Abundance and home ranges of feral cats in an urban conservancy where there is supplemental feeding: a case study from South Africa

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There is much debate surrounding the impact of feral cats (*Felis catus*) on wildlife. Conservancies are usually areas where indigenous flora and fauna are protected and aliens excluded or managed. The University of KwaZulu-Natal's Howard College campus (HCC) is an urban conservancy containing feral cats that are presently not managed, and little is known about their ecology and behaviour. Consequently a feral cat population census was conducted, and their home range investigated. Estimates of the overall campus feral cat population numbers ranged between 23.4–40.0 cats/km^2 with a minimum of 55 identified as resident. They were not randomly distributed in the study area, with spacing patterns being related to resource availability. Home range area and core distribution of eight radio-collared cats were determined over 13 months. Total home range areas were relatively small, with considerable overlap between them. Home ranges were clustered in areas with permanent feeding stations and these were also within the cats' core ranges. Supplemental food resources appear to have a major influence on numbers, home and core range area, and behavior of cats. It is clear that cat densities grow to high levels with reliable and abundant food supply and only ad hoc sterilization. This has implications for their management in the HCC urban conservancy.

Key words: density, conservancy, core range, *Felis catus,* feral cats, population estimate, management, supplemental feeding.

INTRODUCTION

Cats (*Felis catus*) that are feral have been defined as being unowned, unwanted and unconfined cats (Page 1992) that inhabit areas that offer either food or shelter or both (Natoli 1985). Studies show that these cats can exploit a range of different ecosystems, from sub-Antarctic islands (Say 2002) to semi-arid deserts (Apps 1986; Denny 2002). Impacts of feral cats on local wildlife are a contentious issue that is difficult to quantify absolutely. However, this introduced animal has been implicated as a major contributing factor in the decline or extinction of many indigenous species (Dickman *et al.* 1993; Fitzgerald & Turner 2000; Hutchings 2003; Sims *et al.* 2008). Feral cats appear to be a worldwide problem, with studies on their negative aspects conducted in Australia (Jones & Coman 1982; Molsher & Dickman 1999; Molsher 2001; Denny 2002; Molsher 2005), New Zealand (Langham & Porter 1991; Gillies & Clout 2003; Harper 2007), the U.S.A. (George 1974; Patronek 1998; Levy 2003; Schmidt 2007), Europe (Liberg 1984; Mirmovitch 1995; Devillard *et al.* 2003; Sims *et al.* 2008), and oceanic islands (Apps 1986; Bester *et al.* 2002).

Cats are generalist predators (Fitzgerald & Turner 2000; Hutchings 2003), opportunistic in food acquisition (scavenging *vs* hunting) (Tabor 1980; Haspel & Calhoon 1993) and will eat mammals, birds, reptiles, amphibians, fish, insects, carrion, human garbage and plant material (Paltridge *et al.* 1997; Davies & Prentice 1980; Molsher & Dickman 1999; Gillies & Clout 2003; Woods *et al.* 2003; Biro *et al.* 2005). Prey is more at risk in urban environments (Churcher & Lawton 1987) or on islands (Kirkpatrick & Rauzon 1986). Cats switch prey preferences (Fitzgerald & Turner 2000) depending on relative prey availability, ease of capture and abundance (Coman & Brunner 1972; Davies & Prentice 1980). Consequently, feral cats can maintain their population numbers even when prey species become scarce (Denny *et al.* 2002). Feral cats, both rural (Liberg 1984; Devillard *et al.* 2003) and urban (Barratt 1997; Gillies & Clout 2003; Woods *et al.* 2003), are also known to hunt, even if they have access to large amounts of rich refuse or supplemental food supplied by human feeders (Hutchings 2003).

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Both rural and urban feral cat populations have been extensively researched, with most of the results being summarized by Turner & Bateson (2000). However, some populations do not inhabit such clear-cut environments. In rural areas, where population densities are low, feral cats have large home ranges that do not generally overlap (Turner & Bateson 2000; Biro *et al.* 2004; Molsher *et al.* 2005; Harper 2007) unless cats are related (Liberg 1980; Langham & Porter 1991). In urban habitats, however, feral cats occur at much higher densities because of the abundance of edible resources, and home ranges thus tend to be much smaller with some degree of overlap, even between unrelated groups (Page *et al.* 1992; Mirmovitch 1995; Hall *et al.* 2000; Turner & Bateson 2000; Biro *et al.* 2004; Schmidt *et al.* 2007). These overlaps usually occur around feeding sites where the cats will tolerate interactions as long as there is sufficient food (Turner & Bateson 2000). Contact between unrelated feral cats is minimized if the cats use different areas of their overlapping home ranges at different times during the course of the day (Warner 1985; Mirmovitch 1995).

A likelihood of increased feral cat numbers may be that local wildlife may be negatively affected as the overall rate of hunting would increase with the combined effort of increasing numbers of cats. Feral cats may indirectly affect natural predator populations through competition for the same prey species (George 1974; Liberg 1984). Aside from predation and competition, feral cats also interact with native faunas through the transmission of disease (May & Norton 1996; Kauhala *et al.* 2006). Although incidences of transmission of most zoonotic diseases from feral cats to humans is not exactly known (Patronek 1998), cats can be disease carriers (Baxter 1973; Coman *et al.* 1981; Warner 1984) and many cat studies were initiated due to a concern for rabies and the need for sound management policies should an outbreak occur (Page *et al.* 1992; Kauhala *et al.* 2006).

In South Africa, the Howard College Campus (HCC) of the University of KwaZulu-Natal (UKZN) is a registered conservancy. It offers the unique situation of an urban environment alongside a protected, managed habitat that is home to various species of wildlife (Boon & Neal 1999; Boon 2001, 2002). Generally, conservancies aim to eradicate exotic flora and fauna, manage existing indigenous populations and reintroduce species that have become locally extinct. However, the university has a resident feral cat population, whose time of arrival on the campus cannot be exactly traced, and which has not been managed. Ethical responsibilities, public sentiment and logic does not allow for the simple eradication of this animal. Concerned HCC staff members formed 'The Feral Cat Management' committee to try to manage the feral cats through a feeding and an ad hoc sterilization programme (W. Hart, pers. comm.), based on the premises that supplemental feeding would curb their hunting, and that sterilization would keep numbers under control (W. Hart, pers. comm.). There is some support for this strategy (Haspel & Calhoon 1993).

Little is known about the abundance, ecology and behaviour of the HCC feral cat population. Consequently, a population census was conducted, and home range of cats investigated to assist in the formation of a management proposal for the feral cats in the university urban conservancy. It was predicted that home ranges would be determined by resource availability, and in particular supplemental feeding sites.

MATERIALS & METHODS

The study was conducted at the University of KwaZulu-Natal's HCC (Fig. 1) (S29.867, E30.981), Durban, KwaZulu-Natal (KZN), South Africa. The campus consists of urban areas interspersed with conservation-sensitive natural bush habitats and a nature reserve on the northern border (Boon & Neal 1999; Boon 2001, 2002). Most of the central campus is developed with student residences, lecture and food halls, and sporting, academic and administrative activities. Permanent feral cat feeding stations have been set up in some of the more developed areas of HCC (Fig. 1) and are maintained daily by feeding volunteers.

There is debate about sampling frequency in terms of population estimates and home and core range determination. Some stress the importance of data being statistically independent, particularly if intensive data collection only inflates sample size, and contributes little additional information (White & Garrott 1990). However, others suggest that data need only be biologically independent (Lair 1987; de Solla *et al.* 1999). Avoidance of autocorrelation can alter apparent patterns of the animal, and consequently its actual use and distribution. Additionally, current methods used to detect autocorrelation are not necessarily suitable for all organisms (Andersen & Rongstad 1989). It was recommended that data collection occur at short time intervals, although statistical inde-

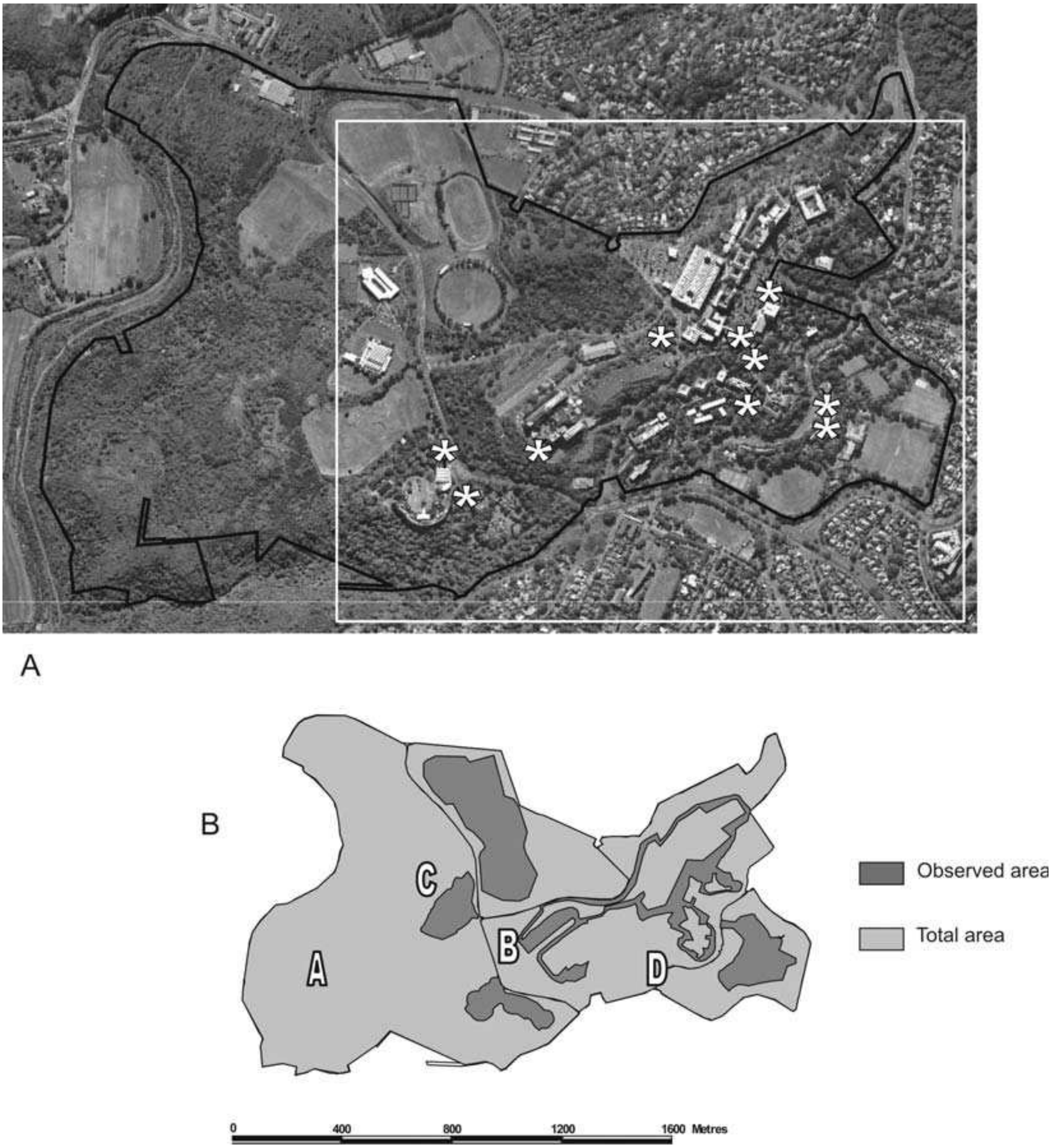

Fig. 1. The Howard College Campus, UKZN, with (**a**) an aerial photograph, with regular cat feeding stations shown (stars) (the white box indicates the area shown in Fig. 4b), and (**b**) the total campus grounds area with the four sub-habitats (A–D) indicated (see methods for details).

pendence might not be met, to achieve better estimates of home-range size and population densities in some species (Reynolds & Laundre 1990; de Solla *et al.* 1999). Autocorrelated observations are often associated with important resources and can reflect features of an animal's use of space (Swihart & Slade 1985, 1997; Lair 1987; Swihart *et al.* 1988). If criteria for biological independence are determined prior to data collection, and appropriate sampling interval followed, it can be argued that statistical measures of autocorrelation are irrelevant (de Solla *et al.* 1999). Small felines are generally crepuscular (Izawa 1983; Langham & Porter 1991), thus dusk and dawn were deemed most suitable to observe feral cats. Feral cats in this study were often located in the same position for consecutive sightings; however, rarely were they disturbed by the trackers when they were located. If they were, they only moved off a few metres from their original positions and then settled again. Observations recorded at least an hour apart were felt to be sufficient to assume biological independence and importantly were related to the cats' behaviour and habitat use.

Estimating population abundance is central to the sound management of a species, particularly an exotic species (Jachmann 2001). Various techniques are used to count mammals, including total counts, strip and line transects, individual recognition, counting/mapping calls and trapping (Sutherland 1997). Although the use of the distance sampling method to calculate density estimates is currently popular (Anderson *et al.* 1983; Sutherland 1997), this technique could not be used in the present study as the heterogenous developed layout of HCC did not allow straight line transects or unrestricted access to the entire study area.

Although absolute counts are often constrained and time-consuming (Jachmann 2001), and some areas on HCC are difficult to access, a direct method of estimating population abundance, namely a total enumeration of the feral cats over time, was conducted using individual recognition (Langham & Porter 1991; Page *et al.* 1992). Use of digital photographs, together with full descriptions of all cats encountered on HCC during the monthly census and the radio-telemetry study (Tennent 2005), allowed identity profiles for most of the observed HCC cats to be catalogued. Cats were recognized from their markings and other notable features like clipped ears, scars or short tails. These profiles were used to determine a total count of feral cats on the HCC.

As cat densities vary greatly depending on habitat type (Liberg 2000), HCC was divided into four sub-habitats according to accessibility and difference in vegetation (Fig. 1). These areas were separated by roads and fences, and permanent cat feeding sites occurred in two of the four areas. Five permanent transects, of varying lengths, were established across these four areas and mostly followed existing roads and pathways. In certain areas, transects cut across open parks, sporting grounds/courts or the open-air theatre. Transects 1 and 2 were situated in Area A, which has a large area of indigenous vegetation and the University's student residences with two permanent feeding sites. Transect 3 was in Area B, the central part of HCC containing lecture venues and administration buildings and several permanent feeding stations at various sites. Transect 4 was located in Area C, the Msinsi Nature Reserve which had no established feeding stations. Transect 5 was located in Area D, an area with student residences and sporting facilities. This area had some development during the study period with some of the open grass areas converted into parking lots.

A group of three researchers (two as observers and one recorder) walked all five transects from 16:00–19:00 and again from 04:00–07:00 the following day. This was repeated 2–6 times each month for 10 months, with increased sampling if there was inclement weather, as this affected visibility. The time zone of 3 h ensured that all transects were walked in each dusk/dawn period.

All cats seen along transects were counted and allocated to an age class: kittens: younger than four months, usually still with their mother; juveniles: no longer accompanied by their mother but still too small to be classified as an adult; or adults. Once a cat was observed, its exact position was recorded using a hand held personal navigator global positioning system (GPS) (Garmin eTrex, U.S.A.).

Walked transects were a form of ground sample counts, with random sampling of variably sized transects (Jachmann 2001). Areas A–D, as well as the total visible areas along transects, were estimated using ArcView 3.1 (ESRI GIS and Mapping Software, U.S.A.). As HCC is well lit both in the early mornings and in the evenings, a large area was visible to the observers at any given time while following the transect line. Thus, the GPS coordinates for each cat were taken on the spot where they were observed and the total observed area around each transect was used to calculate density estimates for each area. Dusk and dawn population estimates were obtained. For the ground sample counts, whole areas around the transect lines were observed while walking. Thus, this method was more representative of a sample area and was then extrapolated to calculate feral cat abundance of the entire area (Greenwood 1997) by working out the number of cats per km^2 for each sub-habitat.

Eight adult feral cats from HCC were trapped and collared within a two-month period. Cats were trapped using live-capture cat traps (900 × 300 × 300 mm) baited with either cat pellets or raw chicken pieces. Traps were set away from public view and checked every 3–4 h. Once a cat was caught, the cage was covered with a dark blanket and transported to a veterinarian. Chanazine 2% and Anaket-V (Bayer) injections (0.3–0.5 ml, depending on body size) were administered to anaesthetize the cats. None of the cats caught had been sterilized so the first four cats were sterilized, and the last four cats were left intact as it was hoped initially to compare the two groups.

While anaesthetized, each cat was fitted with a radio-transmitting collar. These (<5% of total body mass) consisted of a radio transmitter (150 MHz band) with a AA battery pack (designed to last more than 12 months), and a material collar with the aerial woven into the fabric. Collars had been tested on cats at the SPCA in Pietermaritzburg, KZN, under supervision of a veterinarian and two veterinarian nurses. Each cat was photographed, sexed, weighed, measured, and reproductive status and body condition recorded. Cats were monitored until they regained consciousness, and released at their point of capture.

Radio-collared cats were tracked for four consecutive days per month from June 2004 to June 2005. Two teams of three researchers worked in alternate 5–6 h shifts, locating and collecting data on all collared cats every hour starting 19:00 the first evening through to 06:00 of the last morning; a collective time frame of 30 consecutive hours excluding the one-hour breaks in between each shift. Torchlight was seldom used and was mostly unnecessary due to ambient lighting around the campus. A hand-held aerial with a wideband receiver (Arlinco) was used to locate the cats. Time, date and geographical coordinates (using a Garmin eTrex personal navigator), as well as activities, presence of food and number of other cats present were recorded. Usually the exact location of each cat was determined; however, sometimes it was necessary to use triangulation if the area was covered in dense bush.

Home ranges of cats were estimated using ArcView 3.1 (Environmental Systems Research Institute (ESRI) Global Information Systems (GIS) and Mapping Software, Redlands, California U.S.A.) with the kernel analysis function in the home range extension (HRE). Smoothing parameter (bandwidth-h) was the most important step in deriving a kernel density estimator (Worton 1989), but there seemed to be no generally accepted method available for determining the right h-value, so the smoothing factor was determined as follows. First, the location points for each cat were analysed via the adaptive kernel estimator, using the 'h-ref' parameter and the program's default raster resolution value (70) (Rodgers & Carr 1998). A range of h-values were achieved for each cat ($n_t = 48$) and the median of these values was then used as the final smoothing factors to determine diurnal and nocturnal range areas for four periods (vacation 1: winter, semester 1: late winter–spring, vacation 2: summer, and semester 2: late summer–autumn), with a fixed kernel density estimation (Worton 1989; Barg *et al.* 2005; Wronski 2005). Core ranges are described as exclusive areas (Maher & Lott 1995) within an animal's home range that are used intensively (Barg *et al.* 2005). Total home range area as well as core range area (see Barg 2005) were determined and tested for significant differences.

Comparisons between day and night, and between months, as well as between techniques, for the various variables were conducted using either *t*-tests or generalized linear model (GLIM) repeated measures analysis of variance (RM ANOVA) with Statistica (StatSoft, version 7, Tulsa, U.S.A.). Means are expressed as mean ± S.D. in the text.

RESULTS

Abundance

Using the total count method it was determined that there were 55 resident feral cats (including eight collared) on HCC. Of these, 34 were positively identified based on digital photographs and descriptive records. Few new individuals were added after the second month of study as fieldwork progressed as can be seen from the asymptote reached in cumulative numbers of cats suggesting an entire population sampled (Fig. 2). From the monthly total counts, a HCC cat density of 32.0 ± 6.61 cats/km^2 ($n = 9$) (for the entire campus) was calculated.

Feral cats were not present in all areas of HCC. No cats were seen in the Msinsi Reserve throughout the study period. Numbers of feral cats along transects were used to estimate monthly feral cat abundance for Areas A, B and D of HCC, and were expressed as estimates for dusk and dawn respectively (Fig. 3). Five hundred and ninety-one cats were sighted in total during the transect walks; 63% ($n = 371$) in the evenings and 37% ($n = 220$) during the mornings. No significant differences were observed between sub-habitats when comparison of months, time of day and areas were analysed together (GLIM RMANOVA; $F_{(18,40)} = 0.64$, $P = 0.84$). Kittens and juveniles were observed almost every month (Table 1) but their inclusion had no obvious affect on population size. There was difficulty in observing kittens as many were concealed. Consequently, numbers of kittens seen

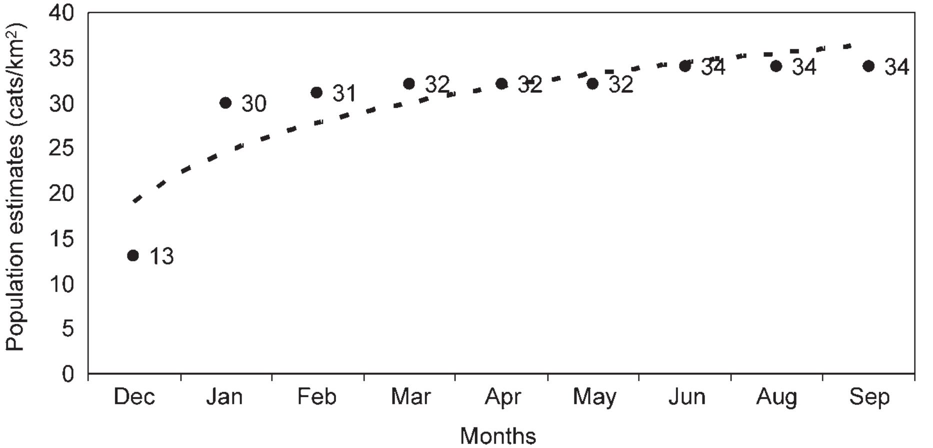

Fig. 2. Comparison of total count numbers of feral cats on Howard College Campus, UKZN, with month during the study. The dotted line shows that after the second month the asymptote was reached in cumulative numbers of cats suggesting the entire population was sampled.

Table 1. Monthly mean number of Howard College Campus feral cats according to age class using the transect counts.

	Dec	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep
Kittens	1.0	2.0	3.0	5.0	0.0	1.0	1.0	0.0	1.0
Juveniles	1.0	1.6	1.0	1.0	0.0	2.5	3.0	2.3	6.0
Adults	11.8	21.0	13.5	10.0	12.5	9.0	8.5	13.0	11.8

each month probably represented an underestimation. Therefore no ratio of adults to kittens was calculated.

Areas A and D were expected to have similar feral cat densities because of their similar habitat structure. However, sampling intensity (%) during transect counts, expressed as the proportion of observed area size of the total area, was 6.4% for Area A compared with 32.1% in Area D, giving calculated cat densities of 66.9 ± 42.8 cats/km^2 and 2.2 ± 3.2 cats/km^2, respectively. By contrast, Area B, considered the high-density area but with a sampling intensity of only 19.0%, had a cat density of 51.0 ± 3.2 cats/km^2, which was less than Area A. Summation of the feral cat numbers obtained from each sub-habitat gave an estimated overall population abundance of 40.0 ± 33.7 cats/km^2 which highlights the need to account for sub-habitat differences.

Home range

Of the eight feral cats fitted with radio-collars, only six (three males; three females) kept their radio-collars for the full duration of the study and were considered for analyses. For these cats, a total of 2275 location points was recorded monthly over the year, of which only 757 (33%) were obtained through triangulation because there were no visual observations of the focal cats. An average of 346 location fixes for each cat was included in the analysis of their home range area.

Estimates of total home range area of the six monitored feral cats were determined using all the location fixes recorded from the entire study period (over 360 h of surveillance; Table 2). All home ranges of collared cats were in the developed

Table 2. Total home range area of feral cats (*Felis catus*) on the Howard College Campus calculated using the fixed kernel method with number of locations (*n*) and the smoothing factor (*h*) used to generate these estimates shown.

Cat	Status*	Gender	*n*	*h*	Total home range (m^2)
020	I	M	321	0.382	65 455
120	I	F	330	0.380	62 037
500	S	F	390	0.370	37 234
550	S	F	316	0.383	108 314
570	S	M	341	0.378	59 804
990	I	M	374	0.373	104 624

*I = intact, S = sterilized; M = male, F = female.

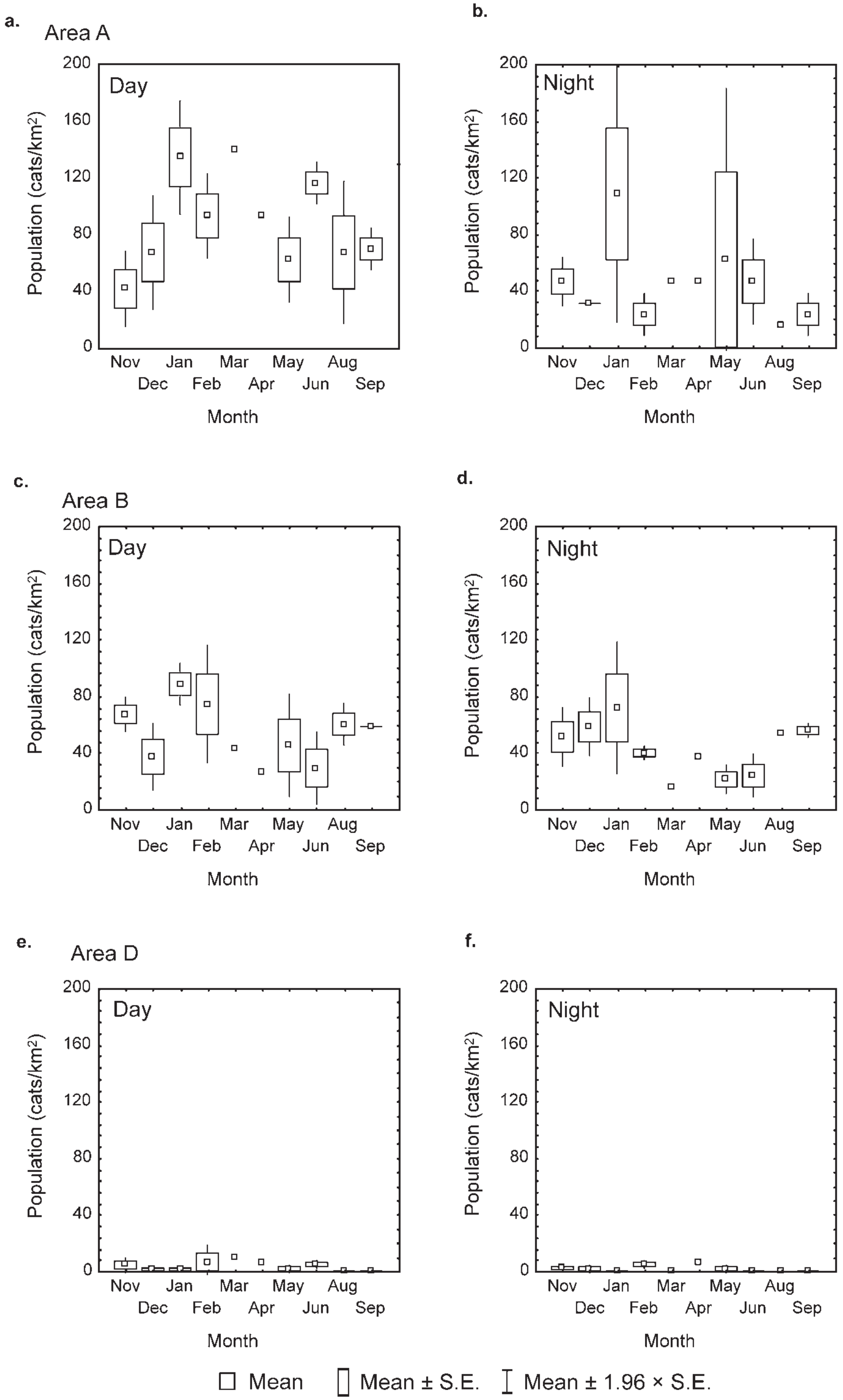

Fig. 3. Comparison of monthly population density estimates of feral cats on Howard College Campus, UKZN, from the transect method for each sub-habitat at different times of day; Area A: (**a**) day and (**b**) night; Area B: (**c**) day and (**d**) night; Area D: (**e**) day and (**f**) night.

Table 3. Variation in home range areas (m^2) of feral cats (*Felis catus*) on the Howard College Campus, UKZN, calculated by the fixed kernel method.

	Semester 1 Late summer–autumn		Vacation 1 Winter		Semester 2 Late winter–spring		Vacation 2 Summer	
Cat	Day	Night	Day	Night	Day	Night	Day	Night
20	77 766	63 737	24 753	68 846	59 467	56 301	77 458	101 588
120	39 002	55 706	14 812	65 353	55 989	63 792	31 569	48 852
500	31 234	29 016	40 899	33 210	17 684	50 023	28 464	33 318
550	11 108	174 585	7 060	45 163	16 019	72 797	13 475	151 201
570	9 876	75 428	10 294	65 053	45 424	32 905	27 217	63 809
990	36 409	54 831	80 496	76 154	19 785	75 878	58 178	75 257
Mean	34 232.5	75 550.6	29 718.9	58 963.3	35 728.1	58 615.9	39 393.4	79 004.1
SE	10 098.9	20 765.4	11 315.1	6 645.2	8 238.7	6 496.5	9 665.3	17 285.6

section of campus where permanent feeding stations were situated. There was no visual evidence of feral cats in the Msinsi Reserve area, although calculations show that a part of the reserve was included in cat 550's outer range. Total home range areas of feral cats differed significantly (*t*-test, $t = 6.41$, d.f. = 5, $P = 0.001$; Table 3), and there was substantial overlapping of all ranges outside the core areas (Fig. 4). However, there was no significant difference in home range between seasons, and between day and night (GLIM RMANOVA; $F_{(3,15)} = 0.355$, $P = 0.786$). Similarly core range areas did not differ significantly between seasons, and between day and night (GLIM RMANOVA; $F_{(3,15)} = 0.179$, $P = 0.909$). However, they were smaller during the day. Core ranges were generally relatively small (Table 4, range 735.47–29 443.68 m^2, shown as filled in areas Fig. 4) and there was no overlap between radio-collared cats. Some feeding stations occurred either within certain core areas (cats 500, 020 and 120) or in close proximity. Some core areas of cats were within range of more than one feeding station. Because some of the study animals lost collars, no differences between non-sterilized and sterilized feral cats were determined.

Supplemental feeding usually occurred between 14:00 and 16:00 daily throughout each semester but was irregular during vacations. One station was not supplied with food for a period of approximately two months (part of S3 in Table 4) and cat 500, a female feral cat born in the area after the station had been established, had home and core ranges areas that were smallest diurnally and greatest nocturnally over this period (aside from this period, her diurnal ranges were bigger for both home and core ranges than her nocturnal range areas). Another of the cat's (Catsterilised 550) transmitters was found to be faulty during the time period S2 (a signal could only be located if the batteries in the receiver were more than half charged) thus values in this time period are lower than expected due to the small number of fixes.

Table 4. Variation in core range areas (m^2) of feral cats (*Felis catus*) on the Howard College Campus, UKZN, calculated by the fixed kernel method.

	Semester 1 Late summer–autumn		Vacation 1 Winter		Semester 2 Late winter–spring		Vacation 2 Summer	
Cat	Day	Night	Day	Night	Day	Night	Day	Night
20	12 726	3 742	12 976	14 600	9 205	13 183	8 186	16 188
120	5 635	9 258	3 174	6 693	11 438	13 910	6 413	7 988
500	4 968	3 884	6 569	5 453	2 506	10 836	5 067	4 588
550	1 034	29 444	735	7 603	1 559	14 695	1 342	25 031
570	1 218	11 224	1 200	16 018	6 129	5 926	4 285	7 485
990	5 852	10 522	19 321	13 919	4 025	11 700	8 163	1 335
Mean	5 238.9	11 345.7	7 329.3	10 714.4	5 810.4	11 708.3	5 576.0	10 436.0
SE	1 737.0	3 856.1	3 025.4	1 888.8	1 586.2	1 292.8	1 065.6	3 548.9

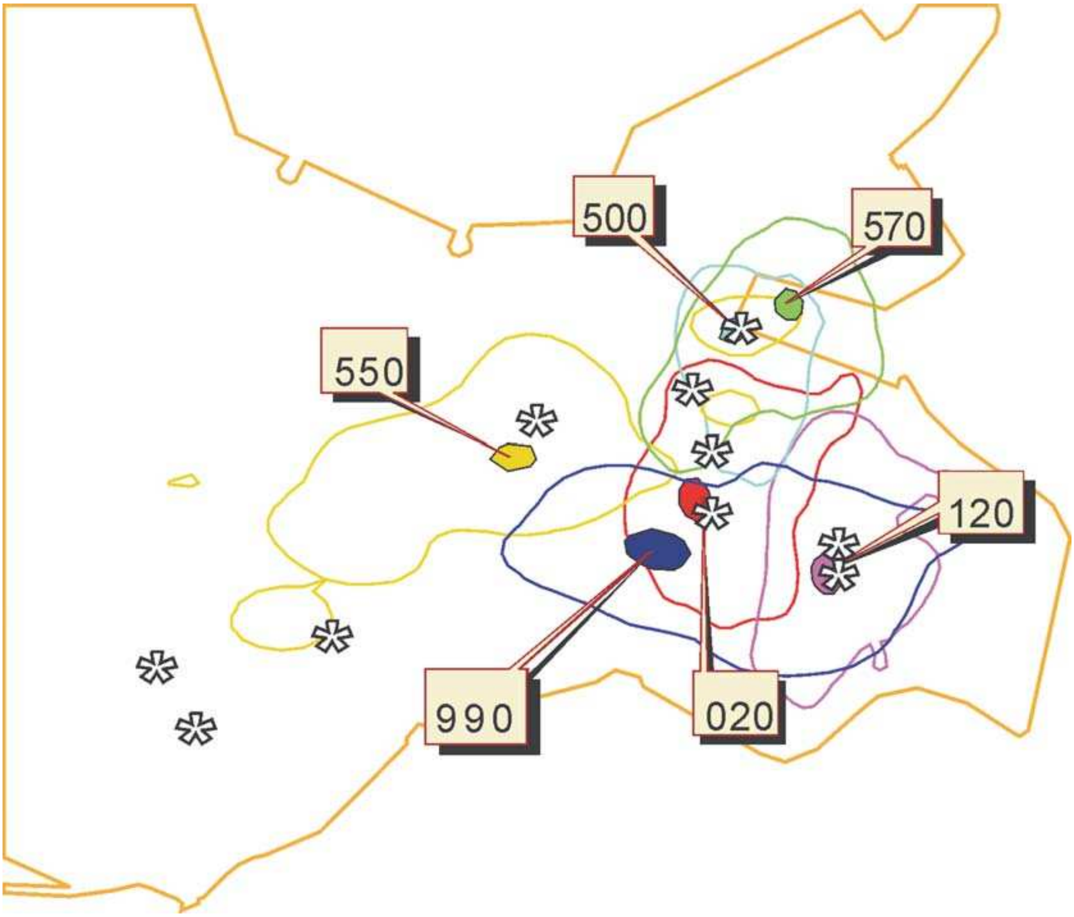

Fig. 4. Total home and core ranges of the six collared feral cats radio-tracked on Howard College Campus, UKZN. Shaded areas represent core areas and contour lines indicate total home range. Numbers in the callout boxes are the identity numbers given to each cat.

DISCUSSION

Feral cat distribution on HCC was not homogenous. The Msinsi nature reserve, an important part of the HCC conservancy, had no feral cats during this study, although a feral cat has been seen there since the study's completion (R. Uken 2005, pers. comm.). Feral cats were concentrated in areas with reliable food resources in the form of feeding stations and poorly contained refuse, and shelters (Tennent 2005). There was apparently less competition and less effort required in acquiring these resources (pers. obs.). Therefore, as in other studies, food abundance was an important factor related to feral cat density with cats concentrated near supplementary feeding sites. An excess of available food may maintain cat numbers when local prey numbers are at a minimum (Turner & Bateson 2000). While feral cat feeding stations may cause a re-distribution of cats instead of actually increasing their numbers (Haspel & Calhoon 1993), the constant supply of food encourages formation of social groups (Laundre 1977), reduces territorial interactions, and perhaps increases longevity of adults (Warner 1985).

Estimates of overall campus feral cat population numbers ranged between 23.4 and 40.0 cats/km^2, although the total count method identified 55 individual resident cats during the study. The HCC feral cat population appears relatively high, particularly in some areas (Liberg 2000). Although higher numbers are generally associated with supplementary feeding stations (Table 5; Liberg 2000). Different sub-habitats within the university grounds gave varying estimations of feral cat density – the lowest in an area without permanent feeding stations and the highest in areas with

Table 5. Density categories of cat populations according to food situation (adapted from Liberg *et al.* (2000)).

Density category (cats/km^2)	General characteristics of the food situation
More than 100	Rich clumps (garbage bins, fish dumps, cat lover handouts).
5 –50	Thinner clumps (farms and other households, bird colonies on islands, or rich dispersed prey).
Fewer than 5	Scarce dispersed prey, might occur in patches, but no rich concentration of food.

several feeding stations. Consequently, it appears that feral cat numbers were at a higher density than would be expected if the feeding sites were not present. Lack of information on numbers of sterilized cats campus-wide further compounded the situation. Most cats identified were observed within the first few months of the study with only a few new individuals identified in subsequent months. However, kittens and juveniles were observed throughout the study period, and some kittens were seen right through to their subadult stage.

Liberg (2000) showed population densities of cats were negatively correlated with home range area. In urban areas, population densities are usually in excess of 300 cats/km^2 and female range areas vary between 300 and 42 400 m^2, while males range between 800 and 240 000 m^2 (Liberg 2000). However, cats at population densities that are intermediate between rural and urban populations usually have home range areas between 7000 and 150 000 m^2. Similarly, range areas in the present study varied between just over 37 000 and 108 000 m^2. Home ranges of the HCC cats also overlapped considerably, with both the intact males occupying almost the same areas (cats 020 and 990), although they still maintained exclusive core ranges. The implications of this are that food is not a limiting factor and that, in fact, it is probably in excess so there is no need for territoriality through competition (Calhoon & Haspel 1989; Maher & Lott 1995).

Tabor (1980) showed that a superabundance of food led to a reduction in home range area and a greater cat density; however, Haspel & Calhoon (1993) argued that such elevated density does not necessarily reflect an actual increase in population size, but rather a redistribution of the cats within the population. Our results show that the cats preferred to rest in areas away from any food sources, but that when active they were usually feeding on site or moving within 5–10 m of the nearest food source (pers. obs.). Prey activity is the primary factor that controls daily activity patterns and its seasonal changes in most carnivores (Izawa 1983), and studies show that instead of having an activity pattern that is correlated to prey activities, most semi-dependent cats (i.e. those feral cats which have become accustomed to daily supplemental feeding at a specific time) show periods of activity that coincide with the arrival of feeders with food (Fitzgerald & Turner 2000). A negative aspect of permanent feeding programmes is a reduction in territoriality, and activity rates are also lower in response to an abundance of edible resources (Tabor 1980; Warner 1985; Konecny 1987) as there is no advantage for territoriality (Konecny 1987).

In conclusion, supplemental food resources, usually in excess, appear to have a major influence on density, home and core range area and location of feral cats in the HCC urban conservancy. It is clear that cat densities grow to high levels with reliable and abundant food supply and only ad hoc sterilization.

This has implications for their management in the HCC urban conservancy.

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