Domestic cats' effect on urban wildlife

– using citizen science and camera traps

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Master's thesis • 30 credits
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Department of Wildlife, Fish, and Environmental Studies
Forest Science programme
Examensarbete/Master's thesis, 2021:3
Umeå 2021

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Credits:	30 credits
Level:	Second cycle, A2E
Course title:	Master's thesis in Forest Science
Course code:	EX0968
Programme/education:	Forest Science programme
Course coordinating dept:	Department of Wildlife, Fish, and Environmental Studies
Place of publication:	Umeå
Year of publication:	2021
Cover picture:	From camera trap
Title of series:	Examensarbete/Master's thesis
Part number:	2021:3

Keywords:	Domestic cat, Felis catus, camera traps, citizen science, visitation frequency

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Abstract

Europe has transformed from areas dominated by agricultural and rural to gradually becoming urban communities. With the development in urban and suburban areas, more non-native species have increased, especially domestic species, about 25% of all Swedish households obtain one or more cats. Domestic cats *(Felis catus)* have contributed to extinction and endangerment of several species of birds, mammals, and reptiles, and constitute a risk for species that are endangered or threatened worldwide. However, the high density of domestic cats in urban areas indicates higher predation on wildlife compared to rural areas with lower densities of domestic cats. Several earlier studies around the world have found evidence that the domestic cat has a negative effect on wildlife, especially avian species. In Sweden, very few studies have been done in the subject on wildlife and its correlation to housing density and domestic cat visitation frequency. This thesis aims to investigate if there is a correlation between wildlife visitation frequency, domestic cats and housing density, using citizen science and camera traps. The data were collected in Umeå municipality, northern Sweden and the analysis was tested on five wildlife species and one species groups using a generalised linear mixed model and divided the domestic cat's visitation frequency into two categories high or low, testing for a nonlinear correlation. I found more Eurasian magpies in locations with a low visitation frequency of domestic cats. In contrast to my expectation, songbirds as a species group showed the opposite pattern, being more common in locations with more cats. The results also show a positive correlation with housing density for both domestic cats and Eurasian magpies. By knowing how the different species explore or avoid areas where the domestic cat has higher visitation frequency can give support when planning to urbanise new areas, and before creating more suburban areas have an insight on the wildlife living there and with the domestic cat is coming to affect wildlife species if domestic cats get a high abundance in that area.

Keywords: Domestic cat, *Felis catus*, camera traps, citizen science, visitation frequency

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Abbreviations

EU	European Union
GLMM	Generalized Linear Mixed Model
PIR	Passive infrared
SLU	Swedish University of Agricultural Sciences
SMHI	Swedish Meteorological and Hydrological Institute
UN	United Nation

1. Introduction

Europe has transformed from areas dominated by agricultural and rural areas to gradually becoming urban communities. Urban areas have always drawn people for work employment and by 1950 at least half of the European population had a permanent residence in urban regions according to the united nation (UN). It is projected that by 2050 two-thirds of the world's population will have permanent residence in urban areas *(Koceva et al. 2016)*. With more cities, scattering and population number in the cities increasing have led to more people moving from larger cities to suburban or pre-urban areas instead *(Dijkstra et al. 2016)*. Consequently, with new locations for suburban and pre-urban areas makes it more difficult to separate the two areas from each other. What used to be forest and well-functioning ecosystem, have been replaced with cities and villages to acclimate the human population growth *(Parsons et al. 2018)*. To preserve and increase biodiversity in cities and reduce the destructive effects of urbanisation cities has established so-called green spaces. The green spaces include native vegetation and untouched surfaces and connecting the green spaces with corridors and domestic gardens through urban areas increase wildlife movement *(Gaston et al. 2007)*. The countryside close to cities were urbanised and included in larger cities where green areas used to be dominated has become smaller or not existing *(Lilja 1994)* this led to a decreasing number of species and lower species richness in the urbanised areas. With the development in urban and suburban areas, more non-native species have increased, especially domestic species *(McKinney 2002)*. Domestic cats (*Felis catus*) ownerships is superior in urban regions and can develop extremely high cat populations compare to rural regions *(Hanmer et al. 2017)*.

The domestic cat is seen as an invasive species that has become one of the most omnipresent and environmentally destructive species in the world *(Loss & Marra 2017)*. Domestic cats have contributed to extinction and endangerment of several species of birds, mammals, and reptiles, and constitutes a risk for species that are endangered or threatened worldwide. Mainly the introduction of domestic cats on smaller islands *(Sims et al. 2008)* has a negative effect on native species that are not used to predators *(Loss & Marra 2017)*. The domestic cat has a comparable behaviour to the wildcat (*Felis Silvestris Silvestris*), and that comparable behaviour creates a prospective of negative correlation between domestic cats' densities with avian densities. However, the high density of domestic cats in urban areas indicates higher predation on wildlife compares to rural areas with lower densities of domestic cats *(Sims et al. 2008)*. The number of prey for each domestic cat in urban areas is low, although with high cat density the predation in urban areas is significant negative on prey species *(Baker et al. 2008)*. Ground dwelling birds have a higher predation rate by the domestic cats regardless of species. Avian species visiting feeding stations are more vulnerable to predation but visiting a garden is no increased risk to become prey by the domestic cat *(Pavisse et al. 2019)*. The domestic cat can have a high population number in urban regions where they are not limited by prey availability. Since the domestic cat is provided food and shelter by their owners the domestic cat does not require predation to survive *(Woods et al. 2003)*. With no limitation in food and shelter, the domestic cat population can reach extremely high densities *(Tschanz et al. 2011)* in urban regions compared to rural and wild regions *(Baker et al. 2008)*. The number of prey from domestic cats is hard to completely know, but it is believed that each domestic cat has three times more prey compared to the number of prey owners register *(McDonald et al. 2015)*. The high densities of domestic cat have created a concern to if the predation pressure will increase and be too strong *(Tschanz et al. 2011)*.

Sweden is not the most populated country in Europe, but it has the greatest rural and urban growth of all the European Union (EU) members *(Dijkstra et al. 2016)*. Approximately 25% of all Swedish households obtain one or more cats and several domestic cats are free-roaming cats. To help the domestic cat get a higher status in Sweden's society new animal welfare regulations have been introduced in June 2020. The regulations contain sharper rules on castration and sterilization on cats allowed staying outside to minimize free-roaming cats *(Jordbruksverket, 2020)*. In Sweden, little research has been done on the domestic cat and their effect on wildlife. Given that Sweden has a large population of domestic cats with and without homes, they are becoming part of the Swedish ecosystem. Knowledge of the interaction of the domestic cat with wildlife and urbanisation levels can contribute to landscape planning *(Hanmer et al. 2017)* and understanding of the position of the domestic cat in Swedish ecosystem.

Several articles around the world have tested the domestic cat predation and correlation with urbanisation and have discovered a correlation between domestic cats and urbanisation *(van Heezik et al. 2010; Hanmer et al. 2017; Pavisse et al. 2019)*. Very few of these articles test the wildlife visitation frequency correlation to domestic cats and only test the correlation with avian species *(Sims et al. 2008; Blancher 2013; Pavisse et al. 2019)*. Therefore, in this thesis, I study the domestic cat effect on wildlife in different urbanised areas. The aim I have for this the is to investigate (i) if wildlife visitation frequency has a correlation with cat visitation frequency in a garden and (ii) if the effects of domestic cats on distinct wildlife groups differ among urbanisations. I hypothesise that (i) Wildlife visitation frequency is lower in areas with high cat visitation frequency compared to areas with low cat visitation frequency, and (ii) Domestic cats have a larger negative effect on birds and smaller mammals and no effect on ungulates in more urbanised areas compared to areas with lower urbanisation.

2. Materials and method

2.1. Study area and camera trapping

In this project, I used a combination of camera traps and citizen science to collect data on cat density and wildlife presence in gardens around Umeå municipality, sited in Västerbotten county, Sweden. Umeå municipality has had a strong population increase and the total number of people living in Umeå municipality 2020 was 128 901. During the last five years, 2015–2020, have the population in Umeå increased with approximately 1850 inhabitants per year (*Umeå Kommun, 2020*).

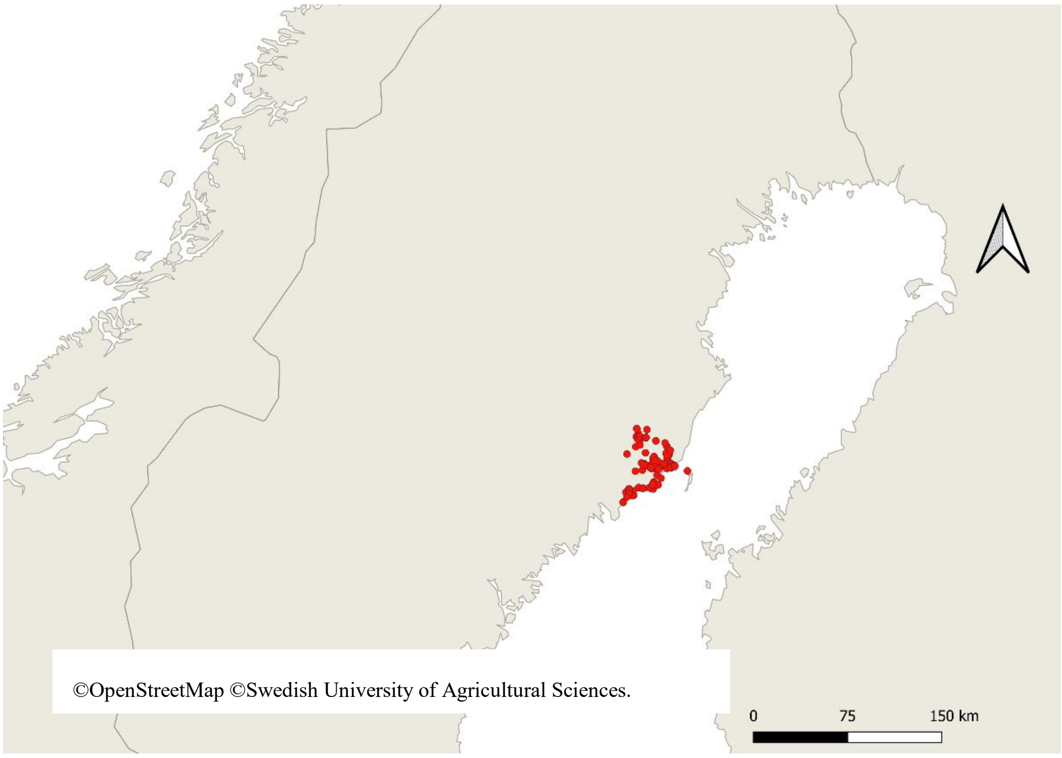

Figure 1: A map over the study area Umeå municipality, the red dots are camera trap locations from the project- 'Meet your wild neighbours'.

The camera traps were part of a citizen science project 'Meet your wild neighbours' by Swedish University of Agricultural Sciences (SLU). The project investigated what wild animals are living in Umeå municipality. There was a total of 147 participants in the project (Figure 1). The Meet your wild neighbours -project started in the middle of September 2019 and ran until the beginning of November 2020. The participants had the camera traps for one month before returning the camera but were allowed to participate several times during the project, and at most one participant participated four times. The camera traps used in the project were of the model Reconyx Hyperfire HC500 with a passive infrared (PIR) sensor. The PIR sensors were set to trigger at the highest sensitivity (to detect the slightest movement) and when the PIR sensor was triggered it took 3 images on 'rapid-fire' with no delay between triggers. To control the function of the cameras they were set to take a time-lapse control image at midday (12:00) and midnight (24:00). The setup for the cameras was following Parsons et al. (2018) method. All participant in the project got the instruction to place the camera perpendicular and parallel to the ground at a hight of 40 centimetres above ground (knee height), to increase detection of smaller species *(Parsons et al. 2018)*. The citizens were also asked to place the camera in their garden or private land, and avoid facing the camera towards public land, compost or supplement feeding stations.

2.2. Classification

To classify the images, I used an open-source web application called TRAPPER. On TRAPPER, all the images were sorted after the participant's number and coordinates. Classifying images in TRAPPER, I first define the observation type, if it was an animal, human or vehicle on the images. If the image contained one or more animals the species was classified by English and Latin name *(Bubnicki et al. 2016)*. The total number of individuals of the same species in the image was counted. In some images, the resolution was too blurry to identify the species or the animal was too far away to determine the species and therefore classified as other. I determined the species sex and age if it was possible to determine in the image. Images taken less than 15 minutes apart could be classified in sequences, which often happened if an animal stayed and triggered the camera trap several times in a row *(Bubnicki et al. 2016)*. The animal(s) in the image was counted only once, although the individual(s) was leaving the image and reappearing again. For each location, I also did an individual recognition of domestic cats, to get an idea of the number of cats in each garden.

2.3. Analysis

2.3.1. QGIS and housing density

The locations from the camera traps were exported from TRAPPER into QGIS *(QGIS version 3.42, QGIS Development Team 2009).* I used a layer provided by Umeå municipality which includes all the buildings in the municipality. I created a buffer zone around the camera trap locations (Figure 2) of 1 square kilometre, and then calculated the number of houses within that buffer to get the housing density for each location. This housing density was used as a proxy for urbanisation, similar to previous studies *(Parsons et al. 2018).*

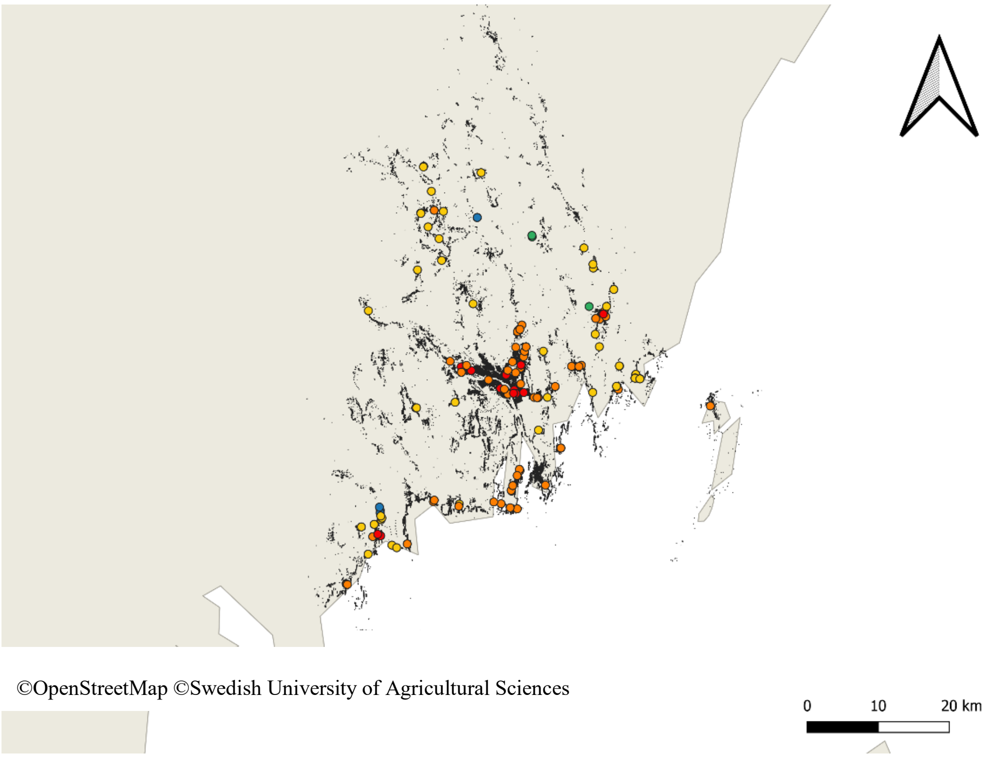
©OpenStreetMap ©Swedish University of Agricultural Sciences

Figure 2: Camera trap locations and their level of urbanization. Although the analysis was done using a continuous scale for housing density, I divided housing density into different urbanization classes for graphical purposes following Parsons et al. (2018). The urbanization classes are "Urban (<1000 houses/km^2, red), Suburban (147.048–1000 houses/km^2, orange), Exurban (12.64–147.047 houses/km^2, yellow), Rural (0.51–12.63 houses/km^2, blue) and Wild (<0.5 houses/km^2, green)" (Parsons et al. 2018).

2.3.2. Statistical analysis

To test both of my hypotheses in R studio *(RStudio Team, 2020*) using a generalised linear mixed model (GLMM) *(Kays et al. 2017; Parsons et al. 2018)* with a Poisson distribution, since I had count data and I added a log-link function using the lme4 package *(Bates et al. 2020)* I added the log-link function *(log10)* on the number of camera trapping days as an offset to the model to correct for differences in camera effort. I did this since not everyone that participated had the camera active for the whole month. As some participants deployed a camera multiple times and in the same location, I added a random intercept per location to correct for multiple measurements at the same location. I only tested species that were recorded in a minimum of 15 locations, with the lowest number of 40 per site to circumvent issues of zero-inflation or model convergence. Since the project Meet your wild neighbours were operating between September 2019 and November 2020, camera images were distributed throughout all seasons. I tested for a difference in visitation frequency in the winter season (1 November – 30 April) compared to non-winter season (1 May – 31 October). The classifications of winter and non-winter seasons derives from the Swedish meteorological and hydrological institute (SMHI) definition of winter *(SMHI, 2020)*. I did this to incorporate potential differences in wildlife visitation frequency as a consequence of domestic cats' activity under the winter season. To test for a potential non-linear response to domestic cats, I tested if wildlife visitation frequency differed between locations with a high or low cat visitation frequency, where I separated for high and low visitation frequency taking locations above or below the median cat visitation frequency.

3. Result

3.1. Wildlife and domestic cat visitation frequency

The total number of cameras used was 111, out of 147, and the average number of days a camera was active were 32 days (minimum = 17 days maximum = 78 days). I could not use all the camera traps as some of the participants failed to follow the instructions. Cameras were not included if they were facing feeding stations, compost areas or not placed horizontal, aimed too high or too low. Participants living outside of Umeå municipality were not included in the analysis. The average housing density was 412 (minimum= 0, maximum = 1,413) houses per square kilometre, the majority of the locations were in suburban areas (Figure 3).

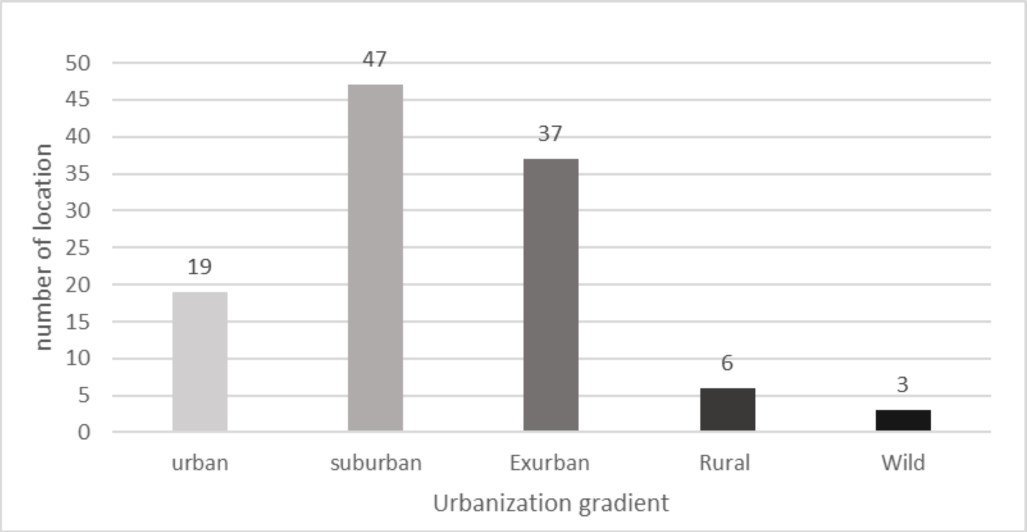

Figure 3:The number of locations classified in each urbanization gradient, using Parsons et al. (2018) classification.

The number of individual domestic cats per camera location ranged from 0 to 5 (average = 1.2). When testing the correlation between the domestic cat and housing density, I found a positive correlation, beta = 2.0, p = < 0.001 (Figure 4).

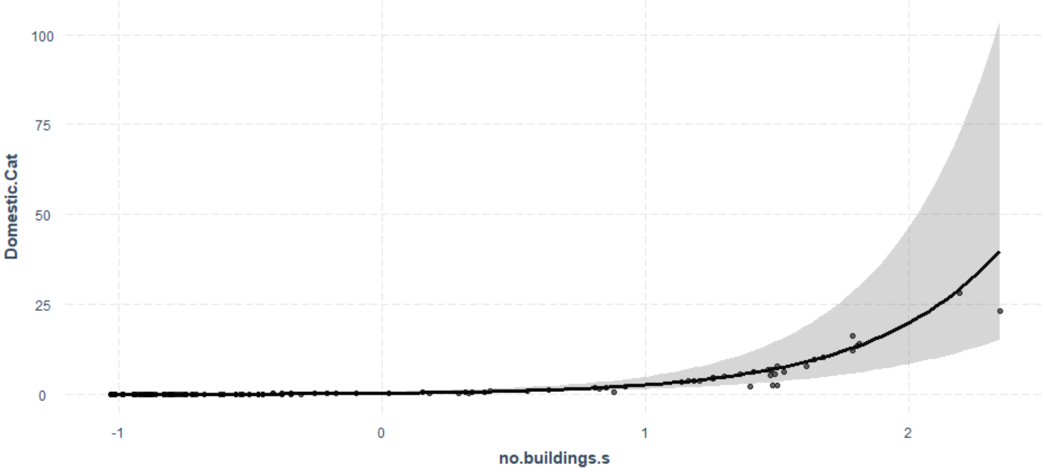

Figure 4: Partial residual plot of the estimates Domestic cat visitation frequency increased with housing density. The plot shows the prediction from the GLMM with a 95% confidence interval.

There were in total 47 mammal and bird species caught on the camera traps. I tested five species and 1 group of species out of the 47 detected species (Table 1). The species I tested in my models were: Eurasian magpie *(Pica pica,* 625 observations), great tit *(Parus major*, with 116 observations), mountain hare *(Lepus timidus,* with 96 observations), red fox *(Vulpes vulpes,* with 58 observations), roe deer (*Capreolus capreolus,* with 468 observations). To get sufficient data on songbirds I tested them together as a combined species group with 281 observations.

Table 1: The number of total observations for the wildlife species tested in the model (GLMM)

Species	**Number of total observations**
Eurasian magpie, *Pica pica*	625
Great tit, *Parus major*	116
Mountain hare, *Lepus timidus*	96
Red fox, *Vulpes vulpes*	58
Roe deer, *Capreolus capreolus*	468
Songbirds	281
Bohemian waxwing, *Bombycilla garrulus*	1
Brambling, *Fringilla montifringilla*	12
Chaffinch, *Fringilla coelebs*	3
Common blackbird, *Turdus merula*	21
Eurasian blue tit, *Cyanistes caeruleus*	2

Species	**Number of total observations**
Eurasian jay, *Garrulus glandarius*	2
Eurasian tree sparrow, *Passer montanus*	5
European robin, *Erithacus rubecula*	25
Fieldfare, *Turdus pilaris*	52
Great tit, *Parus major*	116
Mistle thrush, *Turdus viscivorus*	2
Redwing, *Turdus iliacus*	2
Song thrush, *Turdus philomelos*	11
Spotted Nutcracker, *Nucifraga caryocatactes*	15
White wagtail, *Motacilla alba*	5
Yellowhammer, *Emberiza citrinella*	7

Testing the correlation of wildlife species and high or low domestic cat visitation frequency, I found a correlation with two species (Figure 5). Eurasian magpie had a higher visitation frequency in locations with below average cat visitations, beta = 0.88, p = <0.001 (Figure 6), while songbirds showed the opposite pattern, beta = -2.4, p= <0.001(Figure 7).

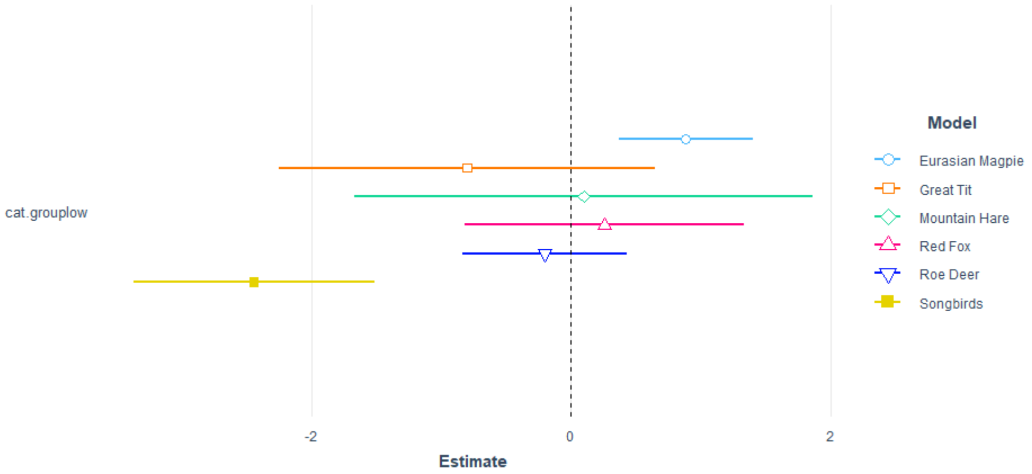

Figure 5: Plot of the coefficient estimates and their 95% confidence interval of the correlation between wildlife species and the difference between below average visitation frequency by domestic cat compared to the group with above average visitation frequency.

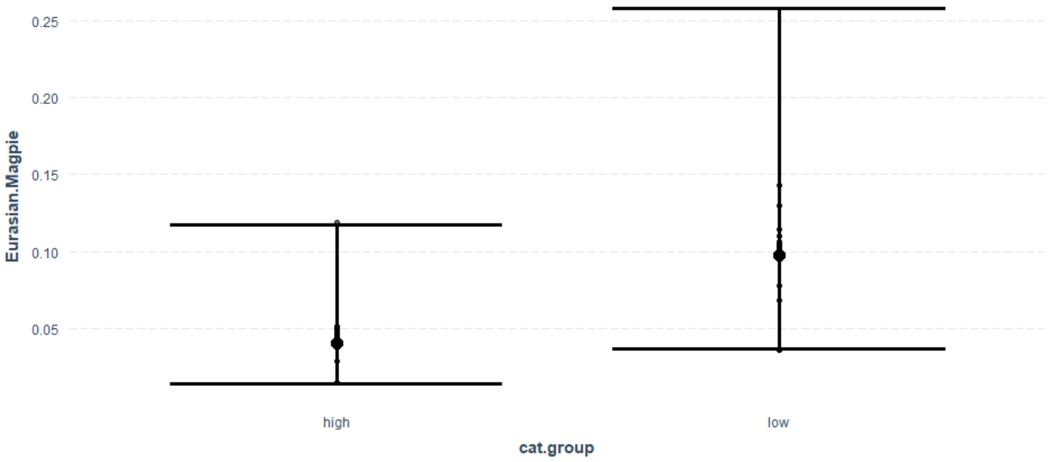

Figure 6: Eurasian magpies showed higher visitation frequency in locations with below average cat visitation frequency. The plot shows the prediction from the GLMM with a 95% confidence interval.

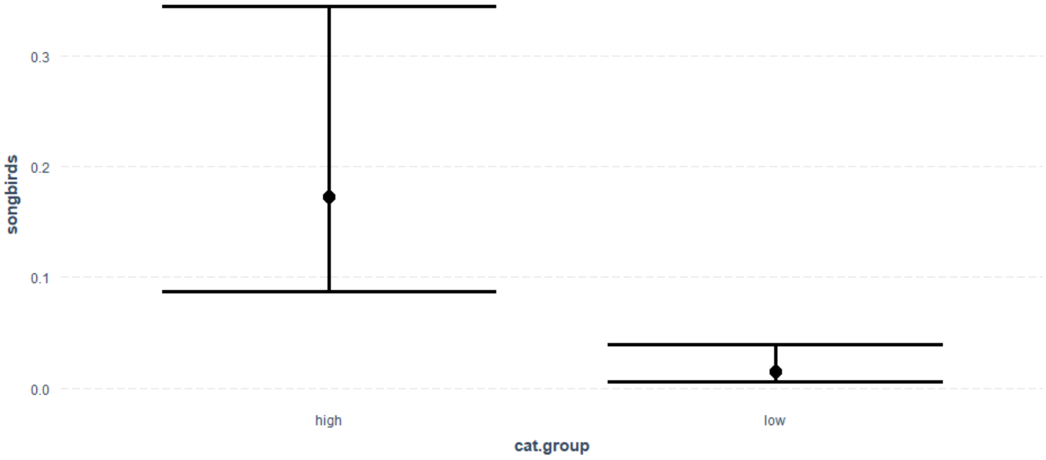

Figure 7: Songbirds showed lower visitation frequency in locations with below average cat visitation frequency. The plot shows the prediction from the GLMM with a 95% confidence interval.

3.2. Housing density

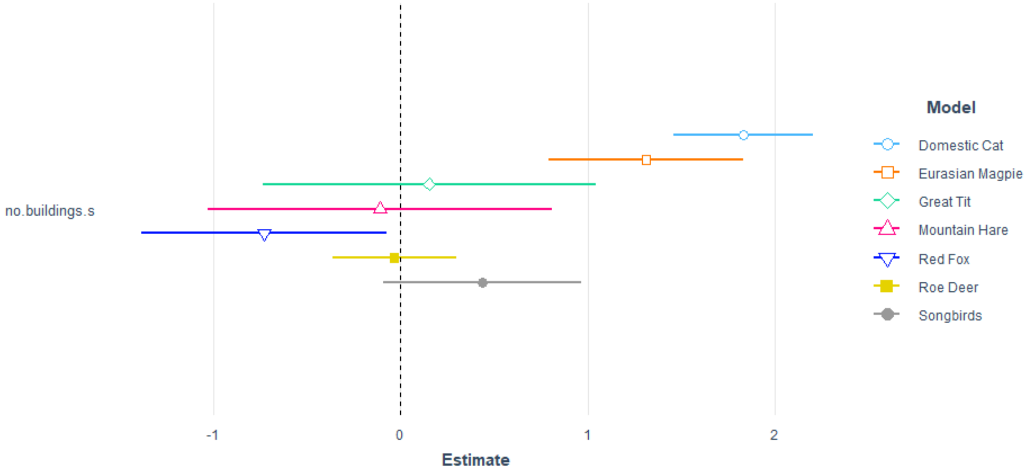

Figure 8: Plot of the coefficient estimates and their 95% confidence interval of the correlation between model species and housing density.

Since the domestic cat had a positive correlation with housing density, I was not able to run a model with both domestic cat and housing density because of the correlation. Instead, I tested the species correlation with housing density without including domestic cats as a factor. I only detected a correlation between Eurasian magpies and housing density (Figure 8). Eurasian magpie's visitation frequency increased with housing density, beta = 1.1, p = < 0.001 (Figure 9). For some species, I found a difference between winter and non-winter season (Appendix 1).

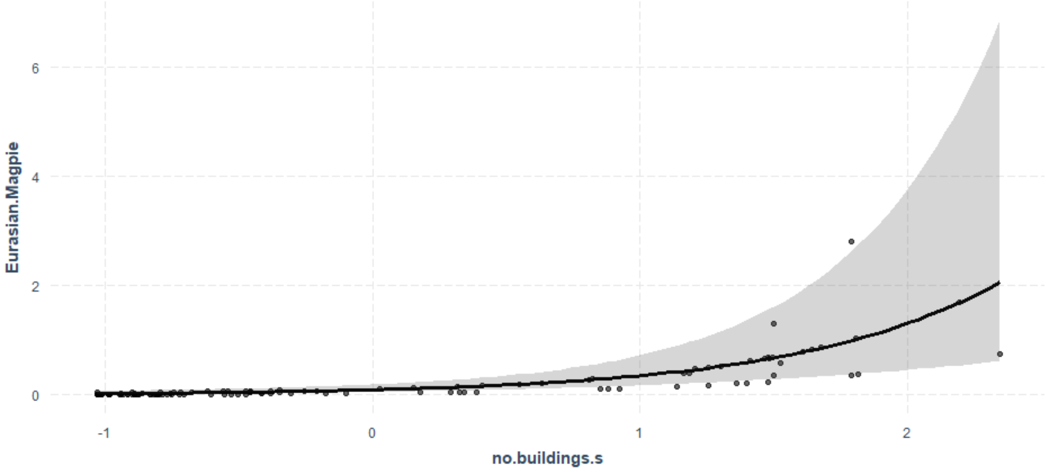

Figure 9: A partial residual plot showing how Eurasian magpie visitation frequency increased with housing density. The plot shows the prediction from the GLMM with a 95% confidence interval.

4. Discussion

I found that the visitation frequency of Eurasian magpies was higher in locations with below average cat visitations (Figure 6). In contrast to my expectation, I found the opposite pattern for songbirds (figure 7). For all other species, I did not find a correlation with domestic cat visitations (Figure 5). When I tried to answer my second research question, if the effects of domestic cats on distinct wildlife groups differ among urbanisation levels, I found a positive correlation between domestic cat visitation frequency and housing density (Figure 4). Because of this correlation, I was not able to test for that question and instead I tested the species correlation with housing density. The result for the model testing the correlation with housing density, I found not only the domestic cat's positive correlation but also that Eurasian magpies had a positive correlation with housing density (Figure 8; Figure 9).

For all species apart from Eurasian magpies and songbirds, I did not discover a correlation with high or low visitation frequency by domestic cats (Figure 4). The reason may be that something else is more important and the species have a correlation with for example availability to food or shelter *(Duduś et al. 2014)* rather than a correlation with the domestic cats. Some avian species can correlate with another avian species, even if the two avian species have different ecology *(Evans et al. 2009)* can the competition between the species have a stronger correlation than domestic cats presents in a garden or housing density. The fact that I found that Eurasian magpies had a lower visitation frequency in locations with above average cat visitations makes it possible to confirm my hypothesis that wildlife visitation frequency is lower in areas with high cat visitation frequency compared to areas with low cat visitation frequency. Corvid species (including the Eurasian magpie) are more neophobic than other bird species, and sceptical to new feeding places and are avoiding objects or other species they don't have control over *(Greggor et al. 2016)* and can therefore actively choose to avoid gardens with high visitation frequency by domestic cats', as they had problems with controlling the domestic cats. Eurasian magpies have a positive correlation with housing density it seems to be favourable for them to exist in more urban areas than in rural or wild, despite the danger and predation risk *(Yamaç & Kırazlı 2012)*. In urban areas the magpies has easier to predate on songbirds nests *(Groom 1993)* and are not as limited by food as in rural or wild areas. Humans usually have a supplement feeding station for songbirds where the Eurasian magpie also can find food. Eurasian magpies have created co-existence with humans *(Yamaç & Kırazlı 2012)* and, as a result, the positive correlation with housing density may be easier, as humans are not a threat to magpies.

In contrast to my expectation, I found a higher visitation frequency of songbirds in locations with above average cat visitations. An explanation for this can be supplementing feeding stations provided by humans in gardens *(Fattorini et al. 2018; Lee et al. 2019)*. Supplement feeding stations for avian species increases the avian population in urban areas even if domestic cats are abundant in these areas *(Sims et al. 2008).* The predation risk by domestic cats is higher on avian species visiting feeding stations instead of only visiting a garden (*Pavisse et al. 2019)*, and with more songbirds visiting gardens where there is a high cat visitation frequency perhaps can help in the future how we think when placing out feeding stations. For example, avoid placing the feeding station in gardens where we know there is high visitation frequency by cats to help the songbirds prevent predation. If the predation of an individual domestic cat is low *(Baker et al. 2008)* can it help to investigate how many domestic cats are in the area and adapt shelter and supplement food positions to areas with fewer individuals of domestic cats.

In my analyses, I did not have sufficient data for every songbird species, so I tested the model on them as a group and obtain an overview of the correlation with high or low visitation frequency by domestic cats. Therefore, I do not know if there is a difference between the species and visiting gardens with more cats. It is possible that some of the species that are feeding on the ground are less in areas with high visitation frequency since they have greater change on becoming prey *(Pavisse et al. 2019).* By knowing how the different species explore or avoid areas where the domestic cat has higher visitation frequency can give support when planning to urbanise new areas, and before creating more suburban areas have an insight on the wildlife living there and with the domestic cat is coming to affect wildlife species if domestic cats get a high abundance in that area. Since the domestic cat has a high abundance in urban areas *(Tschanz et al. 2011)*, and even if the individual cat does not have high predation the predation risk on wildlife, especially avian, species can be affecting avian populations in urban areas negatively *(Baker et al. 2008)*. New animal welfare regulations in Sweden can hopefully help the domestic cat status in society and lead to less free-roaming cats *(Jordbruksverket, 2020)*. Minimize the free-roaming cats can diminish the number of individuals needing to use predation to survive and perhaps it can lead to less predation on smaller mammals, birds, and reptiles in Sweden.

Using citizen science and volunteers to collect the data, I was using in the analyses, can be unreliable. Before starting with the analysis, I sorted out the volunteers located outside of Umeå municipality, camera traps who was placed upside down, or in some other way did not follow the instructions. Using citizen science, it is important to give clear and easy instructions to follow, so data collected from the citizens can be used later in the process. From the results, I saw that most of the locations for the camera traps were in suburban areas in the municipality (Figure 3). When looking into if urbanisation influenced wildlife and domestic cats' visitation frequency is creates difficulties to draw conclusions and have a believable result since most of the camera traps were in the same urbanisation level. If I have had a more distributed sampled area the results from the analyses, I did would have been more reliable and easier to see if it is a difference between wild and urban areas. Using citizen science, I get opportunistic sampling and some areas of the municipality can be missed and not sampled, but it is difficult to use another sampling method when asking volunteers to participate. Another way of doing the sampling and be certain the whole municipality are including could be to use random sampling (Fisher et al. 1943) instead to avoid bias in a location on the data collection. One more bias can be when using volunteers are that they are probably already interested in wildlife and know they have animals in their garden before entering the project. This can affect the analyses and later the results because fewer people not interested in wildlife or have seen wildlife in their garden before do not volunteer to be a part of the project. Before I started with the analyses all the images were classified and it is likely some images are classified as incorrect species or missed in the classification process. If more of the same species are classified incorrect can it affect the result I had from the data.

For the next step in the subject can investigate the relationship the domestic cats have with other species in Sweden and see is there is a difference in the cities in Sweden. As in other countries have found evidence on avian species richness decreases with higher housing density and the domestic cats' increases with housing density *(Sims et al. 2008),* and since the domestic cats predate on avian species which reduced the number of avian individuals in a garden *(Blancher 2013),* can it be interesting to explore if it the same in Sweden's gardens. With exploring and research what the domestic cats mainly predates on can give us knowledge on how the domestic cats affect the ecosystems and direct or indirect not only with predation but also the availability of food or shelter close to urban areas. Other studies in the subject that could be interesting and informative is to research and see what impacts except predation they affect wildlife, competing for food, shelter or territory *(Trouwborst & Somsen 2019).*

My conclusions are the domestic cats' effect on wildlife is not as easy to determent as earlier studies have indicated *(Baker et al. 2008; Loss & Marra 2017)*. The strong positive correlation domestic cats have to urban areas makes it hard to determent the influence of only the domestic cats without the housing densities or if it is something else that are the driving factor. To get a more understanding and insight in how the domestic cats effect our wildlife species in Sweden I think it is important with further studies.

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Acknowledgements

First of all, I give my deepest gratitude to my supervisor Tim Hofmeester who have guided me through the process with arising problems and giving me good advice along the way. I would also give thanks to Joris Cromsigt for being my co-supervisor. I would also give thanks to all the participants and volunteers in the project meet your wild neighbours, without your help, I would not be able to carry out this project.

Appendix 1

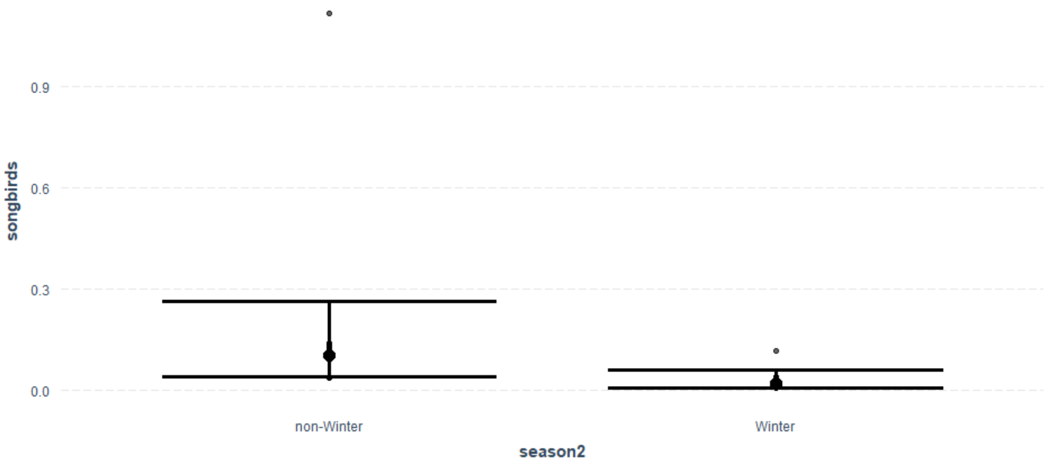

Figure S 1: Songbirds showed a lower visitation frequency in winter compared to the other seasons. The plot shows the prediction from the GLMM with a 95% confidence interval.

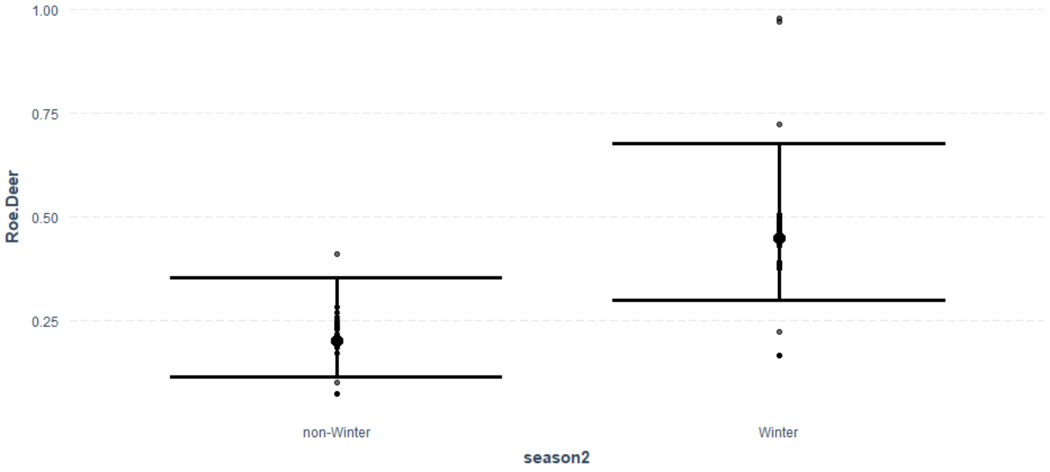

Figure S 2: Roe deer showed a higher visitation frequency in winter compared to the other seasons. The plot shows the prediction from the GLMM with a 95% confidence interval.

Appendix 2

Table S 1: An overview of all detected species from the camera traps, and how many times they have been observed. The Species written in bold is tested in the analyses.

SPECIES	LATIN NAME	TOTAL NUMBER OF VISITS
BLACK HEADED GULL	*Chroicocephalus ridibundus*	29
BOHEMIAN WAXWING	*Bombycilla garrulus*	1
BRAMBLING	*Fringilla montifringilla*	12
CHAFFINCH	*Fringilla coelebs*	3
CHICKEN	*Gallus gallus domesticus*	92
COMMON BLACKBIRD	*Turdus merula*	21
COMMON CRANE	*Grus grus*	2
COMMON GULL	*Larus canus*	37
COMMON PHEASANT	*Phasianus colchicus*	4
COMMON WOOD PIGEON	*Columba palumbus*	4
DOMESTIC CAT	*Felis catus*	1018
DOMESTIC DOG	*Canis familiaris*	198
DOMESTIC RABBIT	*Oryctolagus cuniculus domesticus*	7
EURASIAN BEAVER	*Castor fiber*	1
EURASIAN BLUE TIT	*Cyanistes caeruleus*	2
EURASIAN ELK	*Alces alces*	19
EURASIAN JAY	*Garrulus glandarius*	2
EURASIAN MAGPIE	*Pica pica*	625
EURASIAN OYSTERCATCHER	*Haematopus ostralegus*	5
EURASIAN RED SQUIRREL	*Sciurus vulgaris*	65
EURASIAN TREE SPARROW	*Passer montanus*	5
EURASIAN WOODCOCK	*Scolopax rusticola*	2
EUROPEAN BADGER	*Meles meles*	8
EUROPEAN MOUFLON	*Ovis aries musimon*	3
EUROPEAN PINE MARTEN	*Martes martes*	1

EUROPEAN ROBIN	*Erithacus rubecula*	25
FERAL PIGEON	*Columba livia domestica*	2
FIELDFARE	*Turdus pilaris*	52
GREAT TIT	*Parus major*	116
GREYLAG GOOSE	*Anser anser*	1
HAZEL GROUSE	*Tetrastes bonasia*	1
HOODED CROW	*Corvus cornix*	65
MISTLE THRUSH	*Turdus viscivorus*	2
MOUNTAIN HARE	*Lepus timidus*	96
RED FOX	*Vulpes vulpes*	58
REDWING	*Turdus iliacus*	2
REINDEER	*Rangifer tarandus*	13
ROE DEER	*Capreolus capreolus*	468
SONG THRUSH	*Turdus philomelos*	11
SPOTTED NUTCRACKER	*Nucifraga caryocatactes*	15
WEST EUROPEAN HEDGEHOG	*Erinaceus europaeus*	16
WESTERN CAPERCAILLIE	*Tetrao urogallus*	3
WESTERN JACKDAW	*Coloeus monedula*	13
WHITE WAGTAIL	*Motacilla alba*	5
YELLOW NECKED FIELD MOUSE	*Apodemus flavicollis*	3
YELLOWHAMMER	*Emberiza citrinella*	7

Table S 2: An overview of the result for each species tested in the analyses.

Species	**Estimate**	**Std. Error**	**z value**	**p-value**
cats				
housing density	2.016	0.216	9.323	< 0.001
season (winter)	-0.5233	0.3920	-1.335	0.182
Magpie				
Cat.group	0.884	0.263	3.359	<0.001
housing density	1.121	0.308	3.640	<0.001
season (winter)	-0.022	0.378	-0.059	0.953
Great tit				
Cat.group	-0.805	0.740	-1.088	0.277
housing density	0.487	0.560	0.870	0.384
season (winter)	-1.0975	0.888	-1.235	0.217

Mountain hare				
Cat.group	0.096	0.903	0.107	0.915
housing density	-0.092	0.669	-0.137	0.891
season (winter)	-0.037	0.872	-0.043	0.965
Red fox				
Cat.group	0.258	0.549	0.471	0.638
housing density	0.008	0.393	0.021	0.983
season (winter)	0.021	0.608	0.034	0.973
Roe deer				
Cat.group	-0.204	0.321	-0.634	0.526
housing density	-0.355	0.270	-1.317	0.188
season (winter)	0.799	0.329	2.430	<0.01
Songbirds				
Cat.group	-2.445	0.474	-5.153	<0.001
housing density	0.492	0.370	1.332	0.183
season (winter)	-1.477	0.574	-2.573	<0.01

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