Paper

Risk behaviours exhibited by free-roaming cats in a suburban US town

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Free-roaming cats may experience numerous hazardous encounters in the outdoor environment, including: vehicular accidents, aggression from other animals and exposure to infectious disease. This research quantitatively examined the outdoor activities of 55 owned cats by monitoring pets outfitted with 'KittyCam' video cameras. KittyCams are a type of Crittercam, designed by National Geographic to allow recording of a cat-eye view without disrupting behaviour. We investigated the activities of free-roaming cats in suburban Athens-Clarke County, Georgia, during all four seasons. Research objectives included documenting the type and regularity of risk behaviours exhibited by free-roaming cats and identifying characteristics of pet cats (eg, age, sex, roaming habitat) which predict risky behaviour in the outdoors. The most common risk behaviours exhibited by suburban free-roaming cats included crossing roads (45 per cent of our sample), encountering strange cats (25 per cent), eating and drinking substances away from home (25 per cent), exploring storm drain systems (20 per cent), and entering crawlspaces of houses (20 per cent). Male cats were more likely to engage in risk behaviours than female cats, and older cats engaged in fewer risk behaviours than younger individuals. We hope this information can be used to encourage the public to keep cats indoors more often (with consideration for their indoor quality of life) or supervise them while outdoors.

Introduction

There are an estimated 50–60 million owned, free-roaming pet cats in the USA today (AVMA 2007). According to the Humane Society of the United States (HSUS), free-roaming pet cats have an average lifespan of three years, while indoor cats live 12–18 years. Factors contributing to the reduced longevity of roaming cats include: vehicular accidents, aggression from other cats, exposure to poison, infectious disease, parasites, domestic dogs and wild predators (Nutter 2005, HSUS 2009).

Exposure to infectious disease may be one of the most underestimated risks that free-roaming cats encounter. Free-roaming cats host numerous parasites and infectious diseases, and interactions with cats, either feral or from other households, increases exposure risk. Outdoor cats have been found to have a higher rate of Feline Immunodeficiency Virus (FIV), infection with *Dirofilaria immitis* (heartworm), as well as *Bartonella henselae* (the causative agent of Cat Scratch Disease), when compared with indoor cats (Maruyama and others 2003). In both temperate and tropical regions, outdoor cats are exposed to infectious diseases carried by ectoparasites, such as ticks and fleas. Cat fleas can serve as a vector for Haemobartonellosis (*Mycoplasma haemofelis*), *B henselae*, *Coxiella burnetti*, *Rickettsia felis* (and other flea-born rickettsioses) and *Yersinia pestis* (the etiologic agent of plague) (Comer and others 2004, Case and others 2006). Ticks can also serve as vectors for *Cytauxzoon felis*, an emerging protozoan parasite that is nearly always fatal for domestic cats (Birkenheuer and others 2006). Owned, free-roaming cats may acquire infectious diseases and parasites via encounters with other cats, or through exposure to contaminated environments. The prevalence of parasites and infectious disease among unowned feral cats has been well documented and may pose a risk to pet cats (Yamaguchi and others 1996). Free-roaming cats may contract *Salmonella* species from reptiles and birds and may be poisoned by the toxins excreted by common *Bufo* toads (ie, American toad, Fowler's toad).

Other common risks that free-roaming cats encounter are car collisions, becoming trapped in an enclosed space, or lost. Road accidents constitute a common cause of injury for domestic cats. Rochlitz (2003) estimated vehicle accidents to be the fourth most common cause of cat death in Great Britain. The city of Baltimore, Maryland, annually removes over 500 owned cats found dead on city roads (Childs and Ross 1986). Although cats are usually wary of their surroundings, they often stand little chance against fast-moving vehicles.

While most cat owners are aware of the danger of vehicles to cats, many do not recognise additional dangers. For example, pet owners realise that free-roaming cats are likely to experience traumatic injuries as a result of aggressive encounters with other cats, but they may be unaware of the possible long-term negative effects of such contact (eg, transmission of diseases like FIV). Assertions that indoor cats live longer, healthier lives are not uncommon, though it is expected that only about half of cat owners in our study area keep their cats indoors (Loyd and Hernandez 2012). Thus far, campaigns to promote

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cats maintained indoors (by the American Bird Conservancy and the Humane Society of the United States have had a limited effect on the general public. Many owners perceive the roaming lifestyle to benefit their cat, and in fact, outdoor cats do receive more exercise than indoor cats and have increased freedom to express their natural behaviour (including: scratching, urine spraying and predatory behaviour (Rochlitz 2005)). These benefits may be perceived by owners to outweigh negative behaviours expressed while indoors (eg, spraying), as well as ward off obesity. Although some studies have concluded that obesity is more prevalent in indoor cats (Sloth 1992), they do not account for other factors (such as neutering) to truly test the relationship between body condition and physical stamina or compare psychological wellbeing in indoor versus outdoor cats. Hazards to pet cats may be present whether the animal roams or remains indoors. Rochlitz (2005) discusses household accidents as well as disease (hyperthyroidism, urologic syndrome) associated with cats confined to the interior of the household, but further research is needed comparing the general welfare of indoor and indoor/outdoor pet cats.

Risk behaviours exhibited by free-roaming cats have received minimal research attention in the past, thus, campaigns promoting cats be kept indoors have few convincing statistics to present to a public audience. Identifying risks experienced while roaming in suburban environments and quantifying the frequency of such risks is vital information for both veterinary and public (pet-owning) audiences. Investigating such behaviours could also help quantify the risk of contracting a zoonotic disease. No previous study has examined the interactions of owned, free-roaming cats with other (possibly stray) cats, and the potential health threats resulting from these interactions should not be underestimated. The objectives of this study included documenting the type and regularity of risk behaviours exhibited by owned, free-roaming cats, and identifying characteristics of pet cats (eg, age, sex, roaming habitat) which predict risk behaviour in the outdoors. Point-of-view video cameras were used to monitor roaming pet cats because they provide objective observation of all activities experienced while outdoors, allowing easy quantification of risk behaviours.

Methods

Study site

Athens-Clarke County (ACC) is a unified city-county, in northeastern Georgia. ACC is 125 square miles, the 5th largest city in the state of Georgia and home to The University of Georgia. The most recent US Census estimate (2010) placed the population at 116,714. The number of owned, free-roaming cats is estimated to be 13,500 (calculated using ACC data, Humane Society estimates of pet ownership and our own survey data (Loyd and Hernandez 2012)). The weather in Athens is relatively mild, such that inclement weather is rarely a reason to keep pet cats indoors. A map of participant households is included in Fig 1.

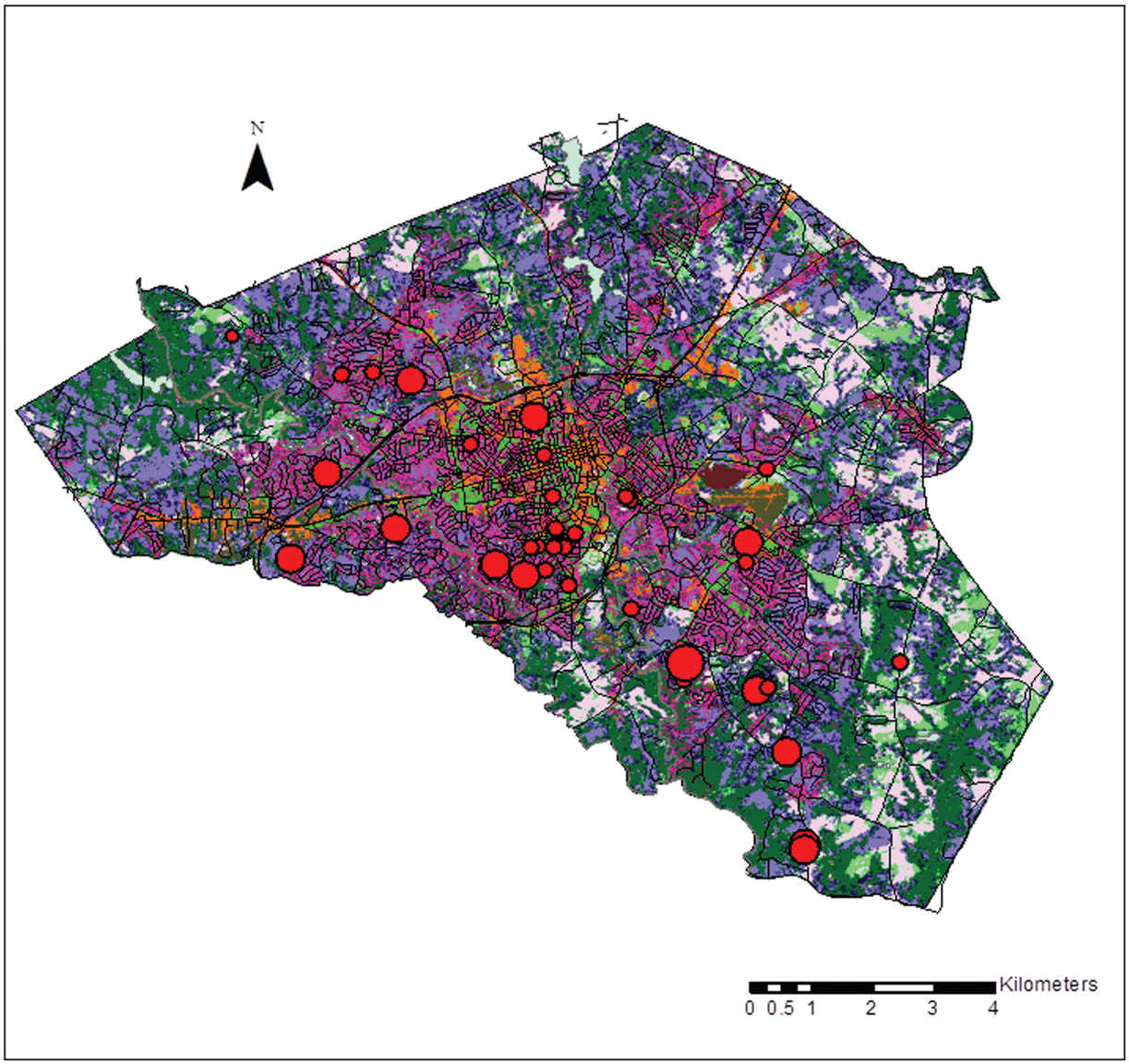

FIG 1: Map of free-roaming pet cats' households monitored by a KittyCam video camera for seven to ten days in Athens-Clarke Country, Georgia, 2011. Larger dots indicate two participating cats per household. Land use and cover classes (from National Land Cover Database) are also shown.

Technology

Animal-borne video systems have been previously used to study habitat use, food habits and general animal behaviour in a variety of species including: marine mammals, sea turtles, penguins and lions (Ponganis and others 2000, Heithaus and others 2002, Hays and others 2007, Herman and others 2007, Moll and others 2007). These Crittercam video systems record an animal-eye view of activities without disrupting behaviour. Point-of-view cameras (KittyCams from here forward) were used to monitor 60 cats (recording took place from November 2010–October 2011). After a trial period indoors, volunteer cat owners placed a KittyCam on their pet for up to 10 days during a four-week period. The volunteers switched the camera on before placing it on their pet, charged the camera at the end of the day, and downloaded video to a portable external hard drive. The recordings took place at the convenience and regular schedule of the pet owners.

The KittyCam system is a rectangular box, approximately 7.5 cm by 5 cm by 2.5 cm and weighing 90 g. KittyCams are mounted on commercially available break-away cat collars. Each unit contains a lithium-ion battery that can record 10–12 hours of cat activity before recharging. An on/off switch allowed the recording to be compatible with each individual household schedule. For example, some cats roam early morning to evening while some are allowed outside at night. The KittyCam has light-emitting diode (LED) lights for recording in dark places and at night. The video cameras were water-resistant, though required some care to prevent damage. Video data are stored onto a 16GB microSD card. Cats were acclimated to the cameras by wearing the collar with camera indoors under supervision before they wore the equipment while roaming (Fig 2).

This research methodology depended on interested and dedicated volunteer cat owners recruited through a random survey on the perceptions of domestic cats and preferences for cat management (Loyd and Hernandez 2012), as well as through advertisements in two local newspapers. As incentive for participation, free annual vaccinations and a total feline health screen were offered to participants. The health screen included: a complete physical exam, body weight, body temperature, a complete blood cell count (CBC), a biochemical profile, and in-house Feline Immunodeficiency Virus (FIV), Feline Leukaemia (FeLV) and heartworm tests (IDEXX Snap Combo). Merial Rabies and Felocell FVRCP vaccines were administered in a standard manner if the cat had not received it within the previous 12 months.

Forty-two cats were additionally tested for *C felis*, *Babesia*, *Bartonella* and *Mycoplasma*. Genomic DNA was extracted from 100 µl of whole blood using the Qiagen DNA Purification Kit (Germantown, MD) following the manufacturer's protocol. A nested PCR protocol that amplifies the entire internal transcribed spacer (ITS)-1 rRNA region of most piroplasms including *Cytauxzoon*, *Babesia* and *Theileria* species was used to detect *C felis* as previously described (Bostrom and others 2008, Shock and others 2011). To detect *Bartonella* species, a PCR protocol that amplifies the internal transcribed spacer (ITS)-1 rRNA region of *Bartonella* species (Cadenas and others 2008) was used.

FIG 2: Owned, free-roaming cat wearing a KittyCam video camera in Athens-Clarke County, Georgia 2011

A PCR protocol known to be specific for the 16S rDNA region of feline haemotropic mycoplasmas (Jensen and others 2001) was used. Q7

All participating cats were previously neutered, and the following information was collected for each participant: age, sex, breed, medical history and use of ectoparasite preventative treatment. Results of the health screens were used in the development of a health predictor to investigate the potential relationship between health issues and roaming cat behaviour. All procedures abided by an animal use proposal approved by the University of Georgia's Institutional Animal Care and Use Committee (#A2010 05-091-R1). If the results of the CBC or chemistry profile suggested any anomaly, or if a cat tested positive for FIV (without previous FIV vaccination) or FeLV, then the health variable for that cat was coded as 1 for dichotomous analysis; no evidence of health issues was coded as 0. If the lab results were abnormal, the owner was contacted and a recommendation was made to have the cat examined by their regular veterinarian.

Video analysis

A list of possible risk behaviours was made a priori and this list was reviewed by two additional veterinarians (Table 1). More than 2000 hours of outdoor video footage was viewed for analysis. The number and type of risk behaviours witnessed in the video for each cat was recorded for each day. Additionally, roaming habitat characteristics and the total hours that cats spent outside each recording day were documented. Roaming habitat was categorised as rural or suburban based upon percentage of green space identified via the 2006 National Land Cover Database for Clarke County, Georgia and proximity (to the household) of neighbours or other urban structures. 'Rural' locations were considered households isolated from other significant structures by a minimum 0.4 km radius and with open space as primary land use.

A negative binomial regression was used to examine the influence of predictors on the number of risks a cat experienced while roaming. To avoid multicollinearity, a correlation matrix was constructed and Pearson correlation coefficients examined for each pair of variables. The negative binomial method was chosen due to the over-dispersed nature of the Poisson-distributed count data, wherein the conditional variance exceeded the conditional mean. Negative binomial regression has the same structure as Poisson regression but includes an extra parameter to model this overdispersion. This type of model was also used to investigate influences on the number of times participating cats crossed roads. Cats witnessed crossing the road at least once were included in this analysis, and the number of predictor variables was reduced based on results of the first regression. To examine whether cats exhibited more risk-taking behaviours while roaming during day or night we calculated the number of risk behaviours per hour for the 13 cats which roamed during both day and night-time hours. The average number of risk behaviours per hour for day and night was then compared using a Wilcoxen Matched-Pairs Signed Rank Test.

Results

Health screen results

Participating cats included an equal number of males and females ranging from 0.5 year to 19.5 years of age (mean age=5.8 years). Two cats were infected with FIV, one with FeLV, and no cats tested positive for heartworms, *Babesia*, *C felis* or *Bartonella*. Six were positive for

TABLE 1: Risk behaviours exhibited by 55 free-roaming cats monitored via KittyCams video cameras in Athens-Clarke County, Georgia, 2011

Risk behaviour	Cumulative count
Crossing road	178
Non-aggressive contact with a stranger cat (infectious disease risk)	28
Consuming solids or liquids not left by owner	20
Entering storm drain	19
Climbing tree	13
Climbing on roof	7
Contact with other medium sized wild animal (injury, disease risk)	1
Crawling into car engine	1

Mycoplasma species. Two cats had values on the chemistry profile consistent with renal insufficiency (high blood urea nitrogen and creatinine), three had an elevated white cell count indicative of an infection, and two displayed a significant eosinophilia, consistent with parasitism.

Video analysis results

A minimum of seven days of footage was collected from 55 of our 60 cats, and thus, only these cats were included in the video analysis. The remaining five collected very little or no video due to various factors including two that did not tolerate the collar and lack of effort by cat owners. Eight cats (15 per cent) roamed in a rural area and 47 (85 per cent) roamed in urban or suburban neighbourhoods. An average of 38 ± 16 hours of outdoor footage per roaming cat was collected (range 18–82 hours) and the mean time spent outside each recording day was 5.5 hours. One hundred and nineteen hours of the 2001 total hours were recorded at night (6 per cent), represented by 13 cats with an average of seven hours each.

Most cats (85 per cent) experienced at least one risk behaviour during seven days of data collection. The average number of risk behaviours exhibited was 5.75 (range 0–28). The most common risk behaviours exhibited by suburban, owned, free-roaming cats in ACC included: crossing roads (45 per cent of our sample), encountering cats that were not from the same household (25 per cent), eating and drinking away from home (25 per cent), exploring storm drain systems (20 per cent), entering crawlspaces (20 per cent), and climbing trees or onto a roof (20 per cent) (Figs 3 and 4). Fifty-two percent of cats were witnessed crossing the road <5 times during seven days of data collection while the remaining (48 per cent) cats crossed roads >5 times during seven days of data collection, in one case up to 24 times during the recording period. All cats witnessed crossing the road lived in suburban areas of the county. Most participants encountering cats (not a housemate) had non-threatening encounters (approaching each other curiously rather than displaying aggressive postures such as ears back and/or hissing). Two individuals were recorded hissing and growling at other roaming cats but no fights were recorded. The range of items that cats ate away from home included: trash, compost, roadkill or other dead animals, and cat food left for stray cats. Cats were witnessed drinking from pools, old children's paddling pools filled with rainwater, and from puddles in parking lots and the storm drain system. Table 1 lists the type of risk behaviours witnessed via KittyCams and includes the collective sum for the number of times each was counted. Unexpectedly, we found that four cats (of the 60 we had some video from), visited other households. While not necessarily a 'risk behaviour', the KittyCam footage suggests that some cats share their roaming time with a second household of residents.

Another behaviour witnessed by a percentage of our sample cats was predation; 30 per cent of KittyCam wearers captured wildlife while roaming outdoors. A total of 39 animals were captured and a minority of these prey items (28 per cent) were consumed by cats (Loyd and others 2013).

The first regression model included the following uncorrelated predictors (r^2<0.2): age, sex, health status, roaming season, roaming habitat and video hours recorded. A deviance goodness-of-fit test found the model fitted the data well (P>0.05). Sex was found to have a significant influence on risk behaviour such that roaming males were more likely to undertake risks than females (β=0.598, se β=0.249, P=0.02) (Table 2). The number of risk behaviours is predicted to decrease slightly with each one year increase in age (β = – 0.122, se β=0.037, P=0.001). An increase in recorded video hours was related to an increase in the number of risk behaviours exhibited (β=0.025, se β=0.037, P<0.001), implying there is a relationship between the time spent outdoors and risks experienced. Habitat also had a significant influence on risks (β=0.851, se β=0.391, P=0.03); roaming in a suburban habitat, compared with rural, increased the likelihood of risk behaviours. The number of risk behaviours experienced by participants was not significantly related to having a negative finding on the health screen or influenced by the season of roaming. Similar results were found in the simpler model used to predict influences on the frequency of crossing roads (Table 3). Males were more likely to cross roads more frequently than females (β=.844, se β=0.308, P=0.01), and an increase in video hours recorded was positively related to an increase in the number of times a cat crossed the road (β=0.559, se β=0.211, P=0.01). Age did not significantly influence the number of times road crossings were witnessed. This model was also found to fit the data well (P>0.05). The average number of risks exhibited per day and night-time recording hour was similar: 0.265 per night roaming hour, and 0.205 per daytime roaming hour (note, these calculations included three individual cats that did not exhibit any risk-taking behaviour during day or night). The values were not significantly different (P=0.625).

Discussion

KittyCams video provides baseline information on the types and frequencies of free-roaming cat activities in suburban neighbourhoods. Many roaming cats engaged in a dangerous activity on a daily basis. Vehicular accidents are a common cause of death, and road traffic seems to pose the greatest hazard to free-roaming cats, as almost half our cats were witnessed crossing roads. It does not appear that cats exhibit risk behaviours more often during day or night-time hours, but this notion needs further assessment. Threat of contracting an infectious disease is another concern, since one-quarter of participating cats were witnessed in close contact with an unknown (possibly stray)

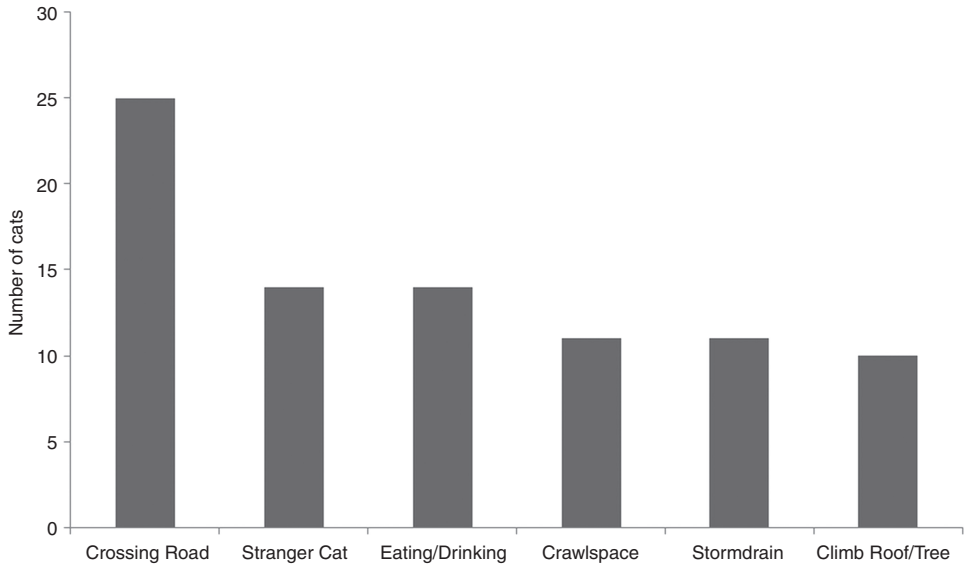

FIG 3: The number of pet cats (n = 55) witnessed engaging in common risk behaviours via KittyCam video cameras while roaming in Athens-Clarke County, Georgia, 2011

FIG 4: Still images pulled from KittyCam video recorded by 55 free-roaming owned cats in Athens, Georgia in 2011

TABLE 2: Influence of predictors on the number of risks experienced by free-roaming cats monitored with KittyCam video cameras in Athens-Clarke County, Georgia, 2011

	Estimate	se	z	P Value	Lower CI	Upper CI
(Intercept)	−0.072	0.588	−0.122	0.903	−1.224	1.081
Male (sex)	0.598	0.249	2.404	0.016	0.110	1.086
Age	−0.122	0.037	−3.314	0.001	−0.194	−0.050
(Health issue)	−0.317	0.305	−1.041	0.298	−0.915	0.280
Warm (season)	0.503	0.293	1.719	0.086	−0.070	1.077
Video hours	0.025	0.007	3.802	0.000	0.012	0.038
Suburban (habitat)	0.851	0.391	2.177	0.029	0.085	1.618

TABLE 3: The influence of cat age, sex and video hours collected by KittyCam video cameras on the number of times owned, free-roaming cats were witnessed crossing roads in Athens-Clarke County, Georgia, 2011

Coefficient	Estimate	se	z	P Value	Lower CI	Upper CI
(Intercept)	−0.385	0.791	−0.487	0.626	−1.935	1.165
Age	−0.050	0.044	−1.121	0.262	−0.137	0.037
Male (sex)	0.844	0.308	2.743	0.006	0.241	1.447
Video hours	0.559	0.211	2.652	0.008	0.146	0.973

cat. This disease risk may not have been reflected in our health-testing results because our sample of cats were homogeneously well cared for (were afforded regular preventive medical care). Although data on preventative healthcare was not analysed in our study, veterinary visits, vaccinations and the application of flea/tick medicine likely contributed to the health of our sample cats, and the importance of such care for indoor/outdoor cats should be stressed. Barn cats, or strictly outdoor cats, might spend a larger portion of time roaming and may not receive the same care from their owners, exposing them to additional risk.

Regardless, limiting roaming behaviour is likely to protect pets from exposure to infectious disease due to contact with other roaming cats or wildlife. With the exception of one encounter with an opossum, potentially dangerous interactions with other wild mesopredators (foxes, raccoons, coyotes, etc) were not witnessed in our videos. This may be due to the temporal differences in the activity of these animals and the diurnal roaming habits of the majority of our sample cats. While we acknowledge the potential risks (disease and parasite consumption) of consuming the prey items captured while roaming, we did not count predation or prey consumption events as 'risk behaviours' in our analysis. Analysis of captured wildlife showed that the majority of captured prey was small reptiles and invertebrates (Loyd and others 2013), and these predation events were not deemed as risky as crossing roads, consuming liquids in storm drains, and so on.

Twenty per cent of free-roaming cats were exposed to possible poisons through consumption of liquids and solids away from home. Drinking from parking lot and storm drain puddles may expose cats to ethylene glycol (antifreeze) or other chemical runoff from vehicles or suburban lawns. The majority of cats roamed close to home (<0.5 km), thus, providing fresh water outdoors for pets (where feasible) may alleviate the consumption of other liquids while roaming. Twenty per cent of our sample frequented risky locations including crawlspaces (where they could become trapped) and storm drains (where they could experience unexpected flooding during a rain event). Owners should be aware that many free-roaming pet cats engage in such activities. The threat of losing their pet may influence the choice to allow their pet to roam free for long periods of time each day. In addition to threats identified by the KittyCams research, cats may also become physically lost while roaming. In fact, of 76 cats originally signed up to enrol in the KittyCams project, two cats became lost, and one was a victim of a car accident before actual participation could be initiated (other volunteer families became non-responsive). Most owners who have found their cat injured or dead from a vehicular collision have subsequently kept their cats indoors; yet, owners whose cat disappears for unknown reasons may be more likely to assume their cat 'adopted' another family, rather than imagine their cat was injured and never found. Last, a minority of our cats roamed in rural areas where additional dangers, such as predation from larger mesomammals (eg, recently expanded populations

of coyotes) are more likely. Our results may underestimate potential dangers to rural cats.

While many veterinarians and animal welfare organisations (eg, HSUS 2010, AARS 2011, PAWS Companions 2012) encourage owners to keep cats safely indoors, a minority of American cat owners do so. This is true even though many municipalities, including ACC, have written codes requiring domestic animals be kept under the control of owners. The common risk behaviours identified through KittyCams, and the video evidence from this project, can be used in public education campaigns to influence future management of some pets. Providing images of pet cat activities allows owners to visualise these otherwise nebulous risks more vividly, and is likely to be more motivating than simple warnings. Images and a downloadable brochure can be found on our website: www.kittycams.uga.edu. Since we found age (younger) and sex (male) positively influenced the number of risks experienced by roaming pets, owners may especially consider keeping younger males indoors, in outdoor enclosures (examples found here: www.paws.org/outdoor-cat-enclosures.html) or only providing supervised outdoor time. Our finding of sex as a predictor of increased risk behaviour, regardless of sterilisation, supports previous findings related to road death (Childs and Ross 1986). Our results also demonstrate that reducing the total roaming time may reduce the number of risks that roaming cats experience. These new insights into cat behaviour can be used to inform future educational campaigns and feline veterinarians. A thorough review with enrichment recommendations and environmental needs of cats that remain indoors (including appropriate environmental conditions, housing, feeding, training, socialisation and other behavioural enrichment) can be found from Ellis and others (2013), Overall and Dyer (2005) and Rochlitz (2005). The welfare of indoor cats should be monitored, and additional research on the success of enrichment techniques for various demographics of cats and directly comparison of the physical and mental status of indoor versus outdoor cats is needed. For those pet owners who wish to maintain indoor-only cats, The Ohio State University College of Veterinary Medicine Indoor Pet Imitative offers many resources on problem solving and keeping indoor cats healthy (indoorpet.osu.edu/cats/).

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