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# Factors determining the home ranges of pet cats: A meta-analysis

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ABSTRACT

Roaming pet cats *Felis catus* are a significant conservation issue because they may hunt, harass and compete with wildlife; spread disease, interbreed with cats in feral populations, and hybridise with wild native felids. Studies of the roaming behaviour of pet cats are often hampered by modest sample sizes and variability between cats, limiting statistical significance of the findings and their usefulness in recommending measures to discourage roaming. We resolved these difficulties through meta-analyses of 25 studies from 10 countries involving 469 pet cats to assess the influence of sex, whether a cat was desexed and housing density on roaming. A complementary linear mixed models approach used data on 311 individual animals from 22 studies and was also able to assess the influence of age and husbandry practices on roaming. This restricted sample gave greater statistical power than the meta-analyses.

Meta-analyses found that: male pet cats had larger home ranges than females, desexing did not influence home range, and cats had larger home ranges when housing densities were low. The linear mixed models supported those results. They also indicated that animals ≥8 years old had smaller home ranges than younger cats. Cats fed regularly, provided with veterinary care and socialised with humans had similar home ranges to cats living in association with households but not provided for in some of these ways. Short of confinement, there is no simple measure owners can adopt to reduce roaming by their cats and prevent the associated environmental problems.



## 1. Introduction

Wandering pet cats (*Felis catus*) (those closely associated with a household providing food and other needs (Baker et al., 2010)) hunt wildlife (Baker et al., 2005; Kauhala et al., 2015), transmit diseases to people and wildlife (Lepczyk et al., 2015), compete with other predators (George, 1974), reduce the reproductive success of prey species by fear of predation (Beckerman et al., 2007) or causing prey to display defensive behaviour that attracts other predators (Preisser et al., 2005), reduce the genetic integrity of wild felids by hybridising (Beaumont et al., 2001), and contribute to feral populations by interbreeding or abandonment of kittens (Jongman, 2007). There are also concerns about unrestrained roaming because of risks to cat welfare (Egenvall et al., 2009; Loyd et al., 2013).

Research on relationships between the home ranges of pet cats and their impacts on wildlife give ambiguous results. Hansen (2010) and van Heezik et al. (2010) concluded that home range did not influence the number of prey caught, but Meek (2003) and Morgan et al. (2009) found a greater diversity of prey in pet cats with larger home ranges. Nevertheless, concern about pet cats entering nature reserves or remnant native vegetation led Lilith et al. (2008) and Metsers et al. (2010) to use data on roaming behaviour to recommend buffer zones around sensitive habitat to protect against cat incursions. Concern amongst owners fuels interest in commercial deterrents for predatory behaviour (Calver et al., 2007; Hall et al., 2015; Nelson et al., 2005; Willson et al., 2015), which might act in part by curtailing roaming behaviour (Hall et al., 2016b). Reduced roaming should also restrict opportunities for other problems such as disease transmission or encounters that could change prey behaviour through fear of predation, but we are unaware of relevant data.

Despite the uncertainty about the relationship between roaming and impacts on wildlife, under the precautionary principle the plausibility that restricting roaming might protect wildlife justifies attempts to reduce roaming while the uncertainty is resolved (Calver et al., 2011). Surveys this century indicate that many owners are reluctant to confine their cats to protect wildlife (Grayson et al., 2002; Hall et al., 2016a; Lilith et al., 2006; MacDonald et al., 2015; Thomas et al., 2012) but there might be other husbandry approaches such as desexing or confining only younger animals that might be more acceptable. A better understanding of the influence of factors such as age, desexing, sex, habitat variables such as housing density, and husbandry on roaming behaviour are important topics, because they might indicate practices owners could adopt or regulators could encourage to reduce roaming.

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One of the primary difficulties in assessing influences on roaming behaviour is the substantial variation between individual cats (e.g. cats in Lilith et al. (2008) had home ranges (95% MCP) between 0.01 and 2.54 ha, while cats in Hall et al. (2016b) had home ranges (95% KDE) between 0.20 and 20.00 ha), causing difficulty in obtaining large enough sample sizes to reach statistically significant conclusions in the face of these variations. For example, several studies on pet cats report larger home ranges for males than females but no statistically significant difference between the two (Kays and DeWan, 2004; Lilith et al., 2008; Morgan, 2002; Thomas et al., 2014), while others do report a significant difference (Corbett, 1979; Liberg, 1980; Schär and Tschanz, 1982). Sample sizes, husbandry of cats, whether the animals were desexed or entire, and possible interactions between these factors might all influence findings. In sum, Kays and DeWan (2004) observed that influences on cat roaming are not well understood, both at the level of individual cat's characteristics such as sex and at the level of environmental factors such as housing density, although better understanding could improve management of cats for wildlife protection.

We sought to overcome these difficulties through meta-analyses of the available data, concentrating on the influence of sex, age, desexing, husbandry practices and housing density on home range. Based on the results, we offer suggestions for managing the roaming of pet cats.

## 2. Materials and methods

### 2.1. Selection of studies

We attempted to find every study that had analysed the home ranges of pet cats. In order to find studies we searched for key words (various combinations of pet, farm, domestic, cats, home range, roaming, wandering) in the Keywords + titles + abstracts in the journal database Scopus. All results were carefully checked for data on cat home range. Scopus does not claim to have complete data prior to 1996, so to locate earlier studies and grey literature such as theses we checked the reference lists of all the papers that either tested for cat home range or referred to studies that did. We continued to do this with any new papers until no new references were found. In the case of theses we attempted to contact the library of the relevant university if the thesis was unavailable online, but unfortunately some had been lost.

Estimates of home range are sensitive to variations in methods, especially the time periods involved and the density of location data. We included studies that used radio-tracking (17) or GPS collars (8) to determine home range. We excluded studies that used observational data only because cats could often not be seen, leading to underestimates of home range.

### 2.2. Study variables

We attempted to find the home range, living conditions (husbandry), age, sex, and breeding status (desexed or entire) for each individual cat in each study. Sometimes this was provided in text or in supplementary material, but for other studies we contacted the authors of the papers or found a relevant thesis with additional information. Information on individual cats was found for 22 of the 25 studies ultimately included.

We considered, but ultimately did not include, numerous other predictor variables including detailed descriptions of the habitat and more details on the study methods (e.g. GPS vs radio-tracking) because of considerable variation in the information reported and because including many predictor variables relative to sample size in statistical models risks overfitting (Anderson, 2008). Instead, we included individual studies as a variable in analyses and regard habitat and methodological effects as part of the variability within studies.

#### 2.2.1. Home range

For some papers only figures of the home ranges were provided and these were analysed with Assess 2.0 image analysis software (Lamari, 2015). Assess 2.0 was developed to determine the area of diseased tissue in plant leaves, so it is readily transferrable to measuring other irregular 2D shapes such as home range. In instances where multiple home ranges were provided for a single cat (e.g. nocturnal and diurnal home ranges or seasonal home ranges) the largest home range for each cat was chosen as a representation of the most extreme possible scenario. All home ranges, irrespective of whether or not authors had demonstrated that home range estimates had plateaued, were included because authors were not always clear on this point (an important reason for including individual studies as a random factor in analyses).

The home range data provided by each study varied in how they were recorded because preferred methods of determining home range have changed over time. They included 100% minimum convex polygons (100% MCP), 95% MCP and 95% Kernel density estimates (95% KDE). For analysis, a single measure of home range in hectares (HR in tables and equations) was defined which used the 95% KDE where available, with the 95% MCP or 100% MCP used where 95% KDE measurements were not given.

#### 2.2.2. Living conditions

These embraced two variables: the husbandry methods used by owners and the housing density where the cats were living. On the basis of husbandry, we distinguished between pet cats and farm cats. Refining the definition of Baker et al. (2010), pet cats were those that belonged to a household and were fed at least daily. They received veterinary treatment when required and had a close relationship with their owners. In the included studies, they often lived in single-cat households and very rarely did more than three cats live in one household. Cats from the same household were sometimes related (i.e. sibling or parent/offspring), but were often living with unrelated cats. Farm cats lived on farms and were usually kept to catch rodents in farm buildings. They were fed regularly (at least daily), but were unlikely to receive veterinary treatment and lived in farm buildings rather than the house. We chose to include farm cats because we wanted to determine if there were any differences in home range based on husbandry practices and not just housing density. Farm cats were also much less likely to be desexed and therefore sex differences and the effect of desexing could be better analysed. We did not include studies that analysed the home range of stray or feral cats that lived on farms unless they also included data for pet or farm cats. Farm cats tend to live in groups of related cats.

With regard to housing density, where possible cats were described qualitatively as rural (pet cats living in non-urban areas of low housing density), farm (rural cats not allowed access to human habitation but living on farm and regarded as owned) and urban (pet cats living in cities or their suburbs with higher housing density than rural). All classifications were based on the information provided by authors in text, which was mostly inadequate to quantify housing density more precisely. Housing density may actually function as a surrogate for cat density, but it can be measured more readily.

#### 2.2.3. Age

It was decided that a categorical measure of age was sufficient for analysis purposes, because this allowed us to accommodate age ranges given in some papers. Cats were classified as “young” if <2 years old, “adult” if at least 2 years old but <8 years old and “mature” if at least 8 years old. Although an age in years wasn't provided for cats in either Macdonald and Apps (1978) (four cats) or Hansen (2010) (eight cats), both studies provided enough information to conclude that the cats were older than 2 years. These cats were included in the adult category.

#### 2.2.4. Sex and breeding status

Cats were classed as male and female and as desexed or entire. If information on the sex of animals or desexed status was not given in the