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Ecological impact of inside/outside house cats around a suburban nature preserve

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Abstract

While subsidised populations of feral cats are known to impact their prey populations, little is known about the ecological impact of inside/outside hunting cats (IOHC). We studied IOHC around a suburban nature preserve. Mail surveys indicated an average of 0.275 IOHC/house, leading to a regional density estimate of 0.32 IOHC/ha. A geographical model of cat density was created based on local house density and distance from forest/neighbourhood edge. IOHC hunted mostly small mammals, averaging 1.67 prey brought home/cat/month and a kill rate of 13%. Predation rates based on kills brought home was lower than the estimate from observing hunting cats (5.54 kills/cat/month). IOHC spent most outside time in their or their immediate neighbours' garden/yard, or in the nearby forest edge; 80% of observed hunts occurred in a garden/yard or in the first 10 m of forest. Radio-tracked IOHC averaged 0.24 ha in home range size (95% minimum convex polygon (MCP)) and rarely entered forest. Confirming this, scent stations detected cats more often near the edge and more cats were detected in smaller forest fragments. There was no relationship between the number of cats detected in an area and the local small mammal abundance or rodent seed predation rates. Cold weather and healthy cat predator populations are speculated to minimise the ecological impact of IOHC on this area.

Domestic cats (*Felis silvestris catus*) are of special concern for conservation biologists because of their record as a subsidised exotic predator of native species. Because they often receive supplementary food from human caretakers, they can reach densities of 100 times or more higher than native carnivores (Coleman & Temple, 1993). The consequences of their hunting have been especially severe on oceanic islands with no native mammalian predators, where native prey species have little innate ability to elude cat predation (e.g. Bloomer & Bester, 1992; Stiling, 1996). Evidence is accumulating that continental cats may also be a conservation concern because of the effects their subsidised populations can have on native prey (Crooks & Soule, 1999; Baker *et al*., 2003).

However, *F. silvestris* lives in a number of distinct domestic and wild situations and it is important to consider this variety when evaluating their conservation risk in any particular situation. Studies on their ecological role have typically focused on worst case scenarios such as feral cats, farm cats and 'cat colonies' (mostly neutered strays fed and given shelter at one centralised structure: Clarke & Pacin, 2002). Truly feral cats receive little or no food from humans and hunt as much as four times more than domesticated animals (Liberg, 1984; Paltridge, Gibson & Edwards, 1997). Most cats living on farms or managed colonies receive supplemental nourishment from humans, but also hunt for meals. These cats live at such high densities that their impact on the local fauna can be substantial (Hawkins, 1998). Managed colonies, in particular, pose a significant threat if located near protected areas (Weber & Dailly, 1998; Clarke & Pacin, 2002).

However, most cats are not as free-ranging; rather, they live as well-fed house pets. Estimates put the owned cat population of the USA at around 60 million and the stray/feral cat population at between 25–40 million (Patronek & Rowan, 1995). It is estimated that over 50% of these owned cats spend time outside their house (APPMA, 1997). These inside/outside house cats (IOHC) typically receive all their food from their owners; their hunting appears to be more recreational or opportunistic, rather than directed towards feeding themselves or their litters (Leyhausen, 1979). Surprisingly, few studies have documented the ecological effects of IOHC; even ranging patterns and hunting rates of this type of cat are poorly known (Fitzgerald, 1990; Fitzgerald & Turner, 2000).

What is the ecological effect of this recreational hunting? A number of studies have sounded the alarm against letting house cats roam outside based on the number of small prey they bring home (Meek, 1998; Robertson, 1998; Woods, McDonald & Harris, 2003). However, only one study has actually documented a negative impact of these IOHC on a wild population of

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prey in natural areas (scrub breeding birds: Crooks & Soule, 1999). In fact, some authors have warned against wide ranging civic regulation without more data about the hunting habits and ecological impacts of domestic cats (Fitzgerald, 1990; Jarvis, 1990). Although small mammals are the most common prey of housecats (Liberg, 1984; Meek, 1998), the impact (or lack there of) of IOHC on natural small mammal populations is rarely mentioned and most discussion has centred on their impact on birds. This question has important ramifications past the mere conservation of the small mammals themselves, since they often play important ecosystem roles as seed dispersers/predators and vectors of diseases (Ostfeld, Manson & Canham, 1997; Ostfeld & Keesing, 2000).

Because IOHC are so prevalent in society, it is important to understand the conservation implications of their predation on native prey in natural habitats. With this as our overall objective, we studied a population of IOHC around the suburban Albany Pine Bush Preserve (APBP), New York, documenting their density, use of the landscape, hunting habits, effect on small mammal populations and effect on rodent seed predation rates using a suite of complementary techniques. If IOHC are a major conservation threat to the preserve, we would expect them to range widely through the preserve, hunt native prey within the preserve at a high rate and reduce the abundance of prey in areas where they hunt the most, thereby also affecting the ecological processes associated with these prey populations.

METHODS AND MATERIALS

Study site

This work was conducted in the forest fragments and neighbourhoods in and around the Albany Pine Bush Preserve (APBP), Albany, New York, USA – a small protected area completely surrounded and bisected by suburban development (Rittner, 1976; Barnes, 2003). This study focused on mixed deciduous/coniferous forests. Our 60 km^2 study area included 37.6 km^2 of forest, with the remaining area being suburban housing and commercial development. At larger scales, this area was flanked by urban development to the east and north and a mix of suburban development and rural areas to the west and south.

Mail surveys of cat owners

In April of 2001 we hand-delivered surveys and self-addressed stamped envelopes to 600 houses that directly bordered or were across the street from the preserve. This one-page survey asked if the respondent owned cats and if their cat(s) hunted outside. Additional questions were asked about wildlife seen in their garden/yard over the last year and potential cat–wildlife conflict.

Prey brought home by cats

Eight households (representing 12 cats) collected and froze 60 dead prey brought home by their hunting cats from early May to late July of 2002. We collected these frozen carcasses and identified their species and age.

Radio-tracking and behavioral observations

We radio-tracked 11 IOHC from 8 households bordering the APBP from May to August of 1991. Cooperative pet owners were identified through our mail survey and they affixed the radio-collars (Advanced Telemetry Systems, Isanti, MN, USA) to their pet cats. In addition, we trapped, radio-collared and tracked one feral cat in the area. We used telemetry to home-in on focal animals and watched their behaviour from a distance with binoculars for a total of 181 h of observation. We recorded exact movement paths onto fine-scale paper maps and then entered these locations into ARCVIEW GIS (3.2). We used headlamps covered with red filters for nocturnal observation. We recorded all hunt attempts ($n = 31$), narrowly defined as a distinct fast chase or pounce after seen or unseen prey. We used the ARCVIEW Animal Movement Extension (Hooge & Eichenlaub, 1997) to calculate 100% and 95% minimum convex polygon (MCP) home range areas. In selecting fixes for the 95% MCP we used an independence interval of 1 h between fixes, since a cat could easily cover its home range in this time (Doncaster & Macdonald, 1997). This reduced 735 total fixes to 249 independent fixes (85% diurnal, 15% nocturnal).

We sought to obtain even sample sizes for each radio-collared cat and to obtain more nocturnal observations, but this was impossible because some cats were typically inside their house, especially at night. Thus, our sample size for each cat is also a general indication of the amount of time that individual spent outside. To evaluate the impact of this low fix number on home range measures we calculated the average 95% MCP for different samples sizes for each individual cat through bootstrap resampling of independent fixes (100 replicates, starting $n = 5$, interval $n = 2$: Hooge & Eichenlaub, 1997).

Scent stations

From June to August 2001 we surveyed 22 forested sites for the presence or absence of domestic cats using 108 scent stations. All study sites had coniferous/deciduous forest cover and were embedded in a suburban landscape (not commercial or industrial). Twenty-one sites had 5 scent stations spaced every 58 m around a circle radiating 50 m from a common centre point; one site had only 3 scent stations due to the small size of the forest fragment. Each scent station was run for 1 night and consisted of a fatty acid scent tablet (Andelt & Woolley, 1996) placed in the centre of a 1 m radius circle of raked sandy soil to record footprints of visiting animals. Each scent station was also monitored using a motion-sensitive camera trap (http://www.Camtrakker.com). If rain obscured tracks, the setup was moved and this site was sampled again later in the summer. Large forest fragments (> 40 ha) were sampled at both their centre (> 100 m from forest edge) and edge (< 100 m from forest edge). Because cats were individually identifiable by coat pattern, we counted the number of cats photographed by the camera-traps at each site as a measure of local abundance.

Modelling cat density

We digitised individual houses in a 60 km^2 area around and including the nature preserve using natural colour digital orthoimagery taken in 2000 (2 ft resolution: http://www.nysgis.state.ny.us). We did not digitise apartment complexes because it was impossible to determine the number of units per building and because most do not allow cats. We combined our average IOHC per house (0.275) with this data on house distribution to estimate the local density of IOHC across the study site. We calculated this using the kernel density estimator of ARCGIS 8.1 (ESRI, Redlands, CA, USA) with a cell size (i.e. resolution) set to represent one domestic garden/yard (50 m) and the search radius (i.e. degree of smoothing) set to represent the diameter of a typical cat home range (183 m). We reduced the predicted density of IOHC within forested areas based on the fraction of our scent stations visited at different distances from the suburban edge (< 50 m, 0.47; < 500 m, 0.05; > 500 m, 0).

Survey of small mammals and seed predation

We conducted small mammal surveys using track tubes (Glennon, Porter & Demers, 2002) in 21 of these 22 forested sites from June–August 2001. We used a 7 × 7 grid of tubes with 20 m spacing whenever possible; in fragments too small for this design, we placed tubes at 20 m intervals arranged to sample as much of the site as possible. Tubes were baited with peanuts, examined and rebaited after 2 days and examined and collected after 4 days. Contact paper strips permanently recorded all footprints from each tube and these were later identified to genus based on a reference collection. We used relative frequency of detection for each mammal species in each area as a measure of relative abundance.

We recorded seed predation rates in September and October of 2001 using the track tube methods described above except that 10 native plant seeds replaced the peanut bait. The three native seed species used were alternated every 3 traps and included species of conservation importance to this ecosystem: pitch pine (*Pinus rigida*), blue lupine (*Lupinus perennis*) and New Jersey tea (*Ceanothus americanus*).

Small mammal abundance and seed predation rates were compared with cat abundance and landscape features using simple linear regression.

RESULTS

Survey of cat owners

Of 600 surveys distributed, 381 (63.5%) were returned. Of these, 35% (134) households reported owning a cat (1–7 cats/house, average = 1.5), totaling 207 cats. Of these cat owners, 39.6% (53 households) had IOHC (total 105 cats), based on their observations of hunting behaviour or prey brought home. Of the 105 hunting cats reported, all but three were neutered.

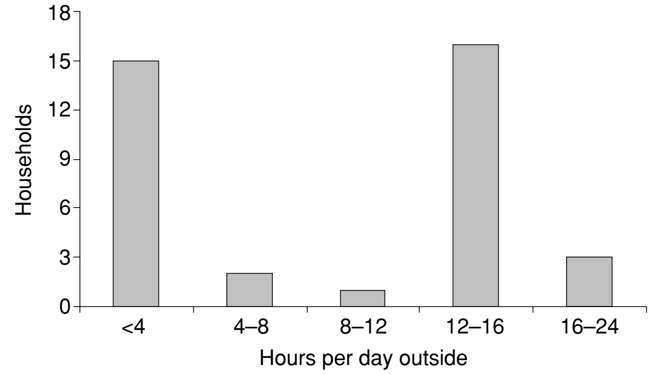

Fig. 1. Hours spent outside by cats from 37 households with outside cats, as reported by owners.

Most owners of IOHC reported that their cats were out for just a few hours per day, or for about half of the day (Fig. 1). The average of these approximations across 37 households reporting these results was 8.35 h/day ($\pm$ 6.31).

Out of all respondents, 86% said that they did not know of any feral cats in the area, 6.7% ($n = 21$) knew of 1 feral cat, 4.5% ($n = 14$) reported 'a few', while 2.2% ($n = 7$) reported knowing of 'many'.

Most owners did not report conflict between their cats and wildlife; this was not obviously related to the hunting behaviour of their cats, nor the wildlife activity they observed or attracted to their garden/yard (Table 1). Owners of hunting cats were more likely to report a missing cat than owners of inside cats. Approximately one-third of cat owners viewed the coyote as a threat to their pets, but only 4% of hunting cats were restricted because of this threat, while 15% of inside cat owners reported this as a motivation for restricting their cat's movement.

Cat hunting and ranging behaviour

Judging from dead prey returned to residences, our study population hunted primarily small mammals (86%) and, to a lesser extent, birds (Table 2). This averaged 1.67 prey/cat/summer month (Table 3). Almost half of these prey items were juvenile animals (Table 2) and most were common species for the area. This hunting was variable between individuals, ranging from 1 to 16 prey taken over the summer.

We documented 31 attempted hunts in 181 h of observation (0.17 hunts/h). Birds were the target in 22.6% of these attempts, small mammals in 51.6% and the target was unknown in 25.8% of the hunts (although it was probably small mammals). Eight of these hunts resulted in a capture (all small mammals, 26% capture rate), and four out of the eight animals escaped alive (13% total kill rate). Multiplying this average hunt rate by the average hours spent outside per day by IOHC suggests a kill rate of

Table 1. Response of cat owners to mail survey and the relationships between responses as determined by logistical regression

	Percent of respondents		P-value (χ^2, odds ratio) for logistic regression of independent value below with dependent value to left for all cat owners			
	Owners of hunting cats ($n = 53$)	Owners of inside cats ($n = 72$)	Have hunting cat	Have bird feeder	Seen raccoon in last year	Seen coyote in last year
Have had cat harassed by wildlife	8.2%	3.1%	0.43 (0.61, 1.39)	0.71 (0.14, 1.37)	0.068 (3.33, 0.20)	0.11 (2.61, 0.19)
Have had a cat disappear	21%	7.4%	**0.047 (3.95, 1.73)**	0.86 (0.03, 0.91)	0.66 (0.20, 0.76)	0.12 (2.39, 0.34)
View coyote as threat to cats	32%	38%	0.88 (0.02, 0.97)	0.38 (0.76, 1.5)	0.61 (0.27, 0.75)	0.13 (2.30, 0.37)
Restrict cat because of coyote threat	4.0%	15%	0.19 (1.74, 0.56)	0.42 (0.65, 1.89)	0.69 (0.16, 1.57)	0.12 (2.39, 0.21)

Table 2. The types of prey brought home by 12 inside/outside house cats from May–June 2001

Prey species	Count	% Juvenile
Deer mice (*Peromyscus sp.*)	28	67.9
Northern short-tailed shrew (*Blarina brevicauda*)	6	0
Eastern cottontail (*Sylvilagus floridanus*)	5	100
Eastern chipmunk (*Tamias striatus*)	5	0
Meadow vole (*Microtus pennsylvanicus*)	4	25
Grey catbird (*Dumetella carolinensis*)	3	0
Cinereus shrew (*Sorex cinereus*)	3	0
Bird species unknown	1	0
Ovenbird (*Seiurus aurocapillus*)	1	0
Carolina wren (*Thryothorus ludovicianus*)	1	0
House wren (*Troglodytes aedon*)	1	0
American robin (*Turdus migratorius*)	1	100
Total	59	47.5
Bird	8 (13.6%)	12.5
Mammal	51 (86.4%)	52.9

Table 3. Estimation of yearly prey killed per inside/outside cat from records of prey brought home to owners and from behavioural observation over three summer months

	Kills brought home	Observed hunts
Kills brought home by 12 cats over 3 summer months	60	
Behavioural observation		
Observed hunts/h		0.17
Observed kills/hunt		0.13
Average h/day outside		8.35
Average kills/day		0.18
Average kills per cat per summer month	1.67	5.54

5.54 prey per summer month per cat, which is 3.3 times greater than the rate estimated from prey brought home (Table 3). Most (80.0%) observed hunts were in the garden/yard, or within the first 10 m of the forest edge. We only recorded two hunts more than 20 m into the neighbouring preserve forest (Fig. 2).

Eleven radio-collared IOHC averaged 0.24 ha in home range size (95% MCP), while one feral cat had a home range of 2.23 ha (Table 4). Although this feral cat was initially captured near an old barn in the forest preserve, she was never again recorded in the preserve; instead, she spent her time in a junkyard and car park across the street from the preserve. On average, cats in our study rarely entered the forest; the 95% MCP overlapped with forest for only five out of 11 IOHC in our study, typically to a small extent (average 0.056 ha: Table 4, Fig. 3(a), (b)). The home ranges overlapped with an average of 3.67 gardens/yards, including that of their owners (Table 4), and only one cat ranged over a large number of yards (Fig. 3(c)).

Our sample size is uneven, despite our best efforts to obtain comparable numbers of locations between individual cats, because many cats were often inside their owner's home, especially at night. Thus, the number of fixes (Table 4) is also a relative measure of the time spent outside by different cats. Our bootstrap analysis of 95% MCP size versus number of fixes suggests that home range size probably would have increased little with the addition of new fixes (Fig. 4). Thus, while they may be slight underestimates, our home range sizes are probably good approximations of the area used by these cats. The shape of these bootstrap lines themselves is also an indication of general movement rate and pattern by an individual. It is interesting that 10 of our IOHC had very similar patterns of slow home range increase, which was very different from the one feral cat. The line for the youngest and most active IOHC in our study (Orion) fell between these two groups in slope and area used (Fig. 4).

Twenty-five out of our 108 scent stations detected cats within the forest. Typically, cats were detected only near the suburban/forest edge. We only found cats at sites further than 40 m from this edge 3 times, despite

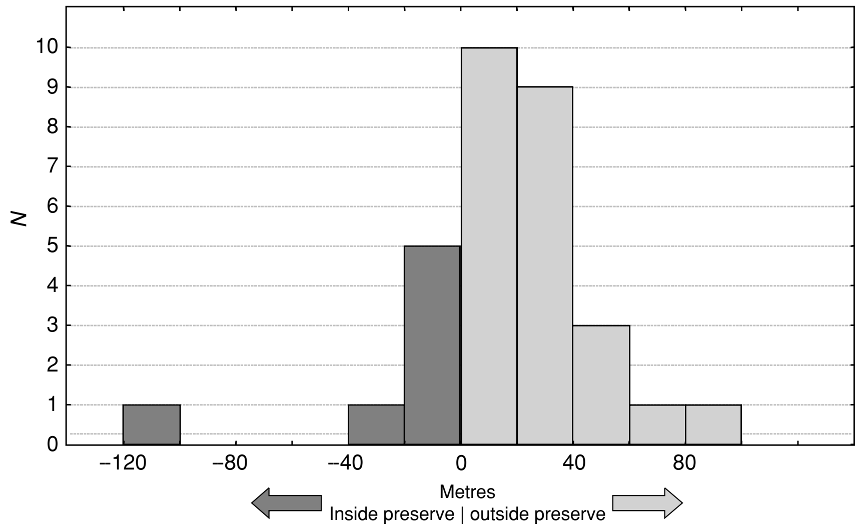

Fig. 2. The location of hunts by house cats relative to the edge of the forest. Negative numbers are within the preserve, positive numbers are outside the preserve.

Table 4. Space use by 11 radio-collared house cats and one feral cat around the Albany Pine Bush Preserve. Number of fixes was limited for some cats because they spent the majority of their time inside their house

Name	Sex	Fixed/ fertile	Age	Hours observed	Total fixes	Independent fixes*	100% MCP (ha)	95% MCP (ha)	Gardens/ yards used (95% MCP)	Min distance to forest from house (m)	Forest overlapped by 95% MCP (ha)
Feral cat											
Tiger	Female	Fertile	Ad	30.3	32	28	5.80	2.23	1	na	0.24
Inside/outside House cats											
Billy	Male	Fixed	4	16.8	83	22	1.12	0.33	8	7	0.037
Charlie	Male	Fixed	4	8.8	69	14	0.39	0.25	1	5	0.17
Dog	Female	Fertile	Ad	6.3	34	12	0.29	0.19	2	75	0
Fred	Male	Fixed	15	8.0	57	12	0.20	0.03	1	4	0
Junior	Male	Fixed	8	8.5	28	17	0.18	0.079	4	95	0
Mookie	Female	Fixed	4	4.8	24	9	0.14	0.061	3	8	0.009
Orion	Male	Fixed	1	46.5	256	56	3.00	1.30	11	12	0.37
Quinton	Male	Fixed	6	21.5	130	22	0.33	0.080	3	4	0
Rusty	Male	Fixed	7	8.8	29	14	0.41	0.11	5	84	0
Smokey	Female	Fertile	Ad	7.5	31	15	0.13	0.12	3	75	0
Willie	Male	Fixed	4	13.5	39	16	0.96	0.12	3	37	0.029
						All average	1.08	0.41	3.8		0.071
						Non-feral average	0.65	0.24	4.0		0.056

* Independent fixes are > 1 h apart.
MCP, minimum convex polygon; Ad, adult.

considerable search effort (Fig. 5). On average, cats were more often detected at scent stations near the forest edge (average distance from edge for stations detecting cats = 35.6 (± 48.4) m, not detecting cats = 170.5 (± 184.8) m: Mann-Whitney U test, $U = 400$, $Z = -4.6$, $P < 0.005$, $n = 108$). There was no effect of the forest fragment size on the presence or absence of cats at a site (Mann-Whitney U test: $U = 39.5$, $Z = 1.37$, $P = 0.17$, $n = 22$). However, after identifying individual cats based on coat colour recorded by camera-traps, we found that smaller forest fragments had more individual cats (Spearman correlation $r = -0.43$, $P = 0.046$, $n = 22$).

Cat density and predation extrapolation

According to our surveys, there were 0.275 IOHC per house (105 IOHC reported by 381 households), which may be extrapolated to 1918 IOHC in our 6000 ha study area (given 6976 houses) and an overall density of 0.32 IOCH/ha. By focusing on houses near the forest preserve, we estimated that there were 850 and 552 cats

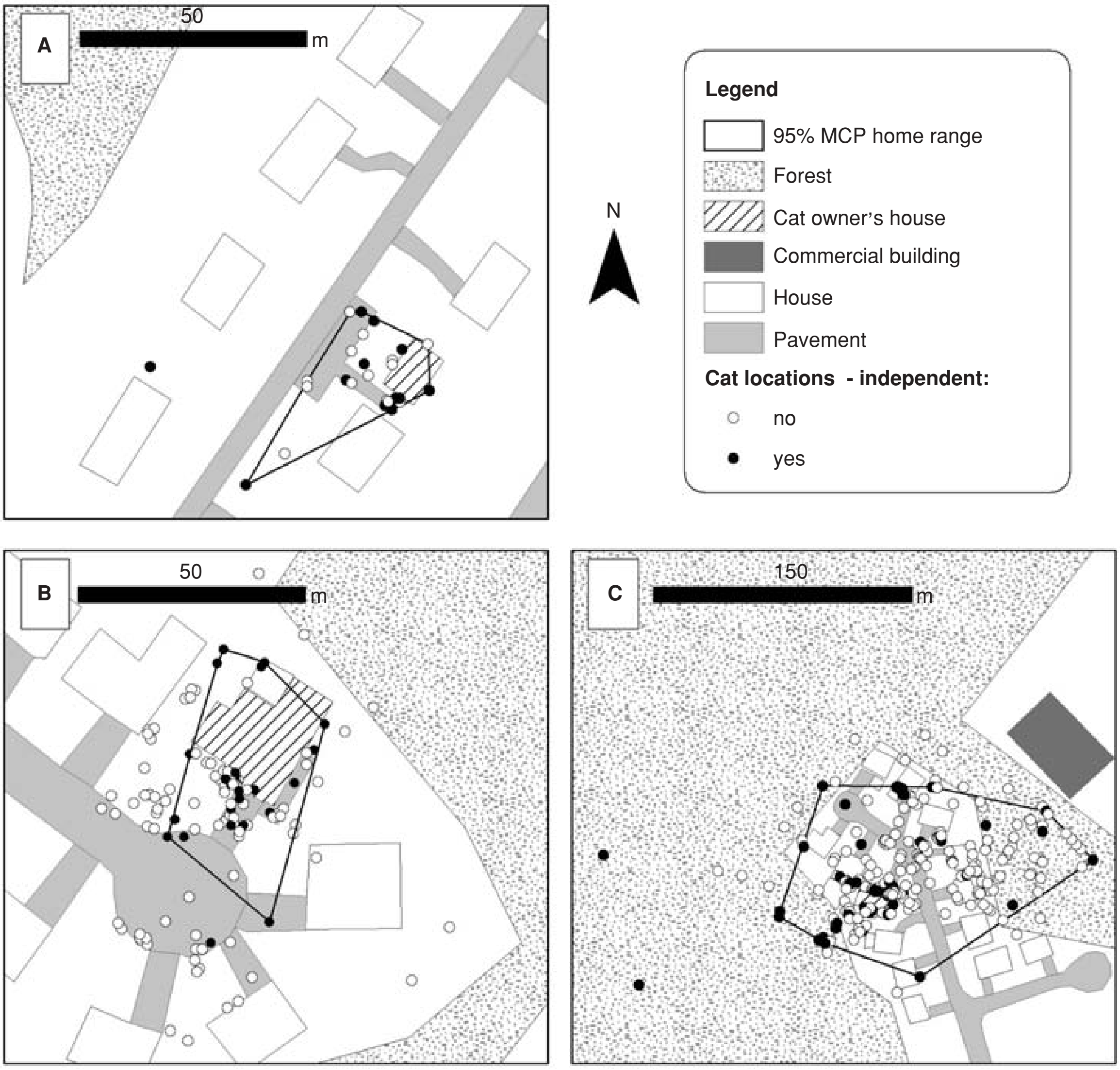

Fig. 3. Locations and 95% minimum convex polygon (MCP) home ranges for three inside/outside house cats. Only independent locations (> 1 h apart) were used to generate the range. Maps (A) and (B) show a range that is typical for cats that did not enter the forest, (C) shows the range of the most widely ranging house cat in our study (Orion).

living within 100 m and 50 m of the edge of the forest preserve, respectively, giving densities of 0.21 and 0.14 IOHC/ha, respectively. To map the local geographical variation of these density estimates we modelled IOHC based on house density and the fraction of cats expected at different distances from the forest/suburban edge (Fig. 6). Local predicted densities varied from 0 to 3.84 cats/ha, with most of the forest preserve predicted to have fewer than 0.1 cats/ha. Many of the smaller forest fragments within neighbourhoods, however, had higher predicted densities.

By combining these density estimates with our average predation rates (prey brought home, observed hunt rate: Table 3), we extrapolated the total predation rate to be 0.53–1.8 prey/ha/summer month within our 60 km^2 study area; considering only those cats likely to hunt in the forest preserve, these rates are 0.35–1.2 prey/ha/summer month within the forest preserve and first 100 m of developed area.

Effect on small mammal populations and seed predation

The number of individual cats detected within the forest at each sample site did not have a significant effect on the total relative density of small mammals (d.f. = 18, $R^2 = 0.00$, $P = 0.9$), on the density of any one rodent species (*Sciurus*: d.f. = 18, $R^2 = 0.07$, $P = 0.24$; *Peromyscus*: d.f.= 18, $R^2 = 0.4$, $P = 0.4$), or on the local small mammal biodiversity (d.f.= 18, $R^2 = 0.06$, $P = 0.29$). There was also no obvious effect of forest edge on small mammal abundance (*Sciurus*: d.f. = 2, $X^2 = 3.0$, $P = 0.22$; *Peromyscus*: d.f. = 2, $X^2 = 2.8$, $P = 0.24$). In addition, there was no relationship between the density of houses near a site and the relative abundance of small mammals

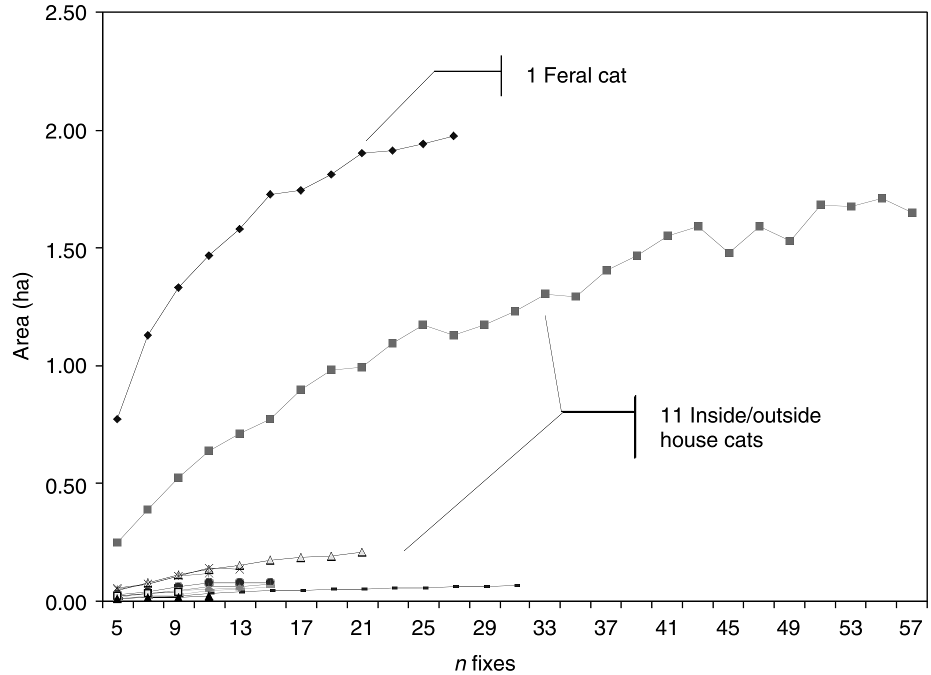

Fig. 4. Average 95% minimum convex polygon (MCP) home range area for 12 radio-collared cats from a bootstrap analysis using independent fixes (independence interval = 1 h, 100 bootstrap replicates). The line between the feral cat and the 10 sedentary housecats was for our most mobile house cat (Orion).

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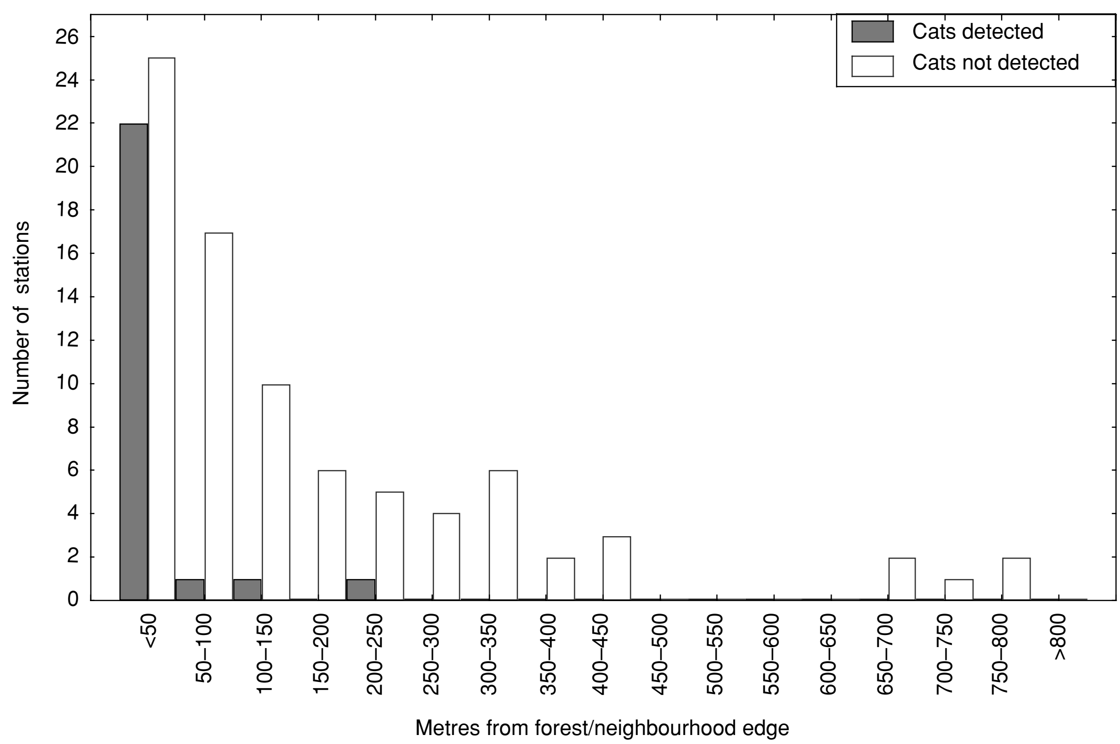

Fig. 5. The presence or absence of domestic cats at 108 scent stations relative to their distance from the forest/suburban edge.

(within 50 m of the site: $R^2 = 0.006$, $P = 0.70$; within 100 m: $R^2 = 0.02$, $P = 0.55$; within 500 m: $R^2 = 0.07$, $P = 0.24$). The local abundance of cats did not affect seed predator activity (All seeds: F = 0.06, $P = 0.81$; *P. rigida*: F = 0.00, $P = 0.98$; *C. americanus*: F = 0.00, $P = 0.96$; *L. perennis*: F = 0.50, $P = 0.49$). However, seed predation was highest at edge sites (d.f. = 2, $\chi^2 = 7.27$, $P = 0.026$).

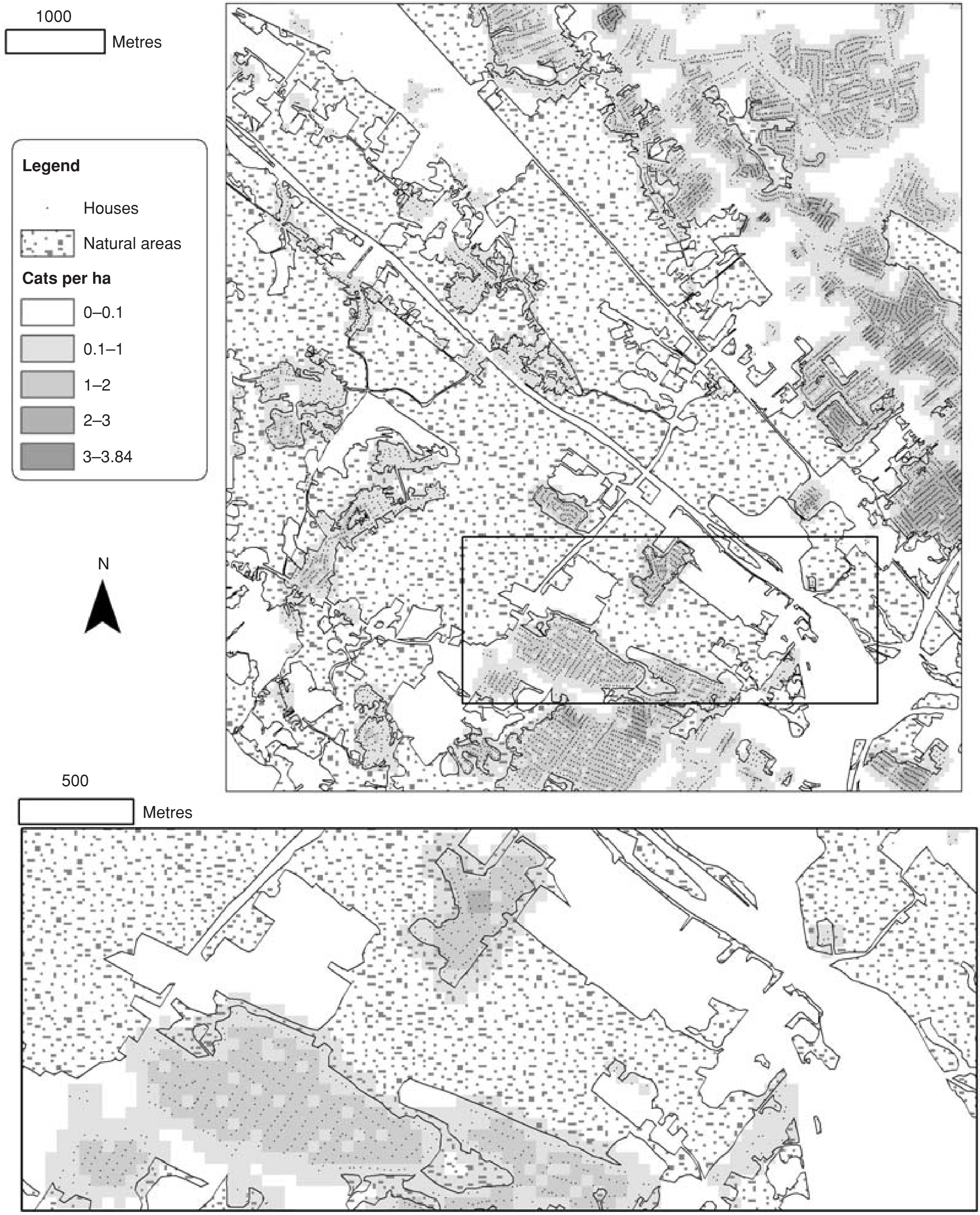

Fig. 6. Predictive distribution of inside/outside house cats around the Albany Pine Bush Preserve based on house density and the known avoidance of non-edge natural areas by these cats. The large scale map shows this model for the entire study area. The inset map shows a closer look at the same model for one portion of the preserve.

DISCUSSION AND CONCLUSIONS

Our data suggest that our study IOHC population is generally similar to those studied elsewhere. The overall percentage of households owning cats in our study (35%) is similar to that from other areas (e.g. Massachusetts 22–34%, Indiana 23–31%: Patronek & Rowan, 1995; California *ca*. 33%: Crooks, 1997). The percentage of owned cats that hunt outside in our study (39.6%) is similar to that reported in Australia (36%: Robertson, 1998) but lower than that in southern California (*ca*. 75%: Crooks, 1997). These comparisons suggest that our density model based on the estimate of 0.275 IOHC per house is roughly similar to what one would find in other suburban settings with a similar house density. Indeed, our predicted local densities of 0c3.8 IOHC/ha (Fig. 6) are in the same range as 25 out of the 29 domestic cat studies covered in a recent review (Liberg *et al*., 2000). It is important to remember that our model only considers IOHC and not feral cats.

The cats in our study primarily hunted small mammals, followed by birds. Although our sample sizes are small, this fits the general hunting patterns observed at other northern continental sites (Fitzgerald & Turner, 2000; Woods *et al*., 2003). The rate at which our study population returned home with kills (1.7 kills/cat/summer month) is within the range reported by similar studies (0.85–3.2 kills/cat/month: for a review, see Woods *et al*., 2003). Our kill rate calculated from observing cat behaviour (5.5 kills/cat/summer month) was higher than our kills-brought-home estimate; this has been suspected by other authors (Carss, 1995; Woods *et al*., 2003), but we know of no similar observational data confirming this for IOHC.

The 95% MCP home range sizes of IOHC in our study averaged 0.24 ha. While these were based on a limited number of (mostly diurnal) fixes, bootstrap analysis suggests that additional samples would not significantly increase most individuals' ranges. We know of no similar range measures for suburban IOHC, although these are much smaller than those found for housecats in Illinois farmland (Warner, 1985) and for all feral cat populations studied (for a review, see Liberg *et al*., 2000).

These small ranges rarely overlapped with a forested area, even if it bordered their owner's garden/yard and only two out of 31 observed hunts were attempted more than 10 m into the forest. Confirming these behavioural observations, our scent station survey in nearby forests detected cats most often near the forest edge and only recorded them at three out of 66 scent stations located more than 40 m from the forest/suburban edge. Other studies have also found that, on average, domestic cats are more abundant near the edge of natural areas (Oehler & Litvaitis, 1996; Crooks, 2002), although there is clearly some variability between individuals (Warner, 1985; Churcher & Lawton, 1987; Carss, 1995; this study). We have a very poor understanding of what factors influence the penetration of cats into natural areas, both in terms of variation between different cats, between different natural areas in a region and between different habitat types. Understanding the relative importance of predation risk, landscape features, native prey abundance, cat condition and human intervention on cat movement would significantly aid cat management and should be a priority for future studies.

There are three factors about our study site that may relate to the conservation risk of local cat populations in positive ways compared with different habitats in other parts of the world. First, harsh New York winters probably function to not only restrict IOHC movement for much of the year (George, 1974; Churcher & Lawton, 1987), but also they may limit the suitability of the area for true feral cats compared with warmer climates. Second, the native potential prey species in mixed coniferous/deciduous forests of northeastern North America may be less vulnerable than other areas because it includes few lizards or low-nesting birds. For example, the scrub nesting birds hunted by IOHC in suburban southern California (Crooks & Soule, 1999) might be expected to be more vulnerable than small mammal or canopy nesting bird populations simply because their low nesting habits are more easily exploited by scansorial cats (i.e. an evolutionary trap: Schlaepfer, Runge & Sherman, 2002). Finally, the nature preserve around these neighbourhoods includes enough forest to support populations of cat predators including coyotes (*Canis latrans*) and fishers (*Martes pennanti*: Kays, Bogan & Holevinski, 2001). The presence of these predators probably functions to limit feral cat numbers, as well as the movement of any IOHC into the forest preserve (Crooks & Soule, 1999). Indeed, approximately one-third of cat owners in the area view coyotes as a threat to their cats (Table 1).

True feral cats were apparently rare in our study area, since only 13.4% of our mail survey respondents reported seeing them in the area and some of these could have been neighborhood IOHC without collars. Likewise, the local animal-control officer reported stray cats in neighbourhoods, but not in forest fragments (Town of Guilderland Animal Control, pers. comm.). Our behavioural research focused on IOHC, but we did radio-collar one feral cat that was trapped near an old barn within the preserve. In our nocturnal and diurnal tracking over the next 3 months we never again recorded this cat within the preserve. Rather, she was always in either a junkyard or car park across the street from the preserve, highlighting the apparent unsuitability of these forests for *F. silvestris*.

Do inside/outside house cats affect prey populations?

While our extrapolations of 0.35–1.8 prey/summer month taken by IOHC in the area are rough estimates, they give an idea at the scale of predation in the area. To put this in perspective, *Peromyscus leucopus* densities typically range from 2–35/ha and they produce several litters of 3–5 young per year (Whitaker & Hamilton, 1998). Is cat predation enough to affect prey population size given the cat's inefficient hunting of mostly common, juvenile mammals and rare trips into the preserve itself? Our data suggests it is not, since we found no relationships between any measures of the small mammal community and cat

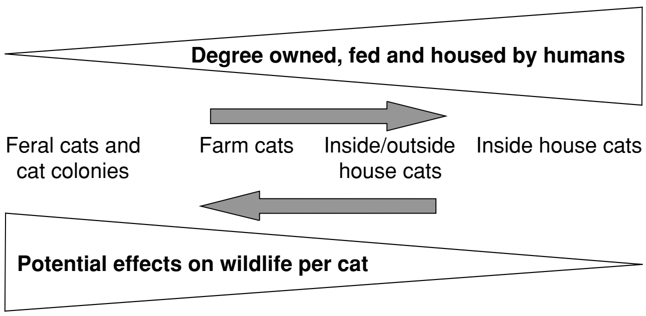

Fig. 7. Hypothesised relationship between the amount of human care received by domestic cats and their potential as conservation problems for natural areas. Effects on wildlife will also be related to cat density, which will vary across sites depending on local environmental and human conditions.

activity. In fact, although we did not detect higher rodent densities at the forest edge, their foraging activity was apparently more intense there, as reflected in our higher seed predation rates at edge sites. Both of these results suggest that cat activity has no influence on small mammal populations or foraging activity in our study site. Because we did not survey bird populations, or track more than one feral cat, we cannot comment on the conservation concerns associated with these two groups in the area.

Within neighbourhoods, IOHC are living at quite high densities. Even inefficient hunting of small mammals by numerous individual cats could result in strong effects on native prey populations within neighbourhoods. Support for this hypothesis is found from one of the few studies addressing small mammal ecology in residential areas, which found wood mice (*Apodemus sylvaticus*) to be less abundant near houses with IOHC (Baker *et al*., 2003). Our data suggests that the largest conservation risk posed by IOHC in this region is in causing the neighbourhoods that divide natural areas to be more inhospitable barriers to small mammal dispersal, rather than directly affecting prey populations within nearby natural areas themselves. If severe enough, such barriers reduce gene flow between populations and limit the potential for recolonisation of habitat by locally extinct species.

Broadly evaluating cats versus conservation

The domestic cat–human relationship has evolved into a variety of forms, from cats being fully dependent on humans for food and shelter, to wholly independent feral cats. It is important to recognise that the potential impact of an individual cat on wildlife will probably vary according to the cat's living situation. Although there is little empirical data, we hypothesise that the more care a cat receives from humans the less likely it is to affect prey populations through hunting because it is less driven by hunger (Fig. 7; Fitzgerald & Turner, 2000). This individual effect is compounded by the fact that free-ranging, non-neutered cats receiving food and shelter from humans are capable of reaching quite high densities (Coleman & Temple, 1993). In these cases, the ecological impact of many hunters might sum up to negatively impact local native wildlife populations, even if their individual hunting is inefficient or uncommon. While feral cats have been the subject of numerous ecological studies, we still know little about the ecology of cats in the middle and right side of this continuum. Thus, despite the major management implications, we are in a poor position to untangle the effects of different types of human care on individual cat hunting behaviour or regional cat density – the two factors most likely to amplify their ecological impact on native prey.

The ecological impact of a cat population is a difficult metric to quantify, yet probably the most important when evaluating the conservation risks associated with their management. While a number of researchers have extrapolated kill rates from a few cats into huge estimates of prey killed by cats over large areas (e.g. free-ranging cats kill as many as 217 million birds/year in Wisconsin (Coleman, Temple & Craven, 1997) and 220 million prey/year in the UK (Woods *et al*., 2003)), these are rarely contrasted with similar estimates of potential prey populations over the same scales. Unfortunately, biologists have rarely sampled both cat and prey populations in such a way that direct effects on prey populations can be shown (e.g. house cats reduce scrub breeding birds: Crooks & Soule, 1999; cat colonies reduce grassland birds: Hawkins, 1998). Such studies must be a priority for future research, in conjunction with population estimates and hunting and ranging data from specific types of cats, if conservation biologists are to accurately advise land managers and public advocacy groups (Clarke & Pacin, 2002; http://www.abcbirds.org/cats/).

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