Roaming habits of pet cats on the suburban fringe in Perth, Western Australia: what size buffer zone is needed to protect wildlife in reserves?

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ABSTRACT

We radiotracked 18 pet cats *Felis catus* from rural and urban areas within the City of Armadale, Western Australia, both at night and during the day between August 2003 and February 2005 to estimate the size of buffer zone required to reduce incursions by pet cats into native bushland. Home ranges of rural cats ranged from 0.07ha to 2.86ha, while those of urban cats were 0.01ha to 0.64ha. Male and female cats had similar home ranges and there was no evidence of seasonal differences in home ranges. The longest linear distance moved by any cat was 300m, so allowing a 20% margin for estimation error a buffer zone of 360m is needed to reduce incursions by pet cats into native bushland in this municipality.

Key words: *Felis catus*, domestic cat, cat regulation, wildlife protection

Introduction

Despite uncertainties over the true impact of predation by pet cats *Felis catus* on wildlife populations in suburbia, some local councils and state governments in Australia have either implemented or are considering implementing regularions to reduce predation (e.g. Anderson 1994, Pergl 1994, Penson 1995, Kelly 1999, Baker 2001, Buttriss 2001, Moore 2001, Lilith *et al.* 2006). Exclusion zones where residents are not permitted to own a cat are one measure that might be considered to create buffer zones around sensitive wildlife habitat. While they are accepted in some new subdivisions (Buttriss 2001), surveys of community opinion suggest that they attract at best luke-warm support in established suburbs (Grayson *et al.* 2002, Lilith *et al.* 2006). Therefore successful implementation requires a detailed knowledge of the roaming habits of pet cats so that any buffer zone adopted is both adequate for wildlife protection and also of minimum size to reduce disruption to owners (see Das 1993, Barratt 1997b and Meek 2003 for relevant Australian studies and Bradshaw 1992 and Kays and De Wan 2004 for relevant international studies).

This paper reports the home ranges of pet cats in the City of Armadale, a local government municipality on the outer fringes of the metropolitan area in Perth, Western Australia. At the time of writing, Western Australia was one of the Australian states yet to introduce statewide regulations governing cat ownership, although several local government municipalities have taken action (Grayson and Calver 2004). At the instigation of the Armadale City Council (the Armadale local government authority, hereafter the ACC), we radio-collared pet cats of known age from urban and rural areas of the city in both summer and winter and tracked them to determine their home ranges based on both nocturnal and diurnal recordings. Our primary aim was to use the data to recommend sizes for buffer zones where cat ownership could be restricted to reduce incursions by pet cats into known wildlife habitat. As secondary aims, we tested the following predictions based on findings in Bradshaw (1992), Das (1993), Barratt (1997b), Meek (2003) and Kays and De Wan (2004):

1. Male pet cats have larger home ranges than females.
2. Pet cats in the rural residential zones have larger home ranges than those in urban residential zones.
3. Home range size is smaller in cooler conditions (winter compared to summer).
4. With regard to activity patterns:
   - pet cats are more likely to roam in adjoining properties (neighbours) and rest only at home.
   - when roaming, pet cats are more likely to use breaks between vegetation rather than wander into the open.

Methods

Site Description

The City of Armadale (32°15'S, 116°02'E) is located approximately 29km south-east of Perth, the capital of Western Australia. The region has a mediterranean climate and experiences six months of hot, dry weather, encouraging the outdoor husbandry of cats. There are over 19,000 dwellings within the City, zoned urban and rural. The 545 square kilometres of the City include the eastern portion of the Swan Coastal Plain, the Darling Scarp and the Darling Range. In the Darling

Pp 65 - 72 in *Too close for comfort: contentious issues in human-wildlife encounters*, edited by Daniel Lunney, Adam Munn and Will Meikle. 2008. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

Range and Scarp, substantial areas are reserved as water catchment (managed by the Water Corporation and the Western Australian Department of Water) and state forest (managed by the Department of Environment and Conservation). The City of Armadale manages *c.* 1000 hectares of parks and reserves (www.armadale.wa.gov.au).

Study design

The original plan involved radio-tracking known-age cats from urban and rural sub-divisions within the City of Armadale in winter and then the same cats again the following summer. Significant logistic difficulties disrupted this plan. There were problems in obtaining volunteers for both rural and urban trials at the planned times, volunteered cats were withdrawn because of health issues with the animals or inappropriate behaviour and there were significant safety and public relations issues in attempting to follow cats in urban streets and obtain accurate fixes in relation to small, fenced lots. As a result, the final study was an incomplete subset of the original design involving these elements:

- a sample of urban cats and one rural cat radio-tracked in July/August 2003 (winter)
- a sample of rural cats radio-tracked in January/February 2005 (summer)
- a subset of the rural cats radio-tracked in January/February 2005 tracked again in August 2005 (winter).

The implications of these limitations for analysis and interpretation are covered under Data Analysis.

Choice of cats

Twenty study cats were volunteered in response to advertisements in local newspapers but two were considered unsuitable after pre-trial veterinary checks. Most cats (16 out of the 18) were fed twice daily with dried biscuits and either canned or raw meat. The others were fed a similar diet only once daily. No cat was kept primarily to hunt rodents on the property. Owners were asked not to alter each cat's daily routines. Only one cat was confined regularly at night.

In common with most radio-tracking studies, we assumed that the radio-collared animals behave in a manner similar to non–collared animals, that the transmitters do not affect them in any way that makes their responses different from non-collared animals and that they are a representative (random) sample of the entire population (White and Garrott 1990). Owners did not complain of changes in the behaviour of their radio-collared cats.

Urban and rural zones

Cats were divided into two distinct residential codes: urban and rural. Residential houses classed as urban were based on lots less than 2000m^2 (½ acre) and residential houses classed as rural were those with lots ranging upwards from 2000m^2 (or over ½ acre blocks). These values reflected differences in block sizes between urban and rural areas instead of using other considerations for zoning that the ACC might have for its classifications.

Radio-tracking

Radio-collars (weighing *c.* 19.6 g with reflective tape, Titley, GPI-393X2 – 2 stage transmitters) were fitted 24 hours prior to commencement of each tracking session and removed by the owners afterwards. Cats were located with a 6-element hand-held Yagi antenna. Locations or fixes (sighted and triangulated) were recorded in geographical coordinates, Universal Transverse Mercator (UTM), using a hand-held Global Positioning System (Sportrak Magellan GPS). For triangulations, two operators simultaneously recorded the bearing of the transmitter from known positions. Where possible, location of operators 1 and 2 were at approximately 45° angle to the animal's estimated location. If the cat was sighted, its behaviour was also recorded into the following classifications: resting, walking, hunting, or other, and, if walking, whether it was using roads or firebreaks to travel between locations.

Tracking in each session was conducted over 2 days; first session commencing at dawn until mid-afternoon (approx. 0530 – 1500hr) and the second session commencing the following day from mid-afternoon until after midnight (approx. 1600 – 0100hr). Fixes on each cat were attempted every hour throughout the sampling period, giving a maximum of 24 readings. Weather conditions were similar during radio-tracking within each season.

Home range analysis

Bearings obtained ftom triangulations were converted into an x, y coordinate (location estimation) using 'Locate II' software, version 1.82 (Nams 2001). All home range and associated analyses were performed using RANGES 6 (v6.213) (Kenward *et al.* 2003). This plots home range on a background map and calculates home range size using the collected coordinates and based on the peeled Minimum Convex Polygon (MCP) (Southwood 1966). For comparability with other studies, the outlying 5% of fixes from the harmonic mean 'centre of activity' were excluded ftom the estimate. Total home range size (both 95% and 75%) for each cat was estimated using the Harmonic Mean Centre (Hc) (Dixon and Chapman 1980) as the peel centre. The harmonic mean method does not restrict the shape of the home range, and provides the most appropriate non-parametric measure of animal activity (Harris *et al.* 1990).

RANGES 6 (v6.213) was also used to calculate the linear distance between designated points or fixes where a cat was seen. The greatest distance between the home site and any observed fix was calculated for the cat with the largest observed home range and taken as an indication of a prudent buffer zone.

Data analysis

The possible influences of Residence (urban/rural), Sex (male/female), Season (July/August vs January/February) and Age (in years) on the 95% estimates of home range size of radio-collared cats were assessed using ANOVA. Overall, the data corresponded to a repeated measures ANOVA design with Residence and Sex as factors, Season as a repeated measures factor and Age as a

covariate. The dependent variable in each case was the 95% estimate of home range size (hereafter HRS). The HRSs were log-transformed before analysis to correct for inequalities in variances (Statsoft Inc. 1999). No special account was taken of the two rural cats whose roaming habits may have been altered by changes in vegetation caused by bushfires near their homes during the study, nor of the single rural cat commonly confined at night.

However, this design was incomplete because no urban cats were tracked in January/February. Accordingly, we followed the advice of Milliken and Johnson (1992) and analysed complete subsets of the design corresponding to hypotheses of specific interest. Five analyses were completed:

1. Urban female cats vs one rural female cat in July/August 2003 to check for residential differences.
2. All urban cats vs one rural female in July/August 2003, also to check for residential differences.
3. All cats from July/August 2003 (urban) vs all cats from August 2005 (rural) to check for residential and sex differences in a two-way factorial analysis. The analysis assumes that the different years have no major influence on the results. The results must also be approached cautiously, because the August 2005 (rural) sample is a subset of the rural cats with the largest home ranges.
4. All cats from July/August 2003 (urban) vs all cats from January/February 2005 (rural) to check for residential and sex differences in a two-way factorial analysis. In interpreting the results, it was important to bear in mind that this analysis confounded the influences of residence and season.
5. Four cats from January/February 2005 (rural) and repeated data from August 2005 (rural), to check for seasonal differences in rural cats.

The use of multiple analyses increases the risk of Type I error (falsely rejecting the null hypothesis). There is considerable debate on the appropriateness of various corrections in response to this problem, especially given that they may increase the likelihood of Type II errors (e.g. Perneger 1988, Moran 2003, Garcia 2004). Accordingly, rather than apply corrections and risk increased Type II errors with our small sample sizes, we present significance statistics and p-values so readers can draw their own conclusions.

Results

The residential zone, age, sex, breed and home range of each cat radio-tracked are shown in Table 1. All cats were desexed. Table 1 shows the details of 16 cats only (from original 20) as two of the cats radio-collared remained

Table 1. Home range (MCP in hectares) data for 16 cats from all radio tracking sessions. N is the number of radio fixes. Numbers in parentheses in the N column indicate the number of fixes when these animals were sampled again in August 2005.* Denotes that the cat was predominantly in the house, or in the same location over the monitoring period (i.e. most of the radio fixes were identical). # denotes lost collar during study altering the number of radio fixes. ^ denotes cats on properties affected by bushfire. F = female and M = male. Residential zones – urban: housing on < 2000m^2; rural: lot size ≥ 2000m^2. DSH = Domestic shorthaired, DLH = Domestic longhaired.

Name												
ID	Resid	Sex	Breed	Age	N	MCP (ha)	MCP (ha)	MCP (ha)				
		Code			(yr)		July/Aug '03	Jan/Feb '05	Aug '05			
							95%	75%	95%	75%	95%	75%
Billy	M1	Urban	M	DSH	5	25*	0.01	0.00				
Cindy	F1	Urban	F	DSH	12½	15*	0.03	0.01				
Cali	F2	Urban	F	DSH	1½	14*	0.02	0.00				
Rogue	F3	Urban	F	DSH	2	14*	0.03	0.01				
Bob	M2	Urban	M	DLH	~ 7	14*	0.08	0.03				
Dustpan	M3	Urban	M	DSH	~ 5	11#	0.64	0.11				
Ziggy	M7	Urban	M	DSH	4	11*	0.10	0.02				
Stripes	F4	Rural	F	DSH	~ 8½	15#	1.12	0.20				
Melba	F5	Rural	F	Tortoise Shell	4	16(4)			0.85	0.19	(0.01)	(0.00)
Pepper	F6	Rural	F	DSH	5	15*			0.07	0.00		
Tigger	M4	Rural	M	DSH	2½	13(6)			0.78	0.48	(0.79)	(0.08)
Charlie	M5	Rural	M	Burmese (blue)	7	8			0.27	0.09		
Max	M6	Rural	M	Brown Havana	3	11(9)			2.54	0.43	(2.86)	(0.49)
DJ	M8	Rural	M	DSH	7	13(5)			1.87	1.21	(1.41)	(0.29)
Puttaton	F7	Rural	F	DSH	2	4^			0.10	0.03		
Scooter	M9	Rural	M	Spotted Mist	10	10^			0.19	0.04		

Figure 1. M1 (Billy) urban: home range size in July 2003 of 0.01ha (Scale 1:2500).

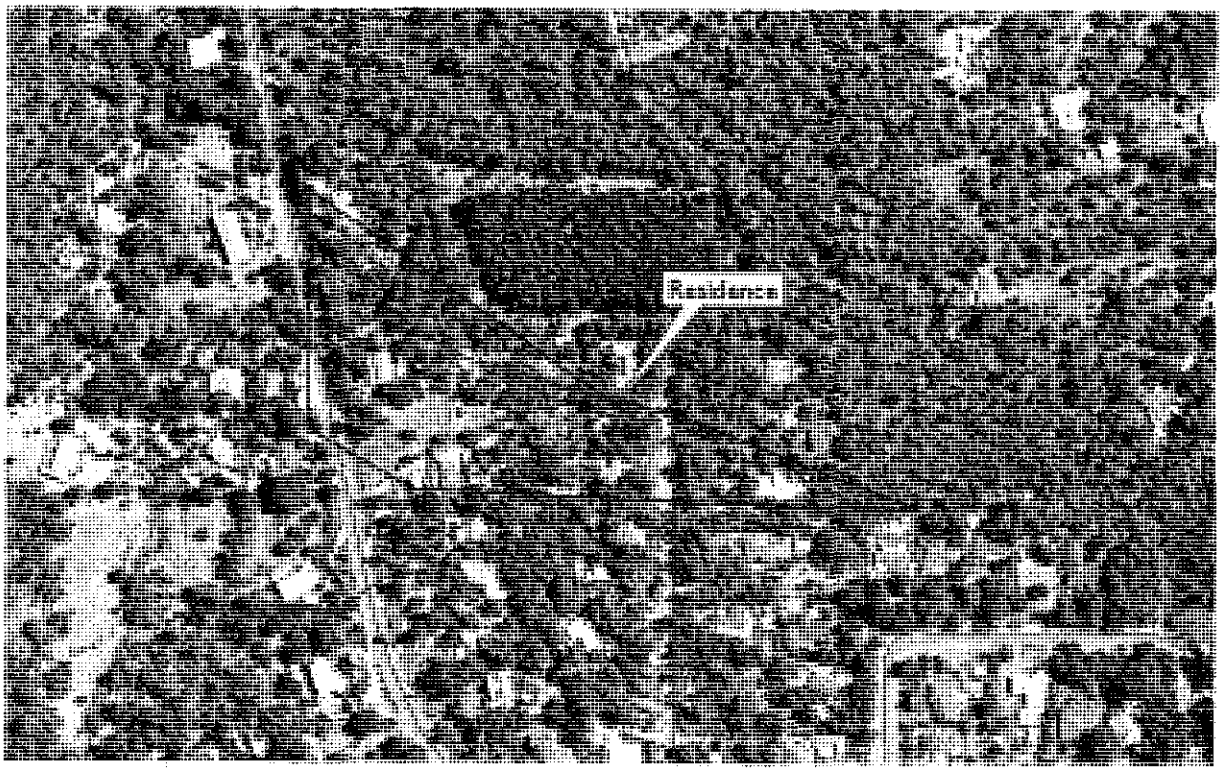

Figure 2. M6 (Max) rural home range in January/February 2005 (in red) and in August 2005 (in blue), Scale 1:2500.

indoors throughout the entire tracking period and a further two cats were eliminated from the study because of health reasons.

All but one cat fell short of the theoretical maximum of 24 readings. Reasons varied. In some cases distances between cats' homes meant long travelling times between cats and rural cats with larger home ranges sometimes took longer to locate in hilly conditions. One cat (M1) had 25 readings because he was opportunistically located when searching for another cat. Most of the fixes of the urban cats were recorded in the owner's yard and all except for M3 stayed within 2 house blocks from home (an approximate radius of <100m). All were free-roaming except for M5, who was regularly confined from dusk to dawn (about 1800 – 0630hrs) and M6 who was confined indoors overnight only if he came

home. Two rural cats (F7 and M9) previously reported by their owners to be free-roaming stayed close to home because of bushfires on their property that month. Home range did not correlate significantly with the number of readings for each cat (r_{14} = -0.09, p >0.5), so there was no bias resulting from cats with larger numbers of readings having larger home ranges.

How big a buffer zone is needed to exclude roaming pet cats from a reserve?

Home ranges for urban pet cats ranged between 0.01 ha – 0.64 ha and rural pet cats from 0.07 ha – 2.86 ha (Figures 1 and 2). The furthest linear distance travelled between a pet cat's home and a fixed location was 300m (rural cat M6 in August 2005). Taking this maximum value and adding a further 20% for a safety margin suggests a buffer zone of at least 360m.

Differences between residential areas and differences between sexes

Using the July/August 2003 data, the home ranges of urban females were compared to the one rural female in one ANOVA, while a second ANOVA compared all urban cats to the one rural female. The rural cat had a significantly larger home range than the urban females ($F_{1,1}$ = 7,479.47, p = 0.007) and also than all urban cats combined ($F_{1,5}$ = 9.11, p = 0.03). The covariate Age was not significant in either comparison.

The home ranges of urban and rural cats of both sexes were also compared in two further ANOVAs: July/August 2003 (urban) vs August 2005 (rural) and July/August 2003 (urban) vs January/February 2005 (rural). Both analyses found significant effects of Residence ($F_{1,7}$ = 8.77, p = 0.02 and $F_{1,11}$ = 5.32, p = 0.04 respectively) while Sex, the Residence x Sex interaction and the covariate Age were insignificant in both cases.

Home range differences between seasons

The four rural cats which recorded the highest home range in January/February 2005 (F5, M4, M6 and M8) were radio-collared again in August 2005 to check if their movements or home range would be affected by seasonal conditions such as shorter day length and cooler temperatures. Repeated measures ANOVA of these data with factors of Sex and Season (the repeated measures factor) and Age as a covariate found no significant difference in seasonal home ranges. Sex, the season x age interaction and the covariate Age were also insignificant.

Observations of roaming and activity patterns in both seasons

Where cats were seen during radio tracking their behaviour at the time was recorded (Table 2). Actual sightings for rural cats were low (approximately half of the radio fixes recorded). In this study area, the residential block sizes usually extend upwards from 2000m² (0.2ha or ½ acre), and generally consisted of native bushland. Those cats observed were either resting or sitting under vegetation in their own yard (68% of the time) and some were seen crouching in tall grass. The majority of the signals for roaming cats came from neighbours' yards. Where cats were not sighted, all fixes obtained via triangulation were in surrounding bushland reserves (73%).

Most urban cats were seen resting under vegetation in their own home or in adjacent properties and, when walking, appeared to use boundary fences. Where not seen, the signals were located within adjoining neighbours' properties.

Discussion

The primary aim of this investigation was to recommend sizes of buffer zones where cat ownership is restricted to reduce incursions of pet cats into nature reserves or conservation sensitive areas within the ACC jurisdiction. Secondary aims were to establish roaming patterns of selected pet cats, (specifically home range size) and compare findings between sexes and between different residential areas. Seasonal effects on home range size were also examined as well as activity patterns when sighted (e.g. roaming or sedentary).

Buffer zones

The five largest home ranges for pet cats found in this study ranged from 0.85ha – 2.86ha. Although all these

Table 2. Observation list for all cats radio-tracked. N(s) denotes the number of sightings within each category. A = within boundary of own home and yard, B = in neighbour's yard (within 100m of own home), C = in neighbour's yard (over 100m from own home) including surrounding bushland, D = along boundary fence or road. *Radio fixes obtained from triangulation i.e. cat not sighted.

Resid code	Cats	A	B	C	D
Urban	Ns (Wandering)	-	2*	-	7
	% of time	-	22%*	-	78%
	Ns (Sedentary)	17	9	-	-
	% of time	65%	35%	-	-
Rural	Ns (Wandering)	4	-	7 32*	1
	% of time	9%	-	16% 73%*	2%
	Ns (Sedentary)	13	-	6	-
	% of time	68%	-	32%	-

cats were rural, it is plausible that urban cats adjacent to a reserve or other tract of vacant land might also range over such distances (one urban cat in this study recorded a home range of 0.64ha). The largest linear distance moved from home by any cat was 300m. Allowing a 20% increase as a margin for error, buffer zones 360m wide around nature reserves or significant native bushland might be needed to prevent incursions by pet cats. However, our sample included only neutered cats and it is possible that entire animals may wander further (Barratt 1997b). Furthermore, our study was based on up to 25 fixes over two days for each cat, which might overlook occasional longer forays. A cautious response might be to increase the buffer zone still further, given that even one free-ranging cat may be a voracious hunter (e.g. Barratt 1997a, 1998). Alternatively, these concerns could be dismissed given that the incidence of neutering in the Armadale cat population is estimated at 91.6% (Lilith *et al.* 2006) and occasional forays will not provide sustained predation pressure.

Cat ownership might be prohibited within the buffer zone, owners in this area might be required to confine cats to their properties at all times or fit them with predation deterrent devices (Calver *et al.* 2007). Given the unenthusiastic response of Armadale residents to enforcing exclusion zones (Lilith *et al.* 2006), implementing buffer zones would require a sensitive public education campaign.

The recommended buffer zone may not be adequate in other regions. For instance, the largest home range identified in this study (2.86ha) is well beneath that found in other Australian studies (Barratt 1997b in Canberra, Australia: 0.02 – 27.93ha, including both diurnal and nocturnal home ranges, based on 10 cats and 13 – 207 fixes/cat; Meek 2003 in Jervis Bay, New South Wales, Australia: 0.02 – 6.51ha, based on 20 cats and 48 – 356 fixes/cat). However, it more than doubles the largest home range of 1.3ha reported in New York, USA by Kays and De Wan (2004) who recorded 24 – 256 fixes each for 11 cats. Although all these studies used more fixes over long periods than we did, there is no obvious relationship between the sample sizes reported (both number of fixes and number of cats) and the home ranges estimated. Therefore we suspect that local conditions are probably most important in determining home range. Therefore the size of buffer zone needed will differ between regions.

Do home range sizes differ between male and female pet house cats?

There were no statistically significant differences in home range sizes between male and female pet cats from the same residential zones, in agreement with Barratt's (1997b) and Meek's (2003) findings in Canberra and Jervis Bay respectively. However, mean home ranges of male pet cats were greater than those for females in both those studies, in agreement with our observations. Sample sizes in all three studies were low and therefore strong conclusions regarding differences (if any) in home range sizes between sexes cannot be achieved, given the high variability between individuals.

Most studies of the home ranges of feral cats show that males have larger home ranges (Jones and Coman 1982, Fitzgerald and Karl 1986, Konecny 1987, Haspel and Calhoon 1989, Smucker *et al.* 2000, Biró *et al.* 2004), while a smaller number of studies did not test for sex-based differences (Naidenko and Hupe 2002) or found no difference in male and female home ranges after statistical testing (Langham and Porter 1991, Page *et al.* 1992). On the basis of our data and the published records, it seems likely that male feral and pet cats do roam more than females although the considerable variability in home range makes statistical validation difficult. Neutering may be a significant factor in sex-based differences in home range size of pet cats (Barratt 1997b), but this is an academic point in Australia where the frequency of neutering exceeds 90% (Grayson and Calver 2004).

Do rural cats have larger home ranges?

Home ranges for urban pet cats ranged between 0.01 ha – 0.64 ha, compared to rural home ranges which ranged from 0.07 ha – 2.86 ha. Differences in home ranges between urban and rural residential areas were found in several different statistical analyses. The most methodologically sound of these were (i) urban females vs one rural female in July/August 2003, and (ii) all urban cats vs one rural female in July/August 2003, because neither was complicated by differences in seasons between urban and rural samples or deliberate selection of a subset of cats with large home ranges, as occurred with the August 2005 (rural) cats. They both indicated a larger home range for the rural cat. The July/August 2003 (urban) and August 2005 (rural) comparison approached significance (with the rural cats having the largest home ranges) and the July/August 2003 (urban) vs January/February 2005 (rural) comparison indicated an effect of residence, albeit confounded by the differences in season. Despite the problems in the latter comparisons, the data overall are strongly suggestive of larger home ranges in rural cats.

Seasonal effects on home range size

No statistically significant effects of season were recorded for the three male and one female rural cats radio-tracked in both summer and winter. Two males showed similar home ranges in both seasons, although their owners reported that they were more likely to return home in rainy or windy conditions during winter and early spring. The other male cat increased his home range despite cooler conditions in August 2005. The sole female cat reduced her HRS in cooler conditions.

Do cats return to the same locations?

Leyhausen (1979) suggested that cats have excellent memory for locality and often return to the precise place of an earlier capture to look for more prey. Two of the four pet cats tracked in two seasons returned to the same locations as before, with the estimated home ranges for each season overlapping substantially. Although one revealed a different roaming pattern, half of its home range still overlapped with the home range from previous tracking sessions. Reasons for this difference were not investigated.

Activity patterns

Cats observed roaming walked under vegetation, near vegetation boundaries or along firebreaks between properties. Only once did we see a cat cross a road in the open and this was at night. Meek (2003) found that the cats in his study also travelled close to fence lines and under vegetation, using roads and tracks only as navigational paths.

However, in contrast to Meek's (2003) study, we found that nearly half of the radio fixes (for rural cats) were in natural bushland, some of which formed the "backyard" of neighbours within this suburb. Many parts of these areas were inaccessible without permission from residents so there were fewer sightings of the cats in the rural areas compared to the urban ones.

Concluding remarks

The roaming data presented here are well short of definitive proof that roaming cats hunt frequently, or that any such hunting is detrimental to wildlife populations. Nevertheless, they do confirm the potential for a problem, because if pet cats did not roam then encounters with wildlife would be greatly reduced. The buffer distances recommended to protect wildlife habitat within the City of Armadale are an option for the ACC to consider in planning any regulations governing cat ownership within its jurisdiction to protect wildlife. Any such measures are unlikely to be a panacea for wildlife conservation within the municipality and, as critics of cat regulation have noted, other actions including habitat protection and restoration, traffic calming and residential zoning should also be considered (e.g. Nattrass 1992, Patronek 1998, Chaseling 2001).

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