberra Ornithologists Group 1992). Although starlings tend to feed on open ground, such as lawns, they usually congregate in flocks and it is possible that sentinel birds warn the flock of impending danger. Starlings were not a common prey type of house cats in Felmersham (Churcher and Lawton 1987).

Native birds commonly caught by house cats were taken in approximately the same proportions as their relative abundance in the suburban environment. However, the statistic used to ascertain preference or avoidance of resources (in this case prey) is a normal approximation for a variable which follows a binomial distribution. Therefore, if the proportional availability of a resource (prey species) is close to zero or one, the number of observations of utilisation of that resource should be larger to maintain a good approximation. On the basis of a rule of thumb calculation given by Neu *et al.* (1974) to estimate sample sizes necessary to maintain the power of the test, results relating to species comprising less than 5% of the bird prey sample in Table 5.2 have an increased likelihood of Type II errors.

Superb fairy–wrens, golden whistlers, and honeyeaters, therefore, may also be preferred prey items of house cats in Canberra, in spite of non–significant (neutral) preference results. The ground and low shrub feeding habits, low vegetation nesting habits and relatively conspicuous movements of superb fairy–wrens are likely to make them particularly susceptible to predation by house cats. Factors increasing the vulnerability of whistlers and honeyeaters to predation by cats are less obvious. It may be that these birds are more prone to collisions with windows than other species, thereby increasing their susceptibility to predation.

It is encouraging then, that populations of superb fairy–wrens and golden whistlers appear to be increasing in suburban Canberra. The declining trend in abundance of yellow–faced honeyeaters from 1988 onwards (Table 5.3) is of concern, but is more likely related to lower rainfall summers and autumns in the Canberra region in 1988, 1991, 1993 and 1994, than to predation by house cats. Yellow–faced honeyeaters breed in summer in the ranges to the south and west of the ACT and migrate in autumn in a north–easterly direction to the coast (Wilson 1963). Small numbers are restricted to the suburbs of Canberra where they over–winter in company with other honeyeater species. In contrast to suburban residents, food resources in the ranges and on route to the coast would likely be relatively scarce during drought years for these migratory birds.

It is possible that predation of relatively small bird species, such as thornbills, is under–represented in the data as the remains of a consumed kill are generally less substantial than for larger species such as rosellas, and therefore less likely to be noticed by the cat owner.

Reptiles comprised seven percent of total prey items. This proportion is similar to that found in other studies, predominantly of feral cats, at similar latitudes (Fitzgerald 1988). All species recorded are described as widespread and common in the ACT with the exception of jacky lizards which are limited in distribution but common (National Capital Development Commission 1984). Seven species were identified but the true number of species caught may have been greater as 82% of prey items were identified only as 'lizard' or 'skink'. Though not recorded in this study, the legless lizard species *Delma inornata* has previously been reported as a prey item of house cats in the ACT (Osborne and Williams 1991).

Amphibians were rarely reported and are considered much less important prey than mammal birds or reptiles in the diet of feral cats (Fitzgerald 1988) and house cats (Churcher and Lawton 1987). Only two amphibian species, both locally common and widespread, were recorded (National Capital Development Commission 1984). However, as for reptiles, the majority of prey items (73%) could not be identified at the species level and therefore the number of species in the Canberra region vulnerable to predation may be considerably higher.

Total predation varied seasonally, though the decrease in hunting activity over winter was not as severe as that observed for house cats in colder climates in the northern hemisphere (Churcher and Lawton 1987). Introduced rodents were taken in large numbers during autumn and winter. In a survey of fauna in CNP reserve units in 1975–76, Kukolic (1990) found Elliot trap captures of *Mus domesticus* were highest in winter. Annual population cycles are typical of seasonally breeding Murid species in eastern, south–eastern and south–western Australia (Watts and Kemper 1989), though *Mus domesticus* and *Rattus rattus* are capable of breeding all year round. Densities are generally lowest in early spring and peak in autumn (Watts and Kemper 1989).

A shift in predation from rodents to birds and reptiles was observed in late spring and summer, possibly in response to falls in the abundance of house mice and because of higher levels of activity among reptiles in the warmer months, increasing their susceptibility to predation. In rural Sweden, seasonal changes in the abundance of preferred prey of feral and farm cats has been shown to influence the level of predation on other prey (Liberg 1984a).

An increasing trend in the proportion of introduced to native birds in the prey sample was observed through late spring and into early summer when numbers of house sparrows (the most common bird species in the prey sample) and blackbirds are peaking in suburban Canberra (Taylor and Canberra Ornithologists Group 1992). Numbers of silvereyes, the most commonly recorded native bird prey species, also peak in spring but then fall away again in summer before building to another peak in autumn (Taylor and Canberra Ornithologists Group 1992).

Reasons for significant differences from a sex ratio of 1:1 for both bird and introduced rodent prey in winter are not immediately apparent. The sample size associated with the result for birds was small. The ratio of male to female prey recorded over the entire year for both prey classes was not significantly different from 1:1. George (1974) found the sex ratio of voles (*Microtus ochrogaster* and *Microtus pinetorum*) captured over three years by three house cats living in his home in southern Illinios was approximately equal.

Predation on juvenile birds, relative to adults, was twice as high in spring and summer as in autumn and winter. This result again appears to be a function of prey availability – in this case of juvenile to adult prey types. Frith (1976:36) states that breeding among bird species in the ACT is a spring and early summer phenomenon, with the month of greatest activity being November when 186 species of birds are nesting.

Predation on juvenile rodents, relative to adults, was fairly constant in all seasons except winter when relatively few juveniles were taken. As house mice reach maturity in as little as four weeks (Hyett and Shaw 1980), this result may reflect low relative abundances of juvenile to adult rodents in mid to late winter following a breeding peak in autumn. Christian (1975) found that domestic cats in the mid–west USA preyed on voles (*Microtus pennsylvanicus*) of different sex and age from a marked population in the same proportion as they appeared in a trapped sample, indicating either that predation by cats was non–selective or that its bias was the same as the trapping bias (Pearson 1985).

The location of house cats with respect to outer suburban edges and the type of habitat immediately adjoining suburban areas had a significant effect on the composition of prey taken. The proportion of rodent to bird and reptile prey items was significantly higher close to suburb edges adjoining rural/grassland environments, than in interior suburban areas or areas close to woodland/open–forest habitats. McMurray and Sperry (1941) found a four–fold increase in the proportion of birds caught by cats in residential and roadside areas compared with rural locations. Howes (pers. comm in Churcher and Lawton 1987) also found the proportion of birds caught by house cats increased as habitat became more urban. A similar phenomenon has been described for Tawny owls *Strix aluco* which take more birds and fewer mammals in built–up areas (Bevan 1965 cited in Churcher and Lawton 1987). Churcher and Lawton (1987) ascribed these spatial changes in the composition of house cat catches to prey availability, with suburban areas supporting more birds relative to mammal populations than rural areas.

The proportion of prey items comprised by birds and reptiles increased significantly toward the edge of suburbs adjoining woodland/open–forest habitats, reflecting changes in total bird abundance toward source habitats in north Canberra suburbs (Munyenyembe 1985). In addition, the proportion of native to introduced bird prey items increased toward woodland/open–forest habitat. This trend also appears to reflect prey species availability as 83% of native bird species recorded in suburban areas by Munyenyembe (1985) were classified as woodland or open forest species.

The proportion of reptile prey items in the total prey sample declined sharply with distance from suburb edges. Available habitat and species mobility probably restrict the distance to which reptile species will invade suburban areas from surrounding habitat, and this appears to be reflected in observed changes in the proportion of prey comprised by reptiles.

Diel variation in both numbers and composition of prey items is evident. The majority of mammals (almost all of which were introduced) were killed between 1800 h and midnight, while birds were generally taken in the morning and reptiles in the afternoon. Differences in the timing of predation on different prey types are almost certainly due to differences in the activity levels, and therefore the availability, of each prey type, as has been noted previously (Bradshaw 1992). Night–time curfewing practices are likely to reduce predation on mammals, both native and introduced, but will probably not greatly reduce predation on reptiles or birds. The nature and extent of house cat curfewing practices in Canberra, and the relationship between the amount of time cats spend outside at night and predation on different prey types are examined in Chapter 6.

In summary, the results of this chapter support evidence from other studies that small mammals may be preferred prey of house cats. In general though, predation reflected spatial and temporal trends in prey availability across a wide range of vertebrate prey. The fact that 47 bird species were recorded as prey items, and that nearly 3% of cats caught greater than 10 vertebrate species over the 12 month survey period, illustrates the exceptional predatory ability retained by some house cats, and the opportunistic nature of hunting behaviour of house cats in general. This is further illustrated by the observed temporal variation (seasonal and diel) in predation on different prey species, and on prey age and gender classes, in response to changes in the abundance of different types of prey, and prey activity patterns.

6 FACTORS AFFECTING THE AMOUNT OF PREY CAUGHT

6.1 INTRODUCTION

It has been shown in numerous studies (e.g., George 1974, Adamec 1976, Churcher and Lawton 1987, Turner and Meister 1988, Trueman 1990, Paton 1991, Bradshaw 1992, REARK Research 1994), and is obvious to cat owners, that many house cats continue to hunt in spite of ample provision of domestic food. Based on figures from the present study and work by several others (Churcher and Lawton 1987, Trueman 1990, Paton 1991, REARK Research 1994) the average Australian house cat may be expected to catch between around 10 and 70 prey items per year, ranging in size from juvenile house mice and small skinks to brushtail possums. Feral cats without access to domestic food or human food scraps, however, would need to catch around 1000 prey items of a similar size and species composition per year to remain alive, given a daily food intake maintenance requirement of around 200 g (Fitzgerald 1980). Liberg (1984b) reported that feral cats in rural Sweden spent nearly twice the amount of time hunting each day than did house–based cats.

Aspects of the domestic lifestyle of house cats, such as the amount of time spent indoors, isolated upbringing of kittens (with respect to observing and practising predatory behaviour), the number of relatively old animals in house cat populations, neutering, and the provision of food, are likely in combination to be responsible for the relatively small amount of prey caught on average. Though it has been demonstrated that cats provided with ample domestic food will engage in hunting behaviour whether hungry or not (Adamec 1976, Turner and Meister 1988), the tendency to kill increases with hunger, as does the willingness to attempt to catch larger, more difficult prey (Biben 1979). Hunger affects the initial stages of the hunt, and the probability of a kill, but visual and auditory stimuli arising from the prey itself can override any considerations of appetite and initiate the predatory approach (Bradshaw 1992). Thus, the removal of hunger through the provision of domestic food, and the reduction in visual and auditory stimuli from prey as a result of significant periods of time spent indoors, may substantially reduce the initiation of predatory behaviour in domestic cats.

There remains however, considerable variation in the amount of prey caught by individual house cats within this reduced predation regime. Churcher and Lawton (1987) examined the effect of cat age and gender, and a number of environmental factors, on predation by house cats in an English village and found a significant amount of variation in the amount of prey caught by individual cats could be attributed to cat age, with old cats catching less prey than young adult cats. There was also some evidence that the amount of prey caught per cat decreased with increasing densities of house cats per hectare. In Tasmania, Trueman (1990) found kittens and old cats caught significantly less prey than young mature cats, and night–time curfews appeared to lower predation on introduced animals but had little effect on predation on native animals. The majority of native prey were birds while the majority of introduced prey were rodents.

Several studies comparing the diet of city and country cats in Europe and North America have shown the range of prey taken by cats on the outskirts of cities and in the countryside is generally far greater than that taken by cats living in built up areas (McMurray and Sperry 1941, Eberhard 1954, Jackson 1951, see also Fitzgerald 1988). Female cats living near the centre of the English village in the study by Churcher and Lawton (1987) took fewer prey than did those on its edges, though it was unclear why a similar effect was not evident in males. Trueman (1990) found urban house cats living near bushland in Tasmania caught more native birds than house cats living in country areas and house cats in urban areas away from bushland.

The main aims of this chapter were to i) examine the amount of variation in predation efficiency between cats and ii) ascertain how much of this variation may be attributed to physical cat attributes, cat management strategies, and suburban environmental characteristics.

6.2 MATERIALS AND METHODS

All cat owners recruited to the study (see Chapter 2 for recruitment methods) were asked to provide information on aspects of the physical attributes, acquirement, upbringing and daily management of their cat(s) by filling out a simple questionnaire for each cat they owned when they commenced data collection (see APPENDIX II). The data collected included:

- The cat owner's address
- The cat's breed or coat colour
- The cat's age
- The cat's weight
- The cat's gender
- The cat's age when desexed
- How the cat was acquired
- The amount (number of meals per day) of food provided,
- The number of bells worn
- Whether the cat was confined inside, and if so, between which hours
- The number of nights the cat spent outside on average per fortnight
- The number of cats in total living on the participants property and neighbouring properties (all sides and corners)

Cat age therefore represented the age of each cat at the commencement of the prey data collection period. Environmental attributes such as the distance from each cat owners home to the nearest non–suburban habitat, and the type of closest non–suburban habitat, were determined with respect to the residential address provided on the questionnaire. Suburb ages were derived from Department of Environment Land and Planning records and from Munyenyembe (1985).

The importance of reported cat attributes, environmental attributes and cat lifestyle and management practices in determining the number of prey items and prey species caught by domestic cats was analysed using factorial analyses of variance, and stepwise multiple regression analyses. Predation data (amount of prey caught per cat per year) were log–transformed prior to all analyses to improve the data distribution from being positively skewed to a more normal distribution.

6.3 RESULTS

6.3.1 Cat Questionnaire Responses

More than 98% (210 of 214) of cats in the study were desexed. Only three cats involved in the study over the entire prey data collection period were not desexed, making comparisons of predation by entire and neutered cats unreliable. However, 14% (n=20) of cats were neutered as adults (older than nine months). The age at which cats were neutered (< or > nine months) was examined as a factor possibly affecting predatory efficiency in subsequent analyses. The ratio of male to female cats involved in the study for entire prey data collection period was 0.89 (n=138).

Twenty–three percent of cats were described by their owners as belonging to recognised breeds or as one cross animals (e.g., Persian cross), the rest of the sample being of indeterminate breeding.

Approximately four percent of cats were fed once daily, 60% twice daily, eight percent three times daily and 28% were fed more than three times each day (i.e., on demand). Approximately 26% of cats wore one bell, nine percent wore two bells and 65% were not belled.

Study participants were initially asked if their cats were restrained inside at anytime of the day or night and if so, between which hours. Thirty–nine percent of cats were kept inside overnight. Of these, 46 % were not confined until 10 pm or later and 67 % were released outside by 7 am or earlier. Forty percent of curfewed cats were not confined until 10 pm or later and released again by 7 am or earlier.

Because confinement practices may have varied from night to night, study participants were additionally asked how many nights in a fortnight their cat spent outside. Thirty–six percent of cats which were said to be restrained overnight spent at least half of all nights outside. Conversely, 33% of cats not confined inside overnight spent less than a quarter of all nights outside.

The mean estimated age of cats in the study was 5.4 years (65 months), and mean estimated weight was 4.5 kg.

6.3.2 Effect of Cat Physical Attributes and Cat Management on the Amount of Prey Caught.

The number of prey items recorded per cat ranged from 0 to 72. The mean (± 2SE) and maximum number of prey items recorded per cat by taxonomic class and native or introduced status during the 12 month prey data collection period are shown in Table 6.1.

There was no difference in total predation (total amount of prey caught per cat per year) between male and female cats ($F=0.12$ $DF=1,7$ $P=0.727$), or between purebred (described by their owners as belonging to recognised breeds or as one cross animals) and other cats ($F=1.20$ $DF=1,7$ $P=0.275$). Whether cats were neutered as kittens or adults (< or > nine months) also had no apparent effect on total predation ($F=0.30$ $DF=1,7$ $P=0.587$). Interaction terms for these variables were non significant ($F=0.60$–2.53 $DF=1,7$ $P=0.441$–0.114).

Table 6.1 Mean and maximum number of prey items recorded per cat (n=138) over the 12 month prey data collection period from May 1993 to May 1994.

	Mean ± 2SE	Maximum
Native Birds	1.24 ± 0.39	14 – 16 †
Introduced Birds	1.09 ± 0.39	13 – 15 †
Total Birds	**2.63 ± 0.70**	**27**
Native Mammals	0.04 ± 0.04	3 *
Introduced Mammals	6.78 ± 2.22	66
Total Mammals	**6.87 ± 2.26**	**66**
Reptiles	**0.60 ± 0.30**	**12 ***
Amphibians	**0.12 ± 0.13**	**7**
Total Prey	**10.22 ± 2.66**	**72**

† 2 unknowns * Taken over 9 months

Neither the number of feeding times per day nor the number of bells worn had any effect on the total amount of prey caught per cat per year (F=2.14 DF=3,9 P=0.098: F=0.90 DF=2,9 P=0.408), or the amount of birds caught per cat per year (F=1.38 DF=3,9 P=0.252; F=2.11 DF=2,9 P=0.125). The interaction term for these two variables was non significant (F=1.46–1.80 DF=4,9 P=2.19–0.132).

The amount of variation in the total amount of prey caught between cats which could be attributed to the variables Cat Age (months), Cat Size (kg) and Nights Outside (number of nights per fortnight spent outside) was analysed using stepwise multiple regression. A negative relationship between total predation and Cat Age (F=8.186 DF=134 P=0.05) and a positive relationship between total predation and Nights Outside (F=8.016 DF=134 P=0.005) was observed. However these terms described only 5.4 % and 5.8 % of variation in total predation respectively. Even less of the observed variation in predation on birds was explained by these two variables. The number of mammals caught per cat per year was positively related to Nights Outside, but the term described only 8.4 % (F=11.777 DF=134 P<0.001) of the observed variation.

6.3.3 Environmental Factors Affecting Predation by House Cats

Predation on native and introduced animals, and variation in the number of species caught by cats, were examined with respect to prey habitat availability and predator density using stepwise multiple regression analyses of the following variables;

- Suburb Age (approximate age of the suburb in which cats were living)
- Distance From Suburb Edge (the distance from the cat owners home to the nearest suburban – rural/reserve interface)
- Adjoining Habitat Type (the type of habitat – rural/grassland or woodland/forest – adjoining the suburb edge nearest the cat owners home) and,

- Cat Density (the number of cats owned in total by the study participant and neighbours on all sides and corners.

A significant interaction term for the variables Distance From Suburb Edge and Adjoining Habitat Type was found in the analysis of predation on introduced animals ($F=27.478$ $DF=134$ $P<0.001$). Subsequent analyses of Distance From Suburb Edge effects were carried out by adjoining habitat type.

Approximately 34 % of variation in predation on introduced animals in suburbs adjoining rural/grassland habitat was explained by the variable Distance From Suburb Edge (Figure 6.1). A further 9 % was attributable to Cat Density. Suburb Age was not included in the model by the stepwise selection procedure ($P>0.05$).

Log (introduced prey +1) = 2.187 – 0.193 (Log Distance From Suburb Edge) – 0.081 (Cat Density)

$$R^2 = 0.427 \qquad P<0.001$$

The amount of introduced animals caught by cats living in suburbs adjoining woodland/open–forest habitat was not significantly related to Distance From Suburb Edge, Cat Density or Suburb Age (stepwise procedure, $P>0.05$).

A small amount of variation in predation on native animals ($R^2=0.071$ $P=0.002$) was attributable to Distance From Suburb Edge (Figure 6.2). No other variable, including the interaction effect between Adjoining Habitat Type and Distance From Suburb Edge significantly improved the fit of the model (stepwise procedure, $P>0.05$).

Variation in the number of species caught by cats was not significantly related to any of the variables tested (stepwise procedure, $P>0.05$).

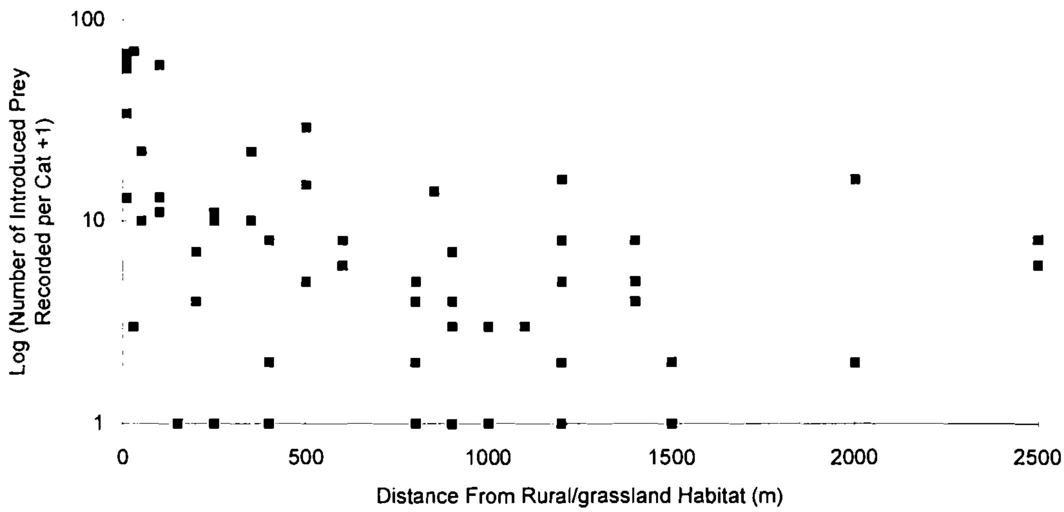


Figure 6.1 Relationship between the number of introduced prey items recorded per cat and distance from rural/grassland habitat adjoining suburban areas.

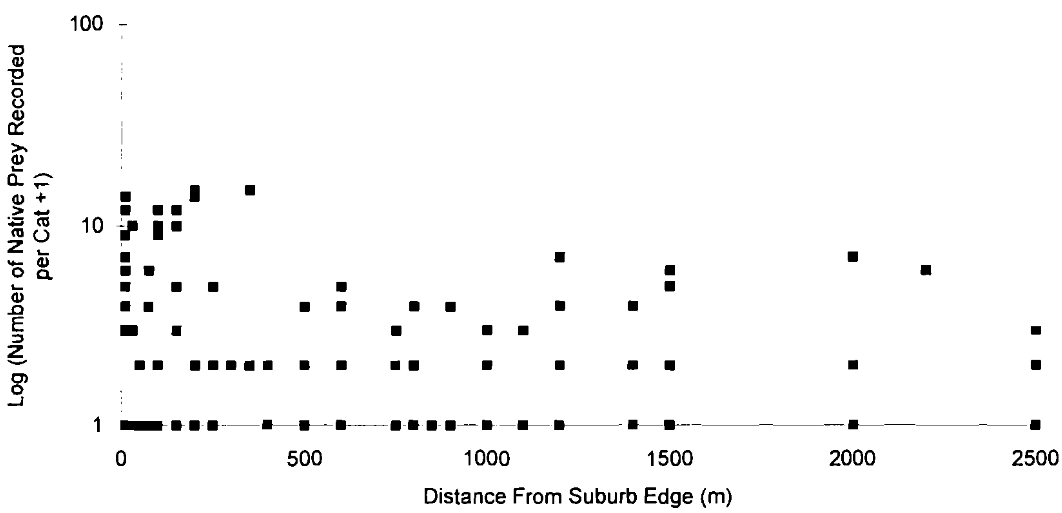


Figure 6.2 Relationship between the number of native prey items recorded per cat and distance from non–suburban habitat.

6.3.4 Surplus Killing

As already mentioned, total predation was not significantly affected by the number of feeding times per day. This result suggests predation was not primarily driven by hunger. However, as shown in Table 6.2, approximately 42% of mammal prey items recorded by cat owners and 48% of bird prey items were substantially eaten (more than 50% of a prey item consumed).

The true proportion of substantially eaten prey may in fact have been considerably higher as the majority of catches not observed by cat owners are likely to have been largely or totally consumed. This bias is probably greatest for relatively small prey types such as many reptile and amphibian species which may often be eaten without trace. The effect is possibly reflected in the lower proportions of mostly or completely eaten reptile and amphibian prey items shown in Table 6.2. Irrespective, the results indicate that a considerable amount of predation by domestic cats is more than merely surplus killing, defined by George (1978:284) as "predation resulting in an uneaten catch".

The relationship between the mean proportion of individual prey items consumed and the total number of prey items caught per cat is shown in Figure 6.3. Mean proportion of individual prey items consumed was positively correlated with the observed amount prey caught ($r=0.237$ $P=0.0014$). However, the low correlation coefficient indicates the result is primarily a function of the large sample size ($n=178$) and does not provide strong support for the supposition that nutritional needs or hunger are motivating those cats catching relatively large amounts of prey.

Table 6.2 Proportions of prey items consumed to different degrees by house cats.

Amount of Prey Item Consumed	Prey Class			
	Mammals (%)	Birds (%)	Reptiles (%)	Amphibians (%)
None (<11%)	53.4	43.9	68.7	90.9
Some (11–49%)	4.3	7.9	0.8	0
Most (50–89%)	5.2	7.2	2.3	0
All (>89%)	37.1	41.0	28.2	9.1
	n=1273	n=529	n=131	n=22

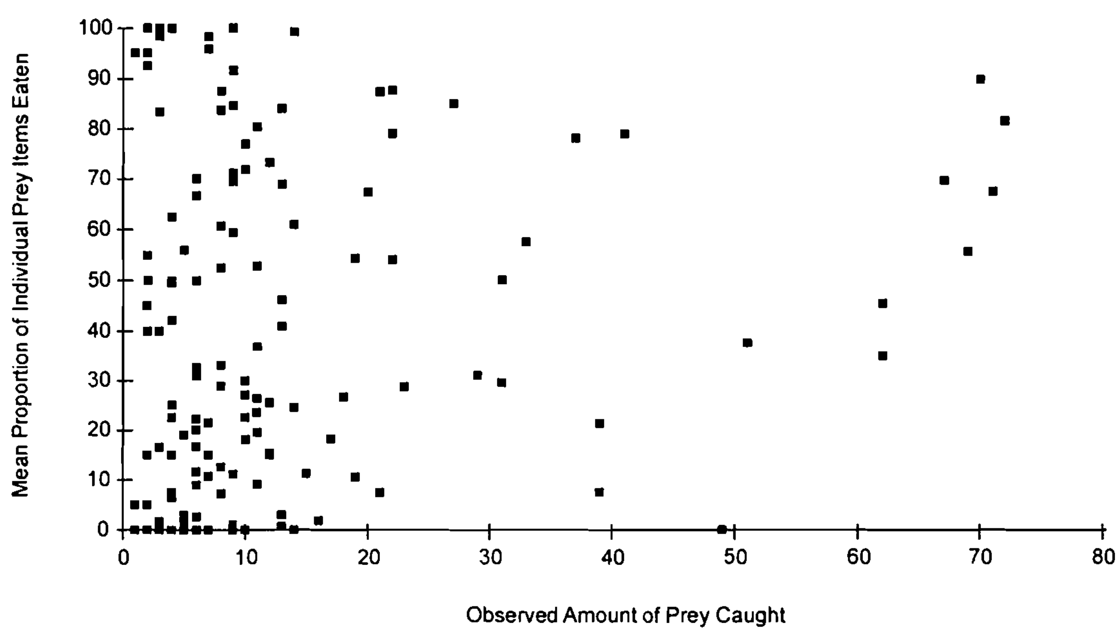


Figure 6.3 Relationship between mean proportion of individual prey items consumed and total number of prey items caught per cat.

6.4 DISCUSSION

Approximately 98% of cat owners surveyed indicated their cats were desexed. An independent study conducted by REARK Research (1994) estimated 96% of Canberra's domestic cat population was desexed. The practice therefore appears to be widely adopted in Canberra. However, reasons for desexing pet cats have not been examined and may vary considerably from household to household. Belling of cats and night–time curfews are much less commonly adopted practices than desexing.

The mean number of prey items which the owners of house cats in Canberra observed their cats to catch over the year of the study was approximately 10. This figure is slightly lower than the average per cat of 14 found for house cats in the English village of Felmersham by Churcher and Lawton (1987), though the difference between the two estimates my not be statistically significant. The range in the number of prey taken by individual cats was large in both studies. Although predatory activity by house cats would be expected to be hampered more by weather conditions in winter in Felmersham than in Canberra, the availability of small mammals, apparently a preferred prey type of house cats, would likely be higher in Felmersham than in Canberra. The estimated average number of prey caught by house cats per year from the present study is, however, seemingly significantly lower than that estimated by Paton (1991) for house cats in and around Adelaide (~32). Some possible explanations for this discrepancy are examined in Chapter 7. Irrespective, all of these estimates are many times lower than would be expected for cats receiving no domestic food supplement (Fitzgerald 1980).

Predatory efficiency did not appear to be significantly influenced by cat gender, age when desexed, cat breed, the number of bells worn, the number of feeding times per day, or the size (weight) of cats. More specific, detailed and rigorous experimental analyses of some of these factors would reduce the chance of type II errors occurring either as a result of non–random distribution of treatments among the sample population, such as the wearing of bells, or loosely defined or inadequately sampled treatment categories, such as desexing or cat breed categories.

Cat age and the number of nights spent outside described a small amount of the observed variation in the amount of prey caught, particularly in relation to introduced mammal prey. Cat age has been related to the amount of prey caught by house cats previously by Churcher and Lawton (1987). The amount of nights a successful hunter is allowed to spend outside is likely to significantly influence the amount of mammalian prey, both native and introduced, caught. Current curfewing practices in Canberra potentially allow many cats that are considered curfewed by their owners to hunt for many hours after dusk prior to be confined inside their owner's home. In addition, 36% of curfewed cats, (comprising only 39% of the total house cat population) spend at least half of all nights outside. Predation on birds and reptiles was not related to the number of nights cats spent outside. Night–time curfews are unlikely to reduce predation on these prey types because of their diurnal activity patterns, as has previously been suggested by Trueman (1990), particularly in light of the early hour at which most curfewed cats are released outside in the morning.

Spatial environmental attributes were shown in the previous chapter to significantly effect the composition of prey types caught by house cats in Canberra. The distance from cat owner's homes to rural/grassland habitat has been shown in this chapter to explain a significant amount of variation in the total amount of introduced rodent prey caught by house cats. In addition, the amount of rodent prey caught is weakly negatively correlated with cat density, a trend also observed by Churcher and Lawton (1987). It is possible that this relationship is due to a greater proportion of prey items being missed by people who own a relatively large number of cats compared to those with just one or two animals. However, the effect of distance to source habitats (such as rural/grassland habitat for rodents and woodland/open–forest habitat for native birds and arboreal mammals) on predation on different prey types probably legitimately reflects changes in prey availability, though the relationship with native animals is weak compared to that with introduced rodents.

In spite of the contribution of variables such as cat age, proportion of nights spent outside, cat density and distance from prey source habitat, much of the variation in predatory efficiency between individual cats remains unexplained. Some of this variation may be attributed to differences in the observational ability and effort of cat owners, and perhaps also to differences in the degree to which individual cats are inclined to present catches to their owners. However, much of the remaining variation is likely explained by the fact that cats exhibit a large degree of behavioural individuality (Mendl and Harcourt 1988). Panaman (1981) recorded clear differences in the time spent hunting, and the hunting efficiency, of five adult female farm cats.

The most important influences determining behavioural differences or personalities among cats are still not clear. In summarising the work of others, Mendl and Harcourt (1988) state that by six months of age, considerable variation in predatory ability in kittens of two and three months has vanished, though some forms of predatory skill still vary. A variety of factors, particularly adult experience, are suggested to be responsible for the catch–up effect of previously inept kittens in terms of predatory ability. Bradshaw (1992) states that the available evidence points towards experiences involving real prey, rather than play involving motor patterns in kittens, as being the most important determinant of hunting skills in the adult life. A single experience of killing and eating a particular type of prey can have a profound effect on both prey preferences and hunting skills (Bradshaw 1992). The effect of such learning experiences on predatory efficiency has not been examined in this study and may require further investigation.

Many prey items caught by house cats in the present study were partially or completely consumed in spite of the cats being well fed. Domestic house cats have been observed to hunt immediately after a full meal of domestic food containing meat (Turner and

Meister 1988). Turner and Meister (1988) suggest this behaviour may be related to the fact that domestic cats have evolved hunting small rodents on an opportunistic basis, i.e., hunting frequently for relatively small meals. However, the motivation for well fed house cats to completely or partially consume many of their prey items is unclear. This behaviour may be related to mineral or nutritional requirements, or the phenomenon may be an inherited ancestral behavioural trait to eat some proportion of kills before presenting prey to perceived dependents.

In summary, a domesticated lifestyle, including the satisfaction of daily dietary requirements, significantly reduces predatory activity in most house cats. However, some cats continue to take large numbers of prey. The total amount of prey taken does not appear to be significantly influenced by cat gender, age when desexed or breed. Nor does belling or the number of meals provided per day appear to have a significant influence on predatory efficiency. Cat age and the proportion of nights spent outside explain a small amount of the variation in the amount of prey caught by individual cats. The proportion of nights spent outside is of greatest importance with respect to predation on mammals. Strictly enforced curfews of cats after dark are unlikely to significantly reduce predation on reptiles or many species of birds because of the diurnal activity patterns of these prey types. Current curfewing practices in Canberra are unlikely to be greatly reducing predation on any potential prey type because of the hours between which most cats are confined and the number of nights that normally confined cats manage to remain outside. Environmental attributes such as distance to prey source areas and cat density also explain some variation in predation on particular prey types. However, much observed variation in predatory ability may simply reflect individuality among cats. Isolating kittens from experiences involving capture or handling of live prey, or observation of other cats catching prey, may inhibit their predatory efficiency. Unfortunately however, house cats can learn to hunt successfully from adult experiences alone.

7 EXTRAPOLATING PREDATION ESTIMATES

7.1 INTRODUCTION

The number of prey taken annually by house cats in and around Adelaide and Hobart has been estimated based on either short term monitoring of prey items, or cat owners' estimates of annual predation by their pets (Trueman 1990, Paton 1991). Some of these data have been extrapolated to give crude estimates of the number of animals killed per hectare per year by house cats over the entire continent (Paton 1991, Anderson 1994, Rolls 1994). Predicting wildlife damage due to cat predation on a national level has previously been attempted in the United Kingdom. By extrapolating from a study of the predatory habits of house cats by Churcher and Lawton (1987) in the English village of Felmersham, May (1988) estimated that about 100 million birds and small mammals are killed by house cats in Britain each year, and suggested that this predation posed a serious threat to native wildlife populations.

The validity of May's calculations and conclusions however, have been questioned on two counts (Fitzgerald 1990, Jarvis 1990). Firstly, the predatory activity of companion cats has been shown to vary significantly between urban, suburban, town and country habitats. Several studies comparing the diet of city and country cats in Europe and North America have shown the range and number of prey taken by cats on the outskirts of cities and in the countryside is generally far greater than that taken by cats living in built–up areas (McMurray and Sperry 1941, Jackson 1951, Eberhard 1954, Churcher and Lawton 1987, see also Fitzgerald 1988). As the majority of cats in Britain live in urban areas, extrapolating from one village to the whole of Britain would result in an overestimation of prey numbers taken (Fitzgerald 1990). The second criticism of May's conclusions was that, without measurements of the density and dynamics of prey species, the impact of cat predation on these populations remains unknown. Jarvis (1990) felt that, despite apparently heavy predation by house cats on native wildlife in Britain, prey populations were probably little affected in the long–term.

The aims of this chapter were to, i) describe the distribution of predation data per cat per year and examine the effect of using different measures of average predation per cat to estimate total predation for a cat population or per unit area, ii) ascertain the precision of total predation estimates calculated using study sample means, and, iii) examine the relationship between predation estimates made by cat owners prior to the commencement of the study and the actual number of catches reported over the 12 months of data collection.

7.2 MATERIALS AND METHODS

An estimate of the total number of prey items taken per year by the domestic cat population in Canberra, and associated estimates of precision, were calculated from the median and mean observed number of prey items caught by 138 cats over 12 months using a technique derived to estimate the precision of aerial survey animal counts extrapolated over a large areas from a sub–sample of survey blocks or transects (Caughley 1979). As well as calculating the standard error for extrapolated total predation estimates, the technique allows the sampling intensity required to reduce the standard error to an acceptable percentage of the total predation estimate, e.g., 5 or 10%, to be calculated. The calculations involved are shown below where;

N = domestic cat population of Canberra

n = cat sample size

$\ddot{y}$ = prey sample mean

Y = Number of prey items caught per year in Canberra (observed)

SI = sampling intensity

% = maximum proportion of Y described by SE (Y)

$$Y = N\ddot{y}$$

$$VAR(Y) = N(N-n)/n * S^2y$$

$$SE(Y) = \sqrt{VAR(Y)}$$

$$SI(needed) = SI(used) * VAR(Y)/(Y * \%)^2$$

The estimate of the domestic cat population of Canberra used in the calculations shown above was taken from a report on aspects of population characteristics and hunting behaviour of metropolitan domestic cats in Australia (REARK Research 1994). The report included comprehensive surveys conducted in April 1994 of the population demographics of domestic cats in each of Australia's capital cities (see REARK Research 1994 for details).

Predation intensity on different prey classes was also examined on a per hectare basis in outer suburban areas. The average number of cats per hectare in these areas was estimated from initial letter box drop and doorknocking campaigns carried out in a number of suburbs to recruit cat owners to participate in the study (See Appendix VI). Data collected during these early surveys enabled the average number of cats per house to be calculated. Surveyed areas were divided into hectare squares and the average number of houses per hectare calculated. The number of cats per hectare was then calculated by multiplying the average number of cats per house by the number of houses per hectare.

The relationship between the amount of prey cat owners estimated their cats caught per week month or year, and the amount of prey they observed their cats to catch over the 12 month prey data collection period was examined by regressing estimated predation per year against the observed amount of prey caught.

7.3 RESULTS

7.3.1 Predation Rates per Cat and Total Predation per Annum in Canberra

The median amount of prey recorded per cat was nearly half the mean value owing to the highly positively skewed nature of the data. Most cats (70.3%) were observed to catch less than ten prey items over the year, though for 5.8% of cats, more than 50 prey items were recorded (see Figure 7.1). Frequency histograms of data in each prey category were similarly positively skewed.

Estimated median and mean annual predation by house cats in Canberra using the median and mean number of prey items recorded per cat are shown in Table 7.1. The 95% confidence interval around the mean total prey estimate is ± 25.2% of the estimate.

7.3.2 Predation per Hectare in Outer Suburban Areas

Cat population demographics in outer north Canberra suburbs were surveyed during the study participant recruitment phase by door–knocking and letter box information and questionnaire drops. The average number of houses per hectare in these areas was eight, and the proportion of houses with one or more cats was 0.301. The number of cats per house was 0.478, and the number of house cats per hectare was therefore 3.82. The observed number of prey taken annually by house cats in outer suburban areas (< 200 m from suburb edge) per cat and per hectare is shown in Table 7.2.

7.3.3 Estimated versus Observed Predation

Annual predation per cat estimated by cat owners prior to commencing data collection was more than double the mean observed amount of prey caught per cat over the 12 month data collection period (T=4.3618 DF=271 P=0.0001). Figure 7.1 shows a frequency histogram of recorded numbers of vertebrate prey caught by 138 domestic

Table 7.1 Total annual predation by house cats in Canberra estimated using the study sample median and mean number of prey items recorded per cat.

	Median	Mean ± 95% CI
Native Birds	0	61380 ± 18384
Introduced Birds	0	53955 ± 18393
Total Birds	**49500**	**130185 ± 32659**
Native Mammals	0	1980 ± 1878
Introduced Mammals	123750	335610 ± 103618
Total Mammals	**123750**	**340065 ± 105040**
Reptiles	**0**	**29700 ± 13780**
Amphibians	**0**	**5940 ± 5870**
Total Prey	**297000**	**505890 ± 124053**

Table 7.2 Observed numbers of prey taken per cat and per hectare over 12 months by house cats in outer suburban areas of Canberra (<200m from suburb edge).

	Mean Prey per Cat ± 2SE	Mean Prey per Ha. ± 2SE
Native Birds	1.70 ± 0.90	6.49 ± 3.44
Introduced Birds	0.86 ± 0.66	3.29 ± 2.52
Total Birds	**2.98 ± 1.43**	**11.38 ± 5.46**
Native Mammals	0.09 ± 0.11	0.34 ± 0.42
Introduced Mammals	12.70 ± 6.10	48.51 ± 23.30
Total Mammals	**12.93 ± 6.20**	**49.39 ± 23.68**
Reptiles	**1.37 ± 0.78**	**5.23 ± 2.98**
Amphibians	**0.16 ± 0.20**	**0.61 ± 0.76**
Total Prey	**17.44 ± 6.53**	**66.62 ± 24.94**

cats involved for the full year of data collection superimposed on the frequency histogram of estimated numbers of vertebrate prey caught per annum estimated by the owners of all cats registered in the study. Both data distributions are highly positively skewed and the sample medians are approximately half the sample means. The relatively high frequency of records in the 51–60 class interval of the histogram of estimated predation is a grouping effect, owing to the large number of people who estimated that their cats catch approximately one prey item per week.

The relationship between estimated and observed amount of prey caught is shown in Figure 7.2. The expected model for the data, where predicted estimates exactly match observed estimates, is shown by the dashed line. The fitted regression model was significant (R^2=0.451 DF=133 P<0.0001) and shows that estimated rates of predation greater than around ten prey items per year generally over–estimated predation observed during the study.

7.4 DISCUSSION

Estimates of mean annual predation by domestic house cats from this and previous studies are shown in Table 7.3. Comparison of these estimates is made difficult by the fact that statistics of precision are only provided in the present study. Nonetheless, discussion of the likely accuracy of these estimates, and possible causes of the seemingly significant variation is required. It is also worth discussing the use of mean annual predation per cat, as opposed to the median or data range, to describe predatory activity by house cats. Finally, the validity of using the results of relatively localised studies to predict total predation by larger cat populations or by house cats in different environments is discussed.

The total amount of prey taken by house cats estimated using the methods employed in this and other studies (Churcher and Lawton 1987, Trueman 1990) where cat owners have been asked to collect or record prey taken by their pets over some period of time,

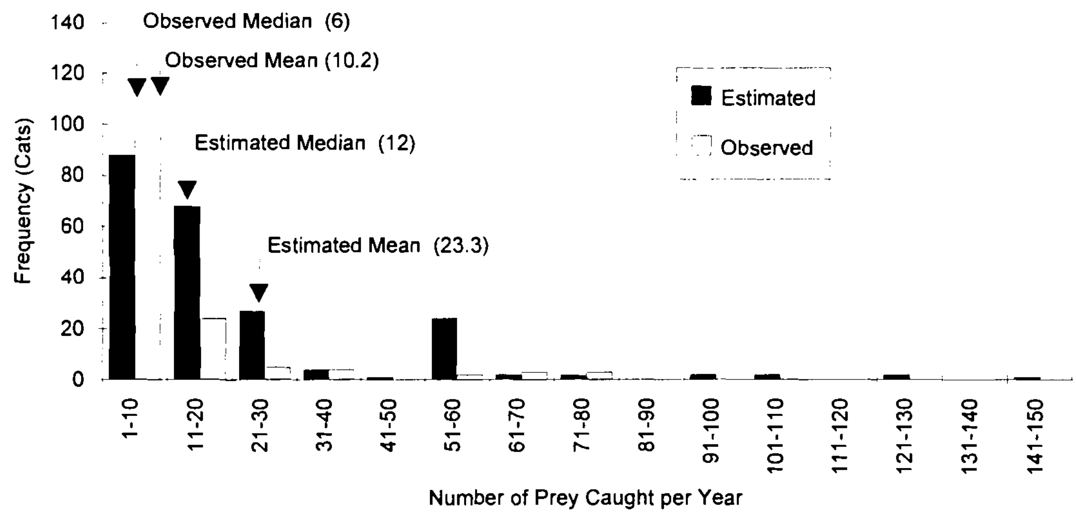


Figure 7.1 Frequency histograms of estimated and observed number of prey items caught by cats over one year.

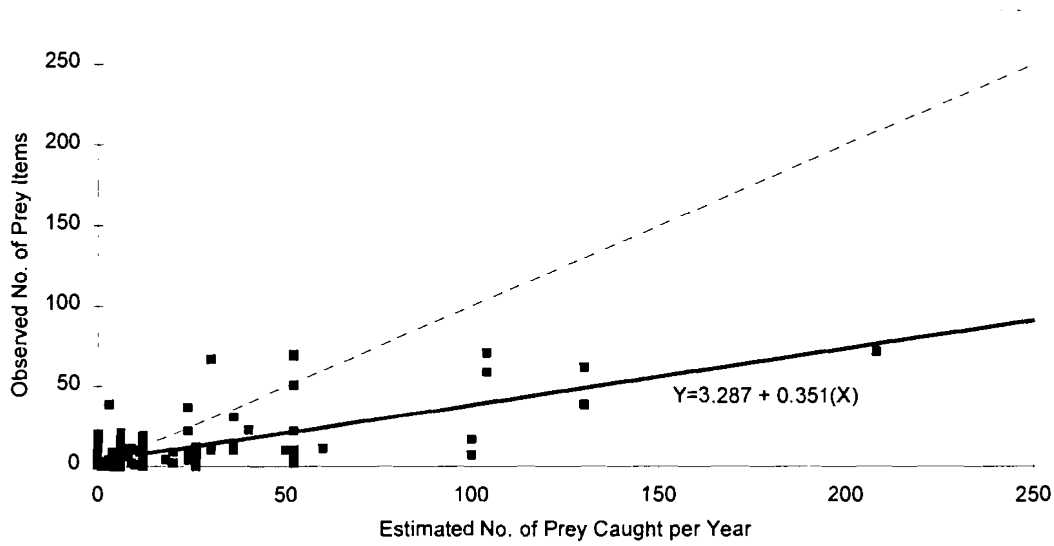


Figure 7.2 Relationship between estimated and observed amount of prey caught by house cats per year. The expected model for the data, where predicted estimates exactly match observed estimates, is shown by the dashed line. The fitted regression model is shown by the bold line.

will underestimate total predation by house cats because some proportion of kills will not be observed by the cat owners. This has been recognised by other workers (George 1974, Churcher and Lawton 1987, Trueman 1990, Paton 1991, REARK Research 1994) and the proportion of prey missed has been suggested to be as much as 50% (George 1974).

In addition, it is possible that with respect to this and other studies (Trueman 1990, Paton 1991, REARK Research 1994), people with cats which were known to catch a lot of prey may have felt intimidated or threatened by the study and therefore declined to volunteer to participate. Every attempt was made in the present study to convince people of the impartial nature of the study and the confidentiality of all information provided (see APPENDIX I).

Trueman (1990), Paton (1991), and REARK Research (1994) estimated the number of prey taken annually by house cats from either short term monitoring of prey items (3 months over winter), or cat owners' estimates of annual predation by their pets. However, the timing of short–term prey item monitoring studies or one–off surveys of the predatory habits of house cats, with respect to different seasons, may influence estimates of the amount of prey caught by cats annually. The results of the previous chapters support the findings of Churcher and Lawton (1987) that there is likely to be significant seasonal variation in the type and amount of prey caught by house cats. Part of the reason annual predation estimated by cat owners was significantly greater than observed predation in this study may have been because people were asked in autumn to estimate the predatory efficiency of their cats at a time when many cats were catching large numbers of house mice. A much different result may have been achieved had the study participants been asked to estimate annual predation by their pets in late winter, when cats were catching relatively few prey items.

In spite of the potential problems with the timing of one–off surveys, it may be argued that estimates from cat owners better reflect true predation than observed predation data.

Table 7.3 Estimated mean annual predation per cat by house cats in this and previous studies.

Area represented in the study	Methodology	n (cats)	Mean prey / cat / year ± 2SE	Reference
English village	Prey collection over 12 months	~ 70	14	Churcher and Lawton (1987)
Suburban / rural Adelaide	Mail survey	700	31.5	Paton (1991)
Urban / Suburban Australia	Phone survey	1550	4.76	REARK Research (1994)
Suburban Canberra	Prey collection over 12 months	138	10.22 ± 2.66	This study

This is because people are likely to adjust the amount they observe their cats to catch upwards to compensate for catches they do not see. Estimated predation data, however, is much less valuable than observed predation data in terms of quantifying prey composition, and for analyses of temporal and spatial trends in the composition of prey caught.

Where data is only collected from cats considered by their owners to be active predators, as was the case in the present study and also that of Trueman (1990), an over–estimate of total predation across the cat population may result. Approximately 25% of cat owners contacted during the participant recruitment phase of the present study said either they had never known their cat to catch vertebrate prey of any kind, or their cat had not been seen hunting (or even been outdoors) for some years, usually due to its age or health (or both). The suggested abstinence from hunting by this proportion of the house cat population has not been factored into the results presented in this study. In addition, the distributions of data describing the frequency of cats catching an estimated or recorded amount of prey per year are positively skewed, as was also found by Churcher and Lawton (1987). As a result, the median number of prey estimated or recorded per year is approximately half the value of the mean, and is a better representation of average predation observed for house cats.

It is apparent that the assumptions and statistical parameters used to extrapolate results from relatively localised studies to wider populations of house cats, will have a substantial effect on estimates of total predation by these populations. For example, given a density of four house cats per hectare, the estimated number of vertebrate prey killed per ha per year using the mean number of prey items recorded by cat owners over one year, and assuming 100% of cats successfully hunt, is 40.8. However, using the sample median and assuming only 75% of cats are actively killing, this estimate drops to 18 vertebrate prey per ha per year. Given that some proportion, perhaps a large proportion, of prey items will be missed by cat owners, it is difficult to say whether 41 or 18 prey per ha per year is more accurate. However, it can be said that variation in predatory behaviour and efficiency between individual cats is large, and that greatly differing predation estimates can be achieved from the same data–set by virtue of the statistical parameters and assumptions used in the analysis.

Several other issues are raised when predation data from a sample of house cats is used to estimate the amount of animals taken by all house cats within or beyond the study area. The first of these is the need to quantify the precision of predation estimates, both of cats in the study sample, and extrapolated estimates of total predation per hectare or per cat population over wider areas. For example, the 95% confidence interval around the total predation estimate for the Canberra house cat population calculated in this study is ± 25% of the estimate. The true total amount of prey caught per year by house cats in Canberra, based on the mean amount of prey recorded per cat in the study sample, may be anything between approximately 350 000 and 600 000. For a level of precision of ± 5% of the total predation estimate, a sampling intensity of approximately 2% of the total house cat population in Canberra, or around 1000 cats, would be required.

Secondly, predation by cats in a relatively localised study is unlikely to be representative of predation throughout the wider cat population because of variation in environmental conditions, including the type and amount of prey available, the density of cats, and possibly because of variation in cat management practices such as confinement and amount of food provided. For example, it is likely that house cats monitored in this study had available to them only a fraction of the abundance and diversity of mammalian prey suggested to have been caught by cats in the study by Paton (1991). Spatial environmental factors and cat management strategies were shown in the previous chapter to influence the type and amount of prey caught by house cats. Even within the present study, the average amount of prey caught by cats in outer suburban areas was significantly greater than the average for all cats in the study.

Finally, even if an extrapolated total predation estimate is considered both accurate and precise, the likely impact of this predation on prey populations remains unknown without at least information on the abundance and population ecology of prey species. Predation estimates alone are not evidence that cats are detrimental to entire taxonomic classes of animals on a national or even regional scale. In Australia, the issue of impact on native wildlife is further complicated by the fact that many house cats take a large number of prey which are introduced species. The impact of house cats on native wildlife in Canberra will be discussed further in Chapter eight.

In summary, variation in predatory efficiency between individual cats is large. While most cats catch relatively few prey items, a small proportion of house cats catch at least one prey item per week and are likely to be catching many more. The median amount of prey caught per year is approximately half the mean. While the median appears to best represent average annual predation by house cats because of the positively skewed nature of the data of observed amounts of prey caught, the higher mean value may in fact be a more accurate estimate of actual average annual predation, because of the proportion kills not observed by cat owners. The accuracy of estimates of predation by house cats using the methodology of this and previous studies remains unclear and estimates of predation by house cats, particularly extrapolated estimates, should be treated with caution. Future studies should at least provide statistics of precision of predation estimates. Maximum predation estimates are important in illustrating potential predation by one or a small number of cats.

8 GENERAL DISCUSSION AND CONCLUSIONS

8.1 IMPACTS OF PREDATION BY HOUSE CATS

The opportunistic nature of predation by house cats, though reported previously, is an important result. As domestic pets, the density of house cats per unit area is roughly constant over time. The population dynamics of suburban cats are therefore uncoupled from fluctuations in prey density, i.e., the predator population exhibits no numerical response. However, it is incorrect to automatically assume this will be problematic for prey populations. Numerous 'natural' predators appear to maintain stable population densities without threatening prey populations by living on alternative foods when their main prey is scarce (Krebs 1994:285). As opportunistic predators apparently exhibiting prey switching behaviour in response to temporal variation in prey abundance (see Chapter 5 and Davis 1957), predation by house cats on any one prey type should decrease as the relative abundance of that prey type declines (type III functional response curve). Provided total predation pressure is not too high, prey switching behaviour by predators in response to prey availability should stabilise fluctuations in the abundance of any one prey type (Krebs 1994:284).

8.1.1 Predation Impacts in Modified Environments

Animal species breeding successfully in suburban environments (i.e., whose population rate of increase is not consistently negative) have either persisted through the disturbances associated with the establishment of the suburb, including the introduction of cats, or have invaded or re–invaded the suburban environment as the quality and diversity of habitat has increased with suburb age, in the presence of cat predators. These populations are therefore not naive to predation by domestic cats. In addition they have access to artificially sustained food supplies, which while they may vary in abundance for different species and in different suburbs, are usually buffered to some degree from climatic fluctuations. Increased heterogeneity of habitat associated with increasing suburban age is also likely to provide more partial refuges in time for prey species, reducing their susceptibility to predation at low densities. For these reasons alone, the effect of predation by domestic cats in suburban environments is much more likely to be measured in terms of changes in community structure than in terms of population extinctions.

The influence of predation by domestic cats on prey abundance and community structure in suburban environments probably increases, relative to the influence of habitat change, with increasing suburb age, particularly in the absence of physical disturbances such as fire. However, it may never be as important as habitat availability, and indeed, may never be of significance at all. For bird communities at least, population abundance and species richness in suburban environments is predominantly determined by the type and quality of source or refuge habitats (forest, woodland and grassland remnants), the distance from suburbs to source habitats, and the availability and diversity of suburban habitat, as determined by factors such as suburb age, the presence or absence of mature eucalypt trees, availability of feeding areas (and particularly of flowering native plants), and small scale structural diversity (Green 1984, National Capital Development Commission 1984, Munyenyembe 1985).

House cats appear to be efficient predators of small to medium sized ground–dwelling and arboreal mammals in Australia. In outer suburban edge environments this may include Petaurid, Phalangerid and Peramelid species. It is possible predation by house cats may severely limit the distribution of these species in suburban environments. However, the loss of a species locally, regionally or nationally, as a direct result of predation by house cats in suburban environments is only likely to occur if the threatened species does not breed in suburban environments but individuals are continually drawn into the suburbs, for example, to feed or as part of a migratory cycle, and are subsequently heavily preyed upon. The attraction to the suburban environment would need to be very great, the proportion of the prey population culled be very high, and the response of the remaining prey population to reduced intra–specific competition be very poor, for such an extinction to occur.

8.1.2 Predation Impacts in Remnant Habitat

The intensity of predation by domestic cats in remnant habitat adjacent to, or surrounded by, suburban areas will be lower than in the suburbs themselves, as only a fraction of the total domestic cat population is likely to make significant excursions into these areas (see Chapter 3). However, total predation intensity may be higher, depending on the presence and abundance of other predators such as foxes and raptors. The effect of domestic food supplement allowing cats to continue to hunt in habitat islands as prey become increasingly scarce, may be more significant than the potentially ameliorating effect of a reduced prey consumption rate. Prey species in remnant habitat have to also contend with fluctuating food supplies in accordance with climatic variation and disturbance events such as bushfires.

The ecological effects of predation by domestic house cats in remnant habitat close to residential environments are likely to be quite different to that in suburban environments. Within a suburb, both predator and prey have successfully invaded a (usually) highly modified environment and the resulting relationship may reflect, superficially at least, an evolved predator–prey relationship on a continental landmass. The effect of domestic cats moving beyond suburban edges into remnant habitat in Australia is likely to be more analogous to the effects wrought by a predator newly introduced to an island environment. The communities in remnant habitats may include species that have not invaded the suburban environment either because of, or in spite of, the domestic cat population, and will be naive to predation of this kind. In addition, while species which successfully invade suburban environments are likely to be mobile and widespread, vertebrate species in remnant habitats may be relatively immobile and patchily distributed.

Predation by house cats may therefore be less intense in remnant habitat than in suburban environments, but has a greater potential to contribute to local extinctions of species. House cats may pose a serious threat to wildlife populations on relatively undisturbed private blocks (e.g., weekend retreats, hobby farms etc.). The results of this study indicate movements by house cats out of residential environments into surrounding habitat are significantly larger at night than during the day, and that prey types most commonly taken at night are mammals. Populations of native mammals in remnant habitat close to residential areas are therefore likely to be most susceptible to predation from house cats. Sugar gliders, juvenile brushtail possums, bush rats and water rats were recorded as prey of house cats in the present study, while ringtail possums, pygmy possums *Cercartetus* spp., feather–tailed gliders *Acrobates pygmaeus*, brush–tailed phascogales *Phascogale tapoatafa*, fat–tailed dunnarts *Sminthopsis crassicaudata*, yellow–footed antechinus *Antechinus flavipes*, planigales *Planigale* spp., and bandicoots *Isodon* and *Perameles* spp., have been reported as victims of house cats in other studies (Trueman 1990, Paton 1991).

The impact of predation by house cats living in residential environments surrounded by or adjoining native bushland on populations of Petaurid, Phalangerid and Peramelid species is likely to be greater than on bird populations because of the generally greater longevity and lower reproductive rates of these mammals, and subsequently lower potential population rates of increase, compared with that of most Passerine bird species in Australia. Also, with the possible exception of brushtail possums, small and medium sized ground–dwelling and arboreal native mammals are relatively sensitive to habitat disturbance and do not adapt well to habitat modification. Many have highly specific habitat requirements. The abundance and stability of populations of these species around residential environments is therefore normally low, and their susceptibility to local population extinctions relatively high.

The presence or absence of introduced species, such as black rats and rabbits, in remnant habitat will be important in predicting the impact of predation by domestic cats on native species. As in suburban environments, predation on introduced species may reduce predation on native species. However, the ability of domestic cats to control introduced species which prey on, or compete with, native species, will be difficult to demonstrate.

8.2 IMPACTS ON PREY POPULATIONS IN THE CANBERRA REGION

Surveys of wildlife in specific parts of the ACT are relatively few and differ greatly in scope (National Capital Development Commission 1984). A brief examination of some possible impacts of predation by house cats on prey populations in the Canberra region based on available published information on the abundance, distribution and ecology of prey species is attempted here. The number of species recorded as prey items of house cats in this study and approximate number of vertebrate species of brushtail possum size or smaller occurring in the suburban Canberra and adjoining rural land and CNP reserves are shown in Table 8.1. It is difficult to determine accurately how many species, particularly birds, may be available to house cats in the Canberra region. Nonetheless, it would appear that most mammal and reptile species and at least half of the bird species capable of invading or surviving in and around suburban environments in Canberra are at risk of predation by house cats. It is possible that prey types generally only found in non–suburban habitat, such as many arboreal and ground dwelling native mammals, will be poorly represented, or not recorded at all, if cats tend to present to their owners prey caught in the vicinity of their home rather than further afield.

8.2.1 Impacts on Birds

The number of bird species recorded as prey represents approximately 50% of all bird species regularly observed in Canberra suburbs and reserve units. Nonetheless, the vast majority of species which, given their natural resources requirements, might be expected to visit or breed in suburban gardens in Canberra continue to occur there. This situation

Table 8.1 The number of species recorded over one year as prey items of house cats in this study and approximate numbers of vertebrate species brushtail possum size or smaller occurring in suburban Canberra and adjoining rural land and CNP reserves.

	Number of Species	
	Recorded as Prey Items *	Regularly occurring within, or close to, Canberra suburbs †
Mammals	10	15 ‡
Birds	47	99
Reptiles	7	11
Amphibians	2	10
TOTAL	66	135

* Likely to underestimate total species caught by the house cat study sample because of unidentified prey items

† From National Capital Development Commission (1984) and Munyenyembe (1985)

‡ Does not include bat species

is not suprising. Most bird species occurring in suburbs have either invaded or re–invaded suburban environments in response to habitat development, irrespective of predation by cats. This is particularly true of open–forest and woodland bird species occurring in suburban Canberra, as many of Canberra's suburbs are situated on previously treeless plains and cleared rural grazing land. A number of Australian studies have indicated bird abundance in suburban environments is largely determined by food and habitat resource availability and competition for these resources (e.g., Green 1984, National Capital Development Commission 1984, Munyenyembe 1985). Predation by house cats on black rats potentially directly benefits some suburban bird species by reducing predation by rats on eggs and hatchlings (Ebenhard 1988).

Adaptable and ubiquitous introduced and native species such as starlings, silvereyes, house sparrows, crimson rosellas, blackbirds and magpie larks comprised much of the bird prey, but the effect that predation on these species may have on inter–specific competition remains unquantified. Common starlings are found in large numbers in suburban and pastoral areas of the ACT and appear to displace red–rumped parrots, *Psephotus haematonotus*, galahs *Cacatua roseicapilla*, and eastern and crimson rosellas from their nest holes (Taylor and Canberra Ornithologists Group 1992). It is thought introduced starlings may pose a long–term threat to these species, particularly in built up areas (Taylor and Canberra Ornithologists Group 1992). Blackbirds have also been suggested to be aggressive competitors with native birds for nesting sites (National Capital Development Commission 1984). Another introduced species which appears to compete successfully with parrots for nesting sites in tree hollows, and which was recorded in the cat prey sample, is the common myna *Acridotheres tristis* (National Capital Development Commission 1984, Martin 1992, Taylor and Canberra Ornithologists Group 1992).

Some benefit to less aggressive native species may be derived from the control of introduced species such as starlings, blackbirds and mynas by house cats. The stable or increasing trends in the abundance of these species in Canberra over the past decade however (Taylor and Canberra Ornithologists Group 1992, see also Figure 8.1), suggests house cats are not having a major impact on these species. Whether starling, blackbird and myna numbers would increase more rapidly, or whether these species would be generally more prolific in suburban Canberra in the absence of house cats is uncertain.

Five terrestrial bird species in the Canberra region, namely the superb parrot *Polytelis swainsonii*, hooded robin *Melanodryas cucullata*, jacky winter *Microeca leucophaea*, southern whiteface *Aphelocephala leucopsis*, and diamond firetail *Emblema temporalis*, are believed to be locally declining in abundance (Taylor and Canberra Ornithologists Group 1992). All five species are savannah woodland inhabitants and their declining numbers are thought to be a function of habitat loss from rural clearing practices and urban expansion (Taylor and Canberra Ornithologists Group 1992). None of these species appears capable of maintaining viable breeding populations in suburban environments alone. Lowland savannah woodland habitats are poorly represented in the ACT reserve network and urban expansion is expected to place even more pressure on the remnants of this habitat type (National Capital Development Commission 1984). Pockets of lowland savannah woodland habitat to the north and south of existing Canberra suburbs will be in close proximity of future Canberra suburbs. Predation by house cats from these suburbs on small isolated bird populations surviving in these habitat patches may be severe enough to cause local extinctions.

8.2.2 Impacts on Mammals

The majority (64%) of house cat prey items recorded in this study were introduced rodents, reflecting at least opportunistic, and possibly preferential, predation of these common suburban species (Hyett and Shaw 1980). Predation by house cats may limit numbers of house mice in outer suburbs and adjoining habitats to an unknown degree. However, as house mice do not appear to compete with small ground–dwelling native mammals such as *Antechinus* for resources (Watts and Aslin 1981:268), predation on this introduced species may not directly benefit Dasyurid species. Native mammals may nonetheless benefit indirectly from high rates of predation on introduced mammals because predation pressure will be deflected from native species. In Canberra, populations of *Antechinus flavipes* (23 captures from ~ 3200 trap nights) and *Antechinus stuartii* (2 captures from ~ 3200 trap nights) were reported on the Mt Majura/Mt Ainslie CNP reserve unit in 1976 within 1.5 kilometres of suburban housing and rural land (Kukolic 1990). In 1992, *A. stuartii* was not found in the Mt Majura/Mt Ainslie reserve in spite of intensive sampling, and the distribution of *A. flavipes* had contracted substantially, though the species was still abundant (25 captures from 4021 trap nights) within a small part of its previous distribution, approximately 1.5 kilometres from residential housing (D. Paull, Australian Defence Force Academy, personal communication). Only dispersing males were captured within 1 km of suburban housing in 1992. The introduced species *Mus domesticus* was present (63 captures from ~ 3200 trap nights in 1976, and 119 captures in 4021 trap nights in 1992) in close proximity to the antechinus population, and *Rattus rattus* was also found in the reserve (9 captures from ~ 3200 trap nights in 1976, and 5 captures in 4021 trap nights in 1992). The frequency of fires in the reserve is thought to be primarily responsible for the apparent loss of *A. stuartii* and contraction of the *A. flavipes* population, though predation by foxes and cats may have contributed to some degree and may still continue to do so (D. Paull, Australian Defence Force Academy, personal communication). Although no Dasyurids were recorded as prey items in the present study, 33 victims of feral and domestic cats received by the Department of Conservation and Environment in Victoria between 1960 and 1990 were Dasyurids, representing six of 11 species occurring in Victoria (Seebeck *et al.* 1991).

The results of this study suggest that sugar gliders are relatively vulnerable to predation from house cats, possibly because the spacing between trees in suburban habitats forces them to spend more time on or near the ground rather than gliding. Petaurid and Phalangerid species comprised 38% of 172 victims of feral and house cats received by the Victorian Department of Conservation and Environment between 1960 and 1990

(Seebeck *et al.* 1991). Thirty–nine of the 172 prey specimens (approximately 25%) were sugar gliders and more than half of these were of suburban or near suburban origin. Six of nine feather–tailed gliders taken by cats also came from near–suburban areas (Seebeck *et al.* 1991).

Habitat in many CNP reserve units has been disturbed to varying degrees by a variety of practices including land clearing, grazing, burning and wood collection, in addition to invasions by exotic weeds, rabbits and introduced mice and rats (National Capital Development Commission 1984). Habitat disturbance appears primarily responsible for low native mammal abundance and species richness in these areas (National Capital Development Commission 1984), though predation by foxes and cats may also have had a substantial impact. As habitat for native ground–dwelling and arboreal mammals in Canberra Nature Park reserves improves, predation by foxes and cats may play an increasingly important role in determining the distribution and abundance of these species.

8.2.3 Impacts on Herpetofauna

Identified reptile prey species represent approximately 65% of common local species. No uncommon species (National Capital Development Commission 1984) were reported, though the proximity of populations of species such as the nationally endangered striped legless lizard *Delma impar* in remnant native grasslands close to existing and proposed residential areas (Kukolic *et al.* 1994) is of concern. This species is considered to be primarily threatened in the ACT by the fragmentation, modification and loss of native grassland habitat due to agricultural practices and urban development (Kukolic *et al.* 1994). However, predation by domestic house cats may result in the loss of a small isolated population. Reptiles which live primarily above the ground in grass or litter, such as striped legless lizards and earless dragons *Tympanocryptis lineata*, are likely to be vulnerable to predation. Populations of the earless dragons in the southern Canberra region will come under increasing pressure from urban expansion and associated disturbances including predation by house cats in the future (Osborne *et al.* 1993).

Working in the favour of reptile populations occurring in close proximity to residential habitats, is the fact that most reptiles are susceptible to predation during the day when they are thermoregulating or active. House cats do not appear to move far (< 200m) from their residential homes into grassland and woodland habitats during the day. The nationally endangered pink–tailed legless lizard *Aprasia parapulchella* is locally abundant on the Mt Taylor CNP reserve unit in spite of this area being only some two kilometres in width and having been surrounded by suburbs for more than 20 years. The fossorial nature of *Aprasia parapulchella* may largely preclude individuals from predation by cats.

Both amphibian species recorded as prey items of house cats in this study are described as common and widespread in the ACT and are found in a variety of habitats around Canberra including parks and gardens near water (National Capital Development Commission 1984).

8.3 CONCLUSIONS

In general, predation by house cats is opportunistic on a wide range of vertebrate prey, though there is increasing evidence that small mammals may be preferred. The fact that 47 bird species were recorded as prey items in this study, and that nearly 3% of cats caught greater than 10 vertebrate species over the 12 month survey period, illustrates the exceptional predatory ability retained by some house cats, and the opportunistic nature of hunting behaviour of house cats in general. This is further illustrated by the observed temporal variation (seasonal and diel) in predation on different prey species, and on prey age and gender classes, in response to changes in the abundance of particular types of prey, and prey activity patterns.

As a consequence of their domesticated lifestyle, including daily provision of food, the average amount of prey caught by house cats is many times less than that expected of feral cats living with no association with people or human habitation. However, some house cats, probably between five and 10 percent of suburban populations, continue to catch relatively large amounts of prey, i.e., more than one prey item per week on average.

The total amount of prey taken does not appear to be significantly influenced by cat gender, age when desexed or breed. Nor does belling or the number of meals provided per day appear to have a significant influence on predatory efficiency. Cat age and the proportion of nights spent outside explain a small amount of the variation in the amount of prey caught by individual cats. The proportion of nights spent outside is of greatest importance with respect to predation on mammals and amphibians. The majority of mammals and amphibians are killed at night, while birds are generally taken in the morning and reptiles in the afternoon. Differences in the timing of predation on different prey types are likely due to differences in the activity levels, and therefore the availability, of each prey type. Environmental attributes such as distance to prey source areas and cat density explain some variation in predation on particular prey types. However, much of the variation in predatory ability between house cats may simply be a function of individual cat personalities.

Frequency distributions of the amount of prey caught per house cat per unit time are highly positively skewed. Data assumptions and statistical parameters used to extrapolate results from localised studies will have a significant effect on estimates of total predation by wider house cat populations. Also, the precision of estimates of total predation is likely to be low (and is often not reported). The accuracy of such estimates will depend on how representative the study cat sample is of the wider house cat population, and on the proportion of prey items not observed by cat owners.

Home range areas of house cats (and subsequently habitat utilisation) appear primarily determined by con-specifics. In particular, the density and spatial distribution of cats utilising separate food resources, and the dominance of individual cats in local social hierarchies, appear to be more important influences than gender or neutering effects. Other factors that significantly influence movement patterns include the time of day or night, and barriers in the form of busy roads. Relatively large movements by house cats normally only occur at night or under heavy cover (e.g., in drains), and active utilisation of habitat beyond suburb edges is also predominantly nocturnal.

Within home range areas, house cat movements during the day are strongly influenced by available cover (including drains, tall grass, fences and shrubs etc.), and the location of resting/sunning spots and hunting sites close to home. At night movement patterns appear influenced by the location of favoured hunting sites toward the outer edges of home range areas, including farm buildings, and tall grass, scrub and forest habitats. Dogs and antagonistic people will also influence the spatial movement patterns of house cats.

The threat of predation by house cats will exist to at least 900 m from residential housing at night and 200 m during the day (possibly further in daylight where good cover is available). Desexing cats will not necessarily remove this threat. The impact of predation beyond suburb edges is likely to be most significant on populations of small to medium sized arboreal and ground-dwelling mammals, because of their nocturnal nature, and because they are seemingly preferred prey types of house cats. Impacts on diurnally active prey types, such as most birds and reptiles, are likely to be confined to habitats closer (< 200 m) to residential development.

Suburban house cat activity peaks relatively late in the evening, around midnight to 0100 h, rather than immediately after dusk when nocturnal prey species are often most active, because of their lack of dependence of prey for food, and because house cats tend to spend the hours around sunset and immediately after dusk inside their owner's homes.

House cat activity is also related to ambient temperature, and nocturnal and diurnal activity patterns vary seasonally in response to daytime maximum and nightime minimum temperatures.

Predation estimates alone do not necessarily reflect relative impacts on different prey types. Nor do high rates of predation prove prey populations are detrimentally effected, particularly in urban environments. Nonetheless, on a small (backyard) scale in suburban environments, and in habitat within 1 km of residential dwellings, including isolated private properties, predation by individual house cats may threaten populations of native wildlife. Hunting by house cats is particularly undesirable in relatively undisturbed habitat because of the fundamental differences in ecological processes operating in these areas, especially isolated remnants, compared with ecologically contrived and modified suburban environments. Adverse impacts on native fauna will always be potentially greatest in undisturbed habitat adjacent to new residential developments.

As habitat for native ground–dwelling and arboreal mammals in Canberra Nature Park reserve units improves, predation by foxes and house cats may play an increasingly important role in determining the distribution and abundance of these species. The presence or absence of introduced species, such as house mice, black rats and rabbits, in remnant habitat will be important in predicting the impact of predation by domestic cats on native species.

Confining cats inside at night should substantially reduce both the home range size of house cats that tend to roam, and the utilisation of non–suburban habitat by house cats living on the edge of suburbs. Effectively enforced night–time curfews should also reduce predation on both introduced and native mammals and amphibians, but will not greatly reduce predation on birds and reptiles. However, cat curfewing practices in Canberra are currently neither widely adopted nor effectively practiced.

8.4 RECOMMENDATIONS AND FURTHER RESEARCH

It is recommended that environmental impact assessments for suburban planning consider house cat movements, particularly when planned suburban areas will abut habitat containing isolated populations of species likely to be preyed on by house cats. To this end, planned housing developments (public and private) should attempt to allow for a one kilometre buffer zone around habitat containing populations of nocturnal fauna potentially threatened by house cats, and at least 200 m where the threatened population is a diurnal species.

Attempts to prevent domestic cats hunting in remnant habitat patches should be integrated with programs to eliminate or control populations of other introduced species, such as black rats and rabbits, which are preyed upon by domestic cats and may prey on or compete with native species. Managing domestic cats to reduce predation on native wildlife in and around suburban areas should always be just one aspect of an overall management plan aimed at removing pest species and establishing, protecting, or rehabilitating native habitat to encourage a considered selection of native wildlife.

The type and magnitude of impacts of predation by house cats on native wildlife populations and community structure will be best described by experimental research. An experimental or pseudo-experimental design should be used to examine the effects of any legislative changes to the management of domestic house cats. The research should aim to measure: i) compliance by the community to the legislative amendments, ii) changes in the predatory behaviour of house cats, and, iii) changes in the relative abundance of species comprising the local vertebrate community.

There is also a need for the population dynamics and causes of mortality of native wildlife in habitat close to new residential development to be investigated and monitored. The effect of cats on the invasion of new suburban environments by native wildlife, relative to habitat effects, and the effect of predation by house cats on competition between introduced and native species, particularly birds, would also be worthy of further research.

Examination of the ways in which people acquire house cats in the ACT, and subsequently ways in which the distribution of cats as domestic pets may be more strictly controlled to ensure more responsible cat ownership, may be warranted.

REFERENCES

ACT Commissioner for the Environment. 1994. *ACT State of the Environment Report*. Goanna Print, Canberra, pp. 196.

ACT Legislative Assembly. 1993. *Feral animals and invasive plants in the ACT.* A discussion paper by the Standing Committee on Conservation, Heritage and Environment, Canberra, pp. 48.

Ackerman, B., Leban, F., Samuel, M., and Garton, E. 1990. User's Manual for Program Home Range, *Technical Report 15, Forest Wildlife and range Experiment Station,* University of Idaho, Idaho, pp. 80.

Adamec, R.E. 1976. The interaction of hunger and preying in the domestic cat: an adaptive hierarchy. *Behavioural Biology* **18**: 263-272.

Alldridge, J.R., and Ratti, J.T. 1986. Comparison of some statistical techniques for analysis of resource selection. *Journal of Wildlife Management*, **50**: 157-165.

Amareskare, P. 1994. Ecology of introduced small mammals on western Mauna Kea, Hawaii. *Journal of Mammalogy,* **75**(1): 24-38.

Anderson, I. 1994. Should the cat take the rap? *New Scientist* No. 1926: 13-14.

Apps, P.J. 1984. Cats on Dassen Island. *Acta Zoologica Fennica*, **172**: 15-116.

Bayley, C.P. 1978. A comparison of the diets of the red fox and the feral cat in an arid environment. *South Australian Naturalist* **53**: 20-28.

Begon, M., Harper, J.L. and Townsend, C.R. 1990. *Ecology: Individuals Populations and Communities*, 2nd Ed. Blackwell Scientific Publications, Boston, pp. 945.

Biben, M. 1979. Predation and Predatory play behaviour of domestic cats. *Animal Behaviour* **27**: 81-94.

Bradshaw, J.W.S. 1992. *The behaviour of the Domestic Cat.* C.A.B. International. U.K., pp. 219.

Bradt, G.W. 1949. Farm cat as predator. *Michigan Conservationist* **18**: 23-25.

Burt, W.H. 1943. Territoriality and home range concepts as applied to mammals. *Journal of Mammalogy,* **24**(3): 346-352.

Catling, P.C. 1988. Similarities and contrasts in the diets of foxes, *Vulpes vulpes*, and cats, *Felis catus*, relative to fluctuating prey populations and drought. *Australian Wildlife Research* **15**: 307-317.

Caughley, G. 1979. Design for aerial censuses. Pp. 15-20 *in* Australian National Parks and Wildlife Service (Special Publication) *Aerial surveys of fauna populations*. Australian Government Publishing Service, Canberra.

Christian, D.P. 1975. Vulnerability of meadow voles, *Microtus pennsylvanicus*, to predation by domestic cats. American Midland Naturalist, **93**: 498-502.

Churcher, P.B. and Lawton, J.H. 1987. Predation by domestic cats in an English village. *London Journal of Zoology* **212**: 439-455.

Coman, B.J. and Brunner, H. 1972. Food habits of the feral house cat in Victoria. *Journal of Wildlife Management* **36**(3): 848-853.

Corbett. L. K. 1979. Feeding ecology and social organisation of wild cats (*Felis sylvestris*) and domestic cats (*Felis catus*) in Scotland. PhD Thesis, University of Aberdeen, Scotland.

Dards, J.L. 1978. Home ranges of feral cats in Portsmouth Dockyards. *Carnivore Genetics Newsletter* **3:** 242-248.

Das, A. 1993. Nocturnal carnivore (*Felis catus* and *Vulpes vulpes*) activity in an urban native park. B.Sc. Honours Thesis, University of Melbourne, Australia.

Darwin, C. 1872. *The origin of species by means of natural selection.* 6th edition, London.

Davis, D.E. 1957. The use of food as a buffer in a predator-prey system. *Journal of Mammalogy* **38**: 466-472.

Dilks, P.J. 1979. Observations on the food of Feral Cats on Campbell Island. *New Zealand Journal of Ecology* **2**: 64-66.

Edward, A.S. 1979. *Street trees in Canberra.* The Australian National University Press. Canberra.

Ebenhard, T. 1988. Introduced birds and mammals and their ecological effects. *Swedish Wildlife Research,* **13**: 1-107.

Eberhard, T. 1954. Food habits of Pennsylvania house cats. *Journal of Wildlife Management* **18**: 284-286.

Elton, C. S. 1953. The use of cats in farm rat control. *British Journal Of Animal Behaviour*. **1**: 151-5.

Erlinge, S., Goransson, G., Hansson, L., Hogstedt, G., Liberg, O., Nilsson, N., Nilsson, T., von Schantz, T. and Sylven M. 1983. Predation as a regulating factor on small rodent populations in southern Sweden. *Oikos*, **40**: 36-52.

Erlinge, S., Goransson, G., Hogstedt, G., Jansson, G., Liberg, O., Loman, J., Nilsson, I. N., von Schantz, T. and Sylven M. 1984. Can vertebrate predators regulate their prey? *American Naturalist*, **123**: 36-52.

Fennell, C. 1975. Some demographic characteristics of the domestic cat population in Great Britain with particular reference to feeding habits and the incidence of the feline urological syndrome. *Journal of Small Animal Practice*, **16**: 775-783

Fitzgerald, B.M. 1990. Is cat control needed to protect urban wildlife? *Environmental Conservation* **17**: 168-169.

Fitzgerald, B.M. 1988. Diet of Domestic Cats and their Impact on Prey Populations. Pp. 123-144 *in* Turner, D.C. and P. Bateson (eds) *The Domestic cat: the biology of its behaviour*. Cambridge University Press, Cambridge.

Fitzgerald, B.M. 1980. Feeding ecology of feral house cats in New Zealand forest. *Carnivore Genetics Newsletter* **4**(2): 67-71

Fitzgerald, B.M. and Karl, B.J. 1979. Foods of feral house cats (*Felis catus* L.) in forest of the Orongorongo Valley, Wellington. *New Zeal. J. Ecol.* **6**: 107-126.

Fitzgerald, B.M. and Karl, B.J. 1986. Home range of feral house cats (*Felis catus* L.) in forests of the Orongorongo Valley, Wellington. *New Zeal. J. Ecol.* **9**: 71-81.

Fraser, I. 1981. *Bird Movements: Black Mountain - A Walkers Guide.* Environmental Centre, South East region, Pink Panther Printing, Canberra.

Frith, H.J. 1976. *Birds in the Australian High Country.* Revised edition, A.H. & A.W. Reed, Sydney.

George, W.G. 1974. Domestic cats as predators and factors in winter shortages of raptor prey. *Wilson Bulletin* **86**: 384-396.

George, W.G. 1978. Domestic cats as density independent hunters and 'surplus killers'. *Carnivore genetics Newsletter*, **3**: 282-287.

Gibb, J.A., Ward, G.D. and Ward, C.P. 1978. Natural control of a population of rabbits, *Oryctolagus cuniculus* (L.), for ten years in the Kourarau enclosure. DSIR Bulletin 223. NewZealand.

Gibson, G. 1978. *Canberra - description.* Australian National University Press, Canberra.

Green, R.J. 1984. Native and exotic birds in a suburban habitat. *Australian Wildlife Research,* **11**: 181-190.

Greenwood, L. 1993. The fight to protect our wildlife. *Habitat Australia*, May edition, pp. 12-14.

Guggisberg, C.A.W. 1975. *Wild Cats of the World.* David & Charles, London.

Haspel, C. and Calhoon, R.E. 1993. Activity patterns of free-ranging cats in Brooklyn, New York. *Journal of Mammalogy*, **74**(1): 1-8.

Hermes, N. 1981. Garden bird chart and survey. *Canberra Bird Notes*, **6**: 112-114.

Hess, A.D. and Swartz, A. 1940. The forage ratio and its use in determining the food grade of streams. *Transactions of the North American Wildlife Conference* **5**: 162-164.

Hyett, J. and Shaw, N. 1980. *Australian mammals. A field guide for New South Wales, Victoria, South Australia and Tasmania.* Thomas Nelson Australia, Singapore.

Ingerwersen, F., Evans, O. and Griffiths, B. 1974. *Vegetation of the Ainslie-Majura Reserve.* Department of Territories and Local Government, Conservation Series No. 2, Canberra.

Ivlev, V.S. 1961. *Experimental Ecology of the Feeding of Fishes.* Yale University Press, New Haven, Conneticut, pp. 302.

Izawa, M. 1983. Daily activities of the feral cat *Felis catus* Linn. *Journal of the Mammal Society of Japan*, **9**: 409-420.

Jackson, W.B. 1951. Food habits of Baltimore, Maryland, cats in relation to rat populations. *Journal of Mammalogy* **32**: 458-461.

Jacobs, J. 1974. Quantitative measurement of food selection - a modification of the forage ratio and Ivlev's Electivity Index. *Oecologia*, **14**: 413-417.

Jarvis, P.J. 1990. Urban cats as pest or pets. *Environmental Conservation* **17**: 169-171.

Johnson, k. 1991. Feral cats: the Northern Territory perspective. Pp. 45-52 *in* Potter, C. (ed) *The Impact of Cats on Native Wildlife.* Workshop Proceedings, ANPWS, Canberra.

Jones, E. 1989. Felidae. Pp. 1006-1011 *in* Walton, D.W. and Richardson, B.J. (eds) *Fauna of Australia.* Mammalia. Australian Government Printing Service, Canberra.

Jones, E. 1992. A purr-fect predator! *Wildlife Australia*, Autumn 1992.

Jones, E. and Coman, B. J. 1981. Ecology of the feral cat, *Felis catus* (L.), in south-eastern Australia 1. Diet. *Australian Wildlife Research* **8**: 537-547.

Jones, E. and Coman, B.J. 1982. Ecology of the Feral Cat, *Felis catus* in south-eastern Australia III. Home ranges and population ecology in semi-arid north-west Victoria. *Australian Wildlife Research* **9**: 409-420.

Kerby, G. and Macdonald, D.W. 1988. Cat society and the consequences of colony size. Pp. 67-81 *in* Turner, D.C. and P. Bateson (eds) *The Domestic cat: the biology of its behaviour.* Cambridge University Press, Cambridge.

Konecny, M.J. 1987. Home range and activity patterns of feral house cats in the Galapagos Islands. *Oikos*, **50**: 17-23.

Krausman, P.R. 1978. Forage relationships between two deer species in Big Bend National Park, Texas. *Journal of Wildlife Management*, **42**: 101-107.

Krebs, C. J. 1994. *Ecology: The Experimental Analysis of Distribution and Abundance,* Fourth Edition. HarperCollins College Publishers, New York.

Kukolic, K. 1990. *A survey of the vertebrate fauna of Mt. Ainslie, Mt. Majura, and Black Mountain, 1975-1976.* Research Report No. 1, A.C.T. Parks and Conservation Service.

Kukolic, K., McElhinney, N. and Osborne, W. S. 1994. *Survey for the striped legless lizard Delma impar during 1993 in the proposed development area E1 comprising sites for the Gunghalin town centre and the suburb of Franklin.* Internal report of the ACT Parks and Conservation Service, Wildlife Research Unit, pp. 33.

Lair, H. 1987. Estimating the location of the focal center in red squirrel home ranges. *Ecology* **68**(4): 1092-1101.

Langham, N.P.E. 1992. Feral cats (*Felis catus* L.) on New Zealand farmland. II. Seasonal activity. *Wildlife Research*, **19**: 707-720

Langham, N.P.E. and Porter, R.E.R. 1991. Feral cats on New Zealand farmland. I. Home range. *Australian Wildlife Research* **18**: 741-760.

Laundre, J.W. and Keller, B.L. 1981. Home-range use by coyotes in Idaho. *Animal Behaviour*, **29**: 449-461.

Laundre, J.W., Reynolds, T.D., Knick, S.T. and Ball, I.J. 1987. Accuracy of daily point relocations in assessing real movement of radio-marked animals. *Journal of Wildlife Management,* **51**: 937-940.

Leyhausen, P. 1979. *Cat Behaviour.* New York : Garland STPM Press, pp. 340.

Leyhausen, P. 1988. The tame and the wild - another Just So Story? Pp. 57-66 *in* Turner, D.C. and P. Bateson (eds) *The Domestic cat: the biology of its behaviour*. Cambridge University Press, Cambridge.

Liberg, O. 1980. Spacing patterns in a population of rural free roaming domestic cats. *Oikos* **35**: 336-349.

Liberg, O. 1984a. Food habits and prey impact by feral and house based domestic cats in a rural area in southern Sweden *Journal of Mammalogy* **65(3)**: 424-432.

Liberg, O. 1984b. Home range and territoriality in free ranging house cats. *Acta Zoologica Fennica*, **171**: 283-285.

Liberg, O. and Sandell, M. 1988. Spatial organisation and reproductive tactics in the domestic cat and other felids. Pp. 83-98 *in* Turner, D.C. and P. Bateson (eds) *The Domestic cat: the biology of its behaviour*. Cambridge University Press, Cambridge.

Macdonald, D.W. and Apps, P.J. 1978. The social behaviour of a group of semi-dependent farm cats, *Felis catus*: a progress report. *Carnivore Genetic Newsletter* **3**: 256-268.

Maddock, I. T. 1983. Lesser long-eared bat *Nyctophilus geoffroyi.* in *The Australian Museum Complete Book of Mammals.* ed. R. Strahan. Sydney : Angus and Robertson.

Martin, W. 1992. *Aspects of ecology of the common myna (Acridotheres tristis* L.). B.Sc. Honours Thesis, University of Canberra, Canberra.

May, R.M. 1988. Control of feline delinquency. *Nature* (Lond.), **332**: 392-3.

McMurray, F.B. and Sperry, C.C. 1941. Food of feral house cats in Oklahoma, a progress report. *Journal of Mammalogy* **22**: 184-190.

Mead, C.J., 1982. Ringed birds killed by cats. *Mammals Review*, **12**: 183-6.

Mendl, M. and Harcourt, R. 1988. Individuality in the domestic cat. Pp. 41-54 *in* Turner, D.C. and P. Bateson (eds) *The Domestic cat: the biology of its behaviour*. Cambridge University Press, Cambridge.

Munyenyembe, F. E. 1985. *Bird density and species richness in suburban Canberra, Australia.* M.App.Sci. Thesis, University of Canberra, Canberra.

Murphy, G.P. 1979. *Parks and Gardens in Canberra.* Australian Government Printing Service, Canberra.

National Capital Development Commission. 1984. *The ecological resources of the ACT.* Technical Paper 42, Canberra.

Neu, C.W., Byers, C.R. and Peek, J.M. 1974. A technique for analysis of utilization-availability data. *Journal of Wildlife Management*, **38**: 541-545.

Newsome, A.E., I. Parer, and Catling, P.C. 1989. Prolonged prey suppression by carnivores - predator removal experiments. *Oecologica* **78**: 458-467.

Osborne, W.S. and Mckergow, F. V. C. 1993. *Distribution, population density, and habitat of the pink-tailed legless lizard, Aprasia parapulchela, in Canberra Nature Parks*. Technical Report 3, ACT Parks and Conservation Service, Canberra.

Osborne, W.S. and Williams, K. 1991. Conservation problems with cats in the Australian Capital Territory. Pp. 14-17 *in* Potter, C. (ed) *The Impact of Cats on Native Wildlife*. Workshop Proceedings, ANPWS, Canberra.

Osborne, W.S., Kukolic, K. and Williams, K.D. 1993. Conservation of reptiles in lowland native grasslands in the Southern Tablelands of New South Wales and the Australian Capital Territory. Pp. 151-158 *in* Lunney, D. and Ayres, D. (eds) *Herpetology in Australia*. Royal Zoological Society of New South Wales, Mosmon, NSW.

Ostle, B. 1963. *Statistics in Research.* Iowa Sate University Press, Ames, Iowa, pp. 487.

Palomares, F. and Delibes, M. 1992. Data analysis design and potential bias in radio-tracking studies of animal habitat use. *Acta Ecologica*, **13**(2): 221-226.

Panaman, R. 1981. Behaviour and ecology of free-ranging female farm cats (*Felis catus* L.). *Zeitschrift fur Tierpscychologie* **56**(1): 59-73.

Paton, D.C. 1991. Loss of wildlife to domestic cats. Pp. 64-69 in Potter, C. (ed) *The Impact of Cats on Native Wildlife*. Workshop Proceedings, ANPWS, Canberra.

Pearson, O.P. 1966. The prey of carnivores during one cycle of mouse abundance. *Journal of Animal Ecology*, **35**: 217-33.

Pearson, O.P. 1971. Additional measurements of the impact of carnivores on California voles (*Microtus californicus*). *Journal of Mammalogy*, **52**: 41-9.

Pearson, O.P. 1985. Predation. Pp. 535-566 in Tamarin, R.H. (ed) *Biology of New World Microtus*. Special Publication of the American Society of Mammalogists.

Pepin, D. 1986. Spring density and daytime distribution of the European hare in relation to habitat in an open field agrosystem. *Z. Saugetierkunde*, **51**: 79-86

Pryor, L.D. and Banks, J.C.G. 1991. *Trees and Shrubs in Canberra.* Little Hills Press, Crows Nest, NSW, pp. 287.

Randall Byers, C., Steinhorst, R.K. and Krausman, P.R. 1984. Clarification of a technique for analysis of utilization-availability data. *Journal of Wildlife Management*, **48**(3): 1050-1053.

REARK Research Pty Ltd. 1994. *The metropolitan domestic cat.* Research Report for the Petcare Information and Advisory Service, Melbourne, pp. 83.

Rolls, E., 1994. *Cats destroy 700m animals a year.* Sun-Herald, January 23, P. 35.

Samuel, M.D. and Garton, E.O. 1985. Home range: a weighted normal estimate and tests of underlying assumptions. *Journal of Wildlife Management*, **49**(2): 513-519.

Schaller, G. 1972. *The Serengeti lion.* University of Chicago Press, Chicago, pp. 480.

Seebeck, J., Greenwood, L., and D. Ward (1991) Cats in Victoria. Pp. 18-29 *in* Potter, C. (ed) *The Impact of Cats on Native Wildlife.* Workshop Proceedings, ANPWS, Canberra.

Simpson, K. and Day, N. 1984. *The Birds of Australia.* Lloyd O'Neil Pty Ltd, South Yarra, Victoria, pp. 352.

Smith, S. 1991. *A checklist of the vertebrates of Tasmania.* Australian Government Printing Office, Hobart.

Spencer, W.D. and Barrett, R.H. 1984. An evaluation of the harmonic mean measure for defining carnivore activity areas. *Acta Zoologica Fennica*, **171**: 255-259.

Strauss, R.E. 1979. Reliability estimates for Ivlev's Electivity Index, the forage ratio, and a proposed linear index of food selection. *Transactions of the American Fisheries Society*, **108**: 344-352.

Strong, B.W. and W.A. Low 1983. *Some observations of feral cats* Felis catus *in the southern Northern Territory.* Technical Report 9. Conservation Commission of the Northern Territory, Alice Springs, N.T., pp. 12.

Swihart, R.K. and Slade, N.A. 1985a. Influence of sampling interval on estimates of home-range size. *Journal of Wildlife Management*, **49**(4): 1019-1025.

Swihart, R.K. and Slade, N.A. 1985b. Testing for independence of observations in animal movements. *Ecology*, **66**(4): 1176-1184.

Swihart, R.K. and Slade, N.A. 1986. The importance of statistical power when testing for independence in animal movements. *Ecology*, **67**(1): 255-258.

Tabor, R. 1981. General biology of feral cats. Pp 5-11 *in* Universities Federation for Animal Welfare (eds) *The Ecology and Control of Feral Cats*. Potters Bar: UFAW.

Taylor, R.H. 1979. How the Macquarie Island parakeet became extinct. *New Zealand Journal of Ecology*, **2**: 42-45.

Taylor, M. and the Canberra Ornithologists Group. 1992. *Birds of the Australian Capital Territory - an atlas.* COG and National Capital Planning Authority, Canberra.

Triggs, B.A., Brunner, H. and Cullen, J. M. 1984. The food of fox, dog and cat in Croajingalong National Park, south-eastern Victoria. *Australian Wildlife Research* **11**: 491-499.

Trueman, P. 1990. *The impact of domestic cats on the wildlife of Hobart.* Unpublished report as part requirement of a B.Sc. Hons degree, University of Tasmania.

Turner, D.C. and Bateson, P. (eds). 1988. *The Domestic Cat: The Biology of its Behaviour.* Cambridge University Press, Cambridge, pp. 222.

Turner, D.C. and Meister, O. 1988. Hunting behaviour of the domestic cat. Pp. 111-121 *in* Turner, D.C. and P. Bateson (eds) *The Domestic cat: the biology of its behaviour.* Cambridge University Press, Cambridge.

Turner, D.C. and Mertens, C. 1986. Home range size, overlap and exploitation in domestic farm cats (*Felis catus*). *Behaviour*, **99**: 22-45.

Viljoen, P.J. 1989. Habitat selection and preferred food plants of a desert-dwelling elephant population in the northern Namib Desert, South West Africa/Namibia. *African Journal of Ecology*, **27**: 227-240.

Warner, R.E., 1985. Demography and movements of free-ranging domestic cats in rural Illinois. *Journal of Wildlife Management* **49**(2): 340-346.

Watts, C.H.S. and Aslin, H.J., 1981. *The rodents of Australia*. Angus and Robertson, Hong kong.

Watts, C.H.S. and Kemper, C.M. 1989. Muridae. Pp. 939-956 *in* Walton, D.W. and Richardson, B.J. (eds) *Fauna of Australia*. Mammalia. Australian Government Printing Service, Canberra.

White, G.C. and Garrott, R.A. 1990. *Analysis of Wildlife Radio-Tracking Data*. Academic Press, San Diego, California, pp. 383.

Wilson, S.J. 1963. Further notes on autumn migration of honeyeaters. *Australian Bird Bander*, **1**: 123-125.

Worton, B.J. 1987. A review of models of home range for animal movements. *Ecological Modelling*, **38**(3/4): 277-298.

Zielinski, W.J., Spencer, W.D. and Barrett, R.H. 1983. Relationship between food habits and activity patterns of pine martins. *Journal of Mammalogy*, **64**: 387-396.

APPENDIX I

Introductory letter and questionnaire

UNIVERSITY OF CANBERRA

Dear Householder,

You may be aware of recent debate about domestic and wild cats as predators in the Australian bush. Arguments have been fuelled by media reports and television programs which have brought the debate into our homes. A lot has been said about the ability of cats to catch wildlife, but the actual impact of this hunting on prey populations remains largely unknown.

Members of the Applied Ecology Research Group at the University of Canberra (UC) are mounting a study to improve our knowledge of the ecology of domestic cats in suburban areas. As part of this study we intend to construct a database containing information on the kinds of animals caught by cats in and around Canberra (including pests and introduced species). **You can assist us greatly by filling out and returning (using the reply paid envelope) the questionnaire attached to the back of this letter.**

If you own a cat, we hope you will consider contributing further to this scientific enterprise. Cat owners willing to be involved in the study will be asked to retrieve animals (or the remains of animals) caught by their cat(s) for collection by a member of the UC study team on a weekly or monthly basis (or whenever is most convenient). We would prefer to gather data in this manner. However, if you do not want to retrieve prey items, you may simply record any catches on data sheets provided. We need to collect data in this way for 12 months. **All participants will be presented with a summary report of the outcomes of the study.**

If you know your cat catches prey of any kind (however rarely) then your help in this study would be greatly appreciated. Plastic bags and foam coolers will be provided to collect prey remains. The study is based on similar work carried out by scientists in South Australia and in the U.K. which received

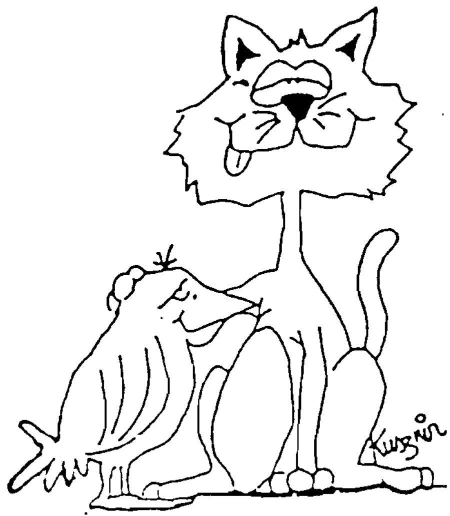
Kirinari Street
Bruce ACT
PO Box 1
Belconnen ACT 2616
Australia
Telephone
+61 6 (06) 201 5111
Facsimile
+61 6 (06) 201 5999

enormous community support. We are hoping participation in this project will be just as good! We would like to begin collecting data as soon as possible so please return the attached questionnaire promptly.

If you would like more information, contact David Barratt at the University of Canberra on 201 2937. You may also contact Arthur Georges on 201 2523.

PLEASE NOTE:- This study is being conducted in fulfilment of the requirements of a Masters degree in Applied Science. You need not be concerned about any repercussions regarding your cat and its activities. No specific records of cat activity will be published. All information will be treated as strictly confidential. We are looking for an honest, unbiased sample of data, which may be used to make better informed decisions about the management of Australia's wildlife in the future.

Thank you for your co-operation. We look forward to working further with you!



Sincerely,

David Barratt.
M. App. Sc. Candidate
Applied Ecology Research Group
University of Canberra

◆ Applied Ecology Research Group - Canberra Cat Survey ◆

Residential Address______________________________

The information on this survey will be used to describe the distribution and abundance of domestic cats in Canberra. Please complete and return as soon as possible. Thank you!

1) Do you presently own or care for a cat?

☐ Yes ☐ No

Fold

If yes, go to question 2 **If no, stop**

2) How many cats do you have?_______

3) How often (per week, month or year) does your cat(s) catch:

a) Mammals (rats, mice etc)______________________

b) Birds______________________

c) Reptiles (lizards, snakes etc)______________________

d) Other (please specify)?______________________

4) I would ☐ would not ☐ (tick one) like to be involved in the study.

Fold

If you would like to participate, please write your name and telephone number here, and a member of the study team will be in contact with you shortly.

Name______________________ Ph:______________________

Thank you for your help!

David Barratt

Applied Ecology Research Group
University of Canberra

APPENDIX II

Questionnaire and datasheets distributed to study participants

◆ Applied Ecology Research Group - Canberra Cat Survey ◆

Name (optional)________________________ Name of cat______________ CAT I.D. No. 527

Address or Suburb________________________________ Tel No.______________

Please complete and return ASAP to: David Barratt, Applied Ecology Research Group, University of Canberra, PO Box 1, Belconnen, ACT 2616

1) How did you acquire your cat (eg, stray, given, R.S.P.C.A., cat breeder, etc.)?

____

2) Do you intend replacing your cat when it dies?

☐ Yes ☐ No

3) What breed (or coat colour) is your cat?

____

4) How old is your cat?______________

5) What sex is your cat? ☐ M ☐ F

6) Has your your cat been desexed?

☐ Yes ☐ No

7) If yes, at what age was your cat desexed?

____

8) How many times a day does your cat eat?

☐ 1× ☐ 2× ☐ 3× ☐ On demand

9) Does your cat wear a bell on its collar?

☐ Yes ☐ No

10) If yes, how many bells?__________

11) Is your cat confined indoors at particular times of the day or night?

☐ Yes ☐ No

12) If yes, between which hours is your cat usually confined indoors?

____

13) How many nights in a fortnight does your cat stay out at night?

____

14) How much does your cat weigh (be as specific as possible)?

____

15) How many cats are owned **in total** between yourself and your immediate neighbours (properties adjoining your own at the sides, back and corners)?

____

Thank-you for your help!

David Barratt
University of Canberra

Prey Item Data Sheet

Cat Name________________

527

Return to: David Barratt, Applied Ecology Research Group, University of Canberra, PO Box 1, Belconnen, ACT, 2616.

Date (dd/mm/yy)	Time of Catch [1]	Prey Class [2]	Prey Species (Common name)	Age of Prey Item [3]	Sex of Prey Item [4]	Percentage prey eaten	Comments

[1] **Time of Catch:** **am1** = 12 midnight - 6am; **am2** = 6am - 12 noon; **pm1** = 12 noon - 6pm; **pm2** = 6pm - 12 midnight.

[2] **Prey Class:** Mammal; Bird; Reptile; Amphibian; Insect. [3] **Prey Age:** Adult; Juvenile; Unknown [4] **Prey Sex:** Male; Female; Unknown

Prey Observation Data Sheet

Cat Name________________

Return to: David Barratt, Applied Ecology Research Group, University of Canberra, PO Box 1, Belconnen, ACT, 2616.

Date (dd/mm/yy)	Time of Catch [1]	Prey Class [2]	Prey Species (common name or brief description)	Age of Prey Item [3]	Sex of Prey Item [4]	Percentage prey eaten	Reason sample not collected

[1] **Time of Kill:** **am1** = 12am-6am; **am2** = 6am-12pm; **pm1** = 12pm-6pm; **pm2** = 6pm-12am.

[2] **Prey Class:** Mammal; Bird; Reptile; Amphibian; Insect. [3] **Prey Age:** Adult; Juvenile; Unknown [4] **Prey Sex:** Male; Female; Unknown

APPENDIX III

Nocturnal and diurnal home range sizes and largest straight–line distances moved from home for suburban and farm house cats.

	Nocturnal Observations			Diurnal Observations		
Cat Sex / Status	n	100% (95%)	Largest Move (m)	n	100% (95%)	Largest Move (m)
SUBURB						
Male	219	43.56 (20.54)	940	232	39.90 (17.19)	900
Desexed Male	18	0.37 (0.23)	90	28	0.02 (0.02)	20
Desexed Male	39	7.90 (6.70)	360	89	8.16 (4.36)	390
Desexed Male	74	0.11 (0.02)	40	47	0.50 (0.14)	80
Desexed Male	92	1.38 (0.89)	180	104	0.66 (0.08)	120
Desexed Male	145	33.09 (22.16)	720	187	1.00 (0.23)	130
Desexed Female	69	0.35 (0.08)	90	226	0.76 (0.46)	80
Desexed Female	74	0.07 (0.04)	30	46	0.13 (0.04)	60
Desexed Female	126	28.14 (27.93)	850	144	4.77 (4.64)	830
Desexed Female	91	0.94 (0.27)	130	108	0.83 (0.09)	50
FARM						
Male	202	7.48 (4.46)	280	245	1.43 (0.91)	110
Male	218	7.40 (1.59)	270	246	3.34 (1.77)	280
Female	214	5.99 (2.42)	290	249	23.38 (3.70)	730
Female	219	5.53 (3.30)	310	246	1.79 (1.48)	180
Female	220	2.77 (1.44)	160	246	4.39 (1.75)	340
Female	219	9.67 (3.18)	350	246	4.39 (1.52)	280
Female	82	3.23 (1.38)	340	92	0.86 (0.77)	170

APPENDIX IV

Mean distance moved between consecutive observations by suburban and farm house cats.

	Mean distance moved between consecutive observations (m)	
	NOCTURNAL	DIURNAL
SUBURBAN CATS		
Male	113.8	58.5
Desexed Male	16.4	6.3
Desexed Male	100.1	62.7
Desexed Male	6.3	17.7
Desexed Male	37.3	12.3
Desexed Male	119.7	11.8
Desexed Female	12.0	22.3
Desexed Female	7.5	9.8
Desexed Female	186.6	30.4
Desexed Female	22.2	15.5
FARM CATS		
Male	58.9	20.0
Male	37.6	26.2
Female	58.6	43.8
Female	66.5	28.6
Female	35.7	42.1
Female	58.2	29.8
Female	58.0	25.6

APPENDIX V

Prey species of house cats recorded during the study.

Family Name	Species Name	Common Name	n
MURIDAE			
	Mus domesticus	House mouse	1095
	Rattus rattus	Black rat	143
	Hydromys chrysogaster	Water rat	2
	Rattus fuscipes	Bush rat	1
	Rattus norvegicus	Brown rat	1
LEPORIDAE			
	Oryctolagus cuniculus	European rabbit	10
		Unknown Bat	5
PETAURIDAE			
	Petaurus breviceps	Sugar glider	4
PHALANGERIDAE			
	Trichosurus vulpecula	Brushtail possum	2

CAVIIDAE			
	Cavia porcellus	Guinea pig	2
UNKNOWN MAMMAL			8
PASSERIDAE			
	Passer domesticus	House sparrow	104
ZOSTEROPIDAE			
	Zosterops lateralis	Silvereye	62
STURNIDAE			
	Sturnus vulgaris	Common starling	50
	Acridotheres tristis	Common myna	5
PYCNONOTIDAE			
	Turdus merula	Blackbird	34
PSITTACIDAE			
	Platycercus elegans	Crimson rosella	23
	Platycercus eximius	Eastern rosella	10
	Alisterus scapularis	King parrot	5
	Psephotus haematonotus	Red–rumped parrot	3

	Melopsittacus undulatus	Budgerigar	2
	Neophema pulchella	Turquoise parrot	1
		Unknown parrot	3
		Unknown rosella	7
FRINGILLIDAE			
	Poephila bichenovii	Double–barred finch	2
	Carduelis carduelis	European goldfinch	1
		Unknown finch	15
MALURIDAE			
	Malurus cyaneus	Superb fairy–wren	14
GRALLINIDAE			
	Grallina cyanoleuca	Magpie lark	13
MELIPHAGIDAE			
	Anthochaera carunculata	Red wattle–bird	11
	Acanthorhynchus tenuirostris	Eastern spinebill	7
	Lichenostomus pencillatus	White–plumed honeyeater	1

	Lichenostomus chrysops	Yellow–faced honeyeater	4
	Philemon corniculatus	Noisy friarbird	2
	Manorina melanocephala	Noisy miner	1
		Unknown honeyeater	7
MUSCICAPIDAE			
	Pachycephala pectoralis	Golden whistler	9
	Petrocia multicolor	Scarlet robin	6
	Rhipidura fuliginosa	Grey fantail	4
	Petroica phoenicea	Flame robin	2
	Eopsaltria australis	Eastern yellow robin	1
	Rhipidura rufifrons	Rufous fantail	1
	Pachycephala nifiventris	Rufous whistler	1
	Zoothera dauma	White's thrush	1
		Unknown fantail	1

CRACTICIDAE			
	Gymnorhina tibicen	Australian magpie	6
	Cracticus torquatus	Butcherbird	2
ANATIDAE			
	Chenonetta jubata	Maned duck	5
MOTACILLIDAE			
	Rhipidura leucophrys	Willie wagtail	4
PLOCEIDAE			
	Emblema temporalis	Red–browed firetail	3
PARDALOTIDAE			
	Pardalotus striatus	Striated pardolote	3
	Pardalotus punctatus	Spotted pardolote	2
		Unkown pardolote	2
ACANTHIZIDAE			
	Acanthiza pusilla	Brown thornbill	2
	Sericornis frontalis	White–browed scrubwren	2

	Acanthiza chrysorrhea	Yellow–rumped thornbill	1
COLUMBIDAE			
	Ocyphaps lophotes	Crested pigeon	2
	Columba livia	Feral pigeon	2
CACATUINAE			
	Callocephalon fimbriatum	Gang gang cockatoo	2
	Cactua roseicapilla	Galah	1
HIRUNDINIDAE			
	Hirundo neoxena	Welcome swallow	2
PHASIANIDAE			
	Coturnix novaezealandiae	Stubble quail	1
ALCEDINIDAE			
	Halcyon sancta	Sacred kingfisher	1
PTILONORHYNCHIDAE			
	Ptilonorhynchus violaceus	Satin bower–bird	1
UNKOWN BIRD			72

SCINCIDAE			
	Tiliqua scincoides	Blue–tongue lizard	4
	Ctenotus robustus	Striped skink	3
		Unknown skink	86
AGAMIDAE			
	Amphibolurus muricatus	Jacky lizard	7
	Pogona barbata	Bearded dragon	1
		Unknown lizard	22
ELAPIDAE			
	Pseudonofa textilis	Eastern brown snake	5
GEKKONIDAE			
		Unknown gecko	3
HYLIDAE			
	Litoria peronii	Peron's tree frog	5
MYOBATRACHIDAE			
	Limnodynastes dumerilii	Eastern Banjo frog	1
UNKNOWN FROG			16

CYPRINIDAE	*Carassius auratus*	Goldfish	4
UNKNOWN VERTEBRATE			2