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Wildlife use of private gardens in south-eastern Norway

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Abstract

Urbanisation typically results in a reduction in biodiversity. Studies of urban wildlife have shown that the increase in extinction risk tends to be higher with increasing urban areas. Yet, in urban environments, private gardens may provide important habitat for a large number of birds, mammals and amphibians worldwide. Of Norway's 5.37 million residents, 82% live in urban settlements. To my knowledge, there are no studies to date that have investigated wildlife in private gardens in Norway using camera traps. The aim of the current study is to investigate what animals can be found in private gardens in south-eastern Norway, and if there is a difference in the occurrence of species between urban and rural areas. I used camera trap data collected with citizen scientists from 71 private gardens and investigated the difference in species occurrences and detectability between urban and rural areas using occupancy models. In total, the camera traps yielded 3193 wildlife detection events. Seven mammal species and several bird species were detected, and the species richness was higher in urban areas. The occupancy analysis showed that the domestic cat (*Felis catus*) and common magpie (*Pica pica*) had a significantly higher detection probability in urban than rural areas, whereas there was no significant difference in occupancy between urban and rural areas for any of the detected species. The results suggest that gardens are important for wildlife both in urban and rural areas, and that urban gardens in south-eastern Norway can support a variety of wildlife.

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1. Introduction

In urban environments, private gardens may provide important habitat for a large number of birds, mammals and amphibians worldwide (Toms & Newson, 2006). The urban green areas can be defined broadly, and include all types of urban open space that range from the highly landscaped (e.g., city parks) to remnant natural areas (e.g., an urban forest) (Gallo et al., 2017). Urbanisation typically results in a reduction in biodiversity, but globally declining taxa can in some cases attain high densities in urban habitats (Goddard et al., 2010). Studies of urban wildlife have shown that the increase in extinction risk tends to be higher with increasing urban areas (McDonald et al., 2008). In addition, the likelihood of a vertebrate being listed as threatened increases with the proportion of species range that is urbanized (McDonald et al., 2008). Differences between urban green areas may play a more important role for mammal dynamics than birds. Most mammals lack the mobility of flight and are more vulnerable to the physical barriers that characterize the urban environment, such as roads, buildings, artificial waterways, and increased human activity (Gallo et al., 2017).

Private gardens of homeowners may constitute a significant part of the urban environment and its green areas, and may thus be important for urban wildlife. For instance, domestic gardens cover 16% and 36% of the total urban areas in Stockholm (Sweden) and Dunedin (New Zealand), respectively (Goddard et al., 2010). In many parts of Norway, it is relatively common to observe a hedgehog eating slugs (Johansen, 2019), a moose chewing fruits (Langvatn, 2019a), or a deer nibbling the garden flowers (Langvatn, 2019b). However, a systematic survey of garden mammal wildlife has not been performed in Norway. The Norwegian Ornithological Society has an annual garden bird count each January/February, but no similar scheme exists for other vertebrate taxa (Norsk ornitologisk forening, 2020).

To study and monitor the animals in private gardens, camera traps can be used. Camera trapping involves the use of remotely triggered cameras that automatically take images and/or videos of animals or other subjects passing in front of them (Rovero et al., 2013). Camera trapping removes the human observer from the survey process, is low-invasive and provides reviewable documentation for other researchers compared with other sampling methods, such as direct observation, trapping, or tracking (O'Connel et al., 2011). Hence, it is possible to provide detailed visual information without requiring on-site human observers or physical capture. This makes camera trapping an important tool in ecological research (Bischof et al., 2014). Data from camera traps can be used to provide estimates of population density, occupancy and to quantify behaviour (McCallum, 2013).

However, camera trapping is not without challenges. For example, the detection of species by a camera is an indicator of presence, but non-detection of a species is not equivalent to absence (MacKenzie et al., 2002). A possible solution for this challenge is to use occupancy models that estimates the occupancy and detectability based on repeated presence-absence surveys of multiple sites (MacKenzie et al., 2002). Occupancy is defined as the proportion of area, patches or sites occupied by a species (MacKenzie et al., 2006). There has been an increasing application of occupancy modelling in camera trap studies, particularly in surveys targeting multiple, unmarked species (Burton et al., 2015). Another challenge is the identification of individuals. In other words, it can be challenging to separate one individual animal from another in camera trap videos. One way to address this problem is to apply occupancy surveys where you register if a species is detected, or not detected, at a particular site (Linkie et al., 2007). Because it is unlikely that all individuals in the surveyed area can be detected in a survey, the detection probability can be a measure of population density and useful to estimate in order to compare data across species (McCallum, 2013).

Of Norway's 5.37 million residents, 82% live in urban settlements (Statistisk sentralbyrå, 2020b). To my knowledge, there are no studies to date that have investigated wildlife in private gardens in Norway using camera traps. This thesis provides an analysis of camera trap data collected with citizen scientists from 71 private gardens in south-eastern Norway. The aim of the study is to investigate what animals can be found in private gardens, and use occupancy modelling to assess if there is a difference in the occurrence of species between urban and rural areas. I hypothesises that:

1) Rural areas will contain more species than urban areas
2) Rural areas have a higher occupancy than urban areas

2. Materials and methods

2.1. Study area

The study was conducted in south-eastern Norway from August 2019 until December 2019. It took place in the counties Oslo, Vestfold and Telemark and Viken. The camera traps were installed in private gardens in the municipalities Asker, Bærum, Drammen, Eidsvoll, Fredrikstad, Frogn, Horten, Lier, Lillestrøm, Lørenskog, Moss, Nesodden, Nittedal, Nordre Follo, Oslo, Rælingen, Vestby and Ås, with majority of them located in Oslo and Ås (Figure 1).

Oslo county has approximately 693 000 inhabitants (Statistisk sentralbyrå, 2020a). Oslo's area is distributed between 62.6% productive forest, 3.9% unproductive forest, 1.8% fully cultivated land and 22.9% developed areas (Norsk institutt for bioøkonomi, 2020a). Vestfold and Telemark county have approximately 419 0000 inhabitants (Statistisk sentralbyrå, 2020a). Productive forest stands for 41.5% of the total area, while unproductive forest occupies 16.8% (Norsk institutt for bioøkonomi, 2020b). This county has 4.1% cultivated land and 1.6% developed. Viken county has the largest number of inhabitants in Norway with a total of approximately 1.2 million people (Statistisk sentralbyrå, 2020a). 50.8% of the total area is productive forest, while 10.8% is unproductive forest. 8.8% is fully cultivated land and 2.5% is developed areas (Norsk institutt for bioøkonomi, 2020c).

All three counties had a mean temperature of 4-6 °C in the inland and 6-8 °C in the coastal areas for 2019 (Norsk Klimaservicesenter, 2020). The most dominating tree species in Norway are Norway Spurce (*Picea abies*), Scots Pine (*Pinus sylvestris*) and Birch (*Betula pubescens, Betula pendula*) (Norsk institutt for bioøkonomi, 2020d). The areas vary from rural, urban to industrial, with large areas used for foresting and agriculture. The landscape, as well as the climate varies from the coast to the inland.

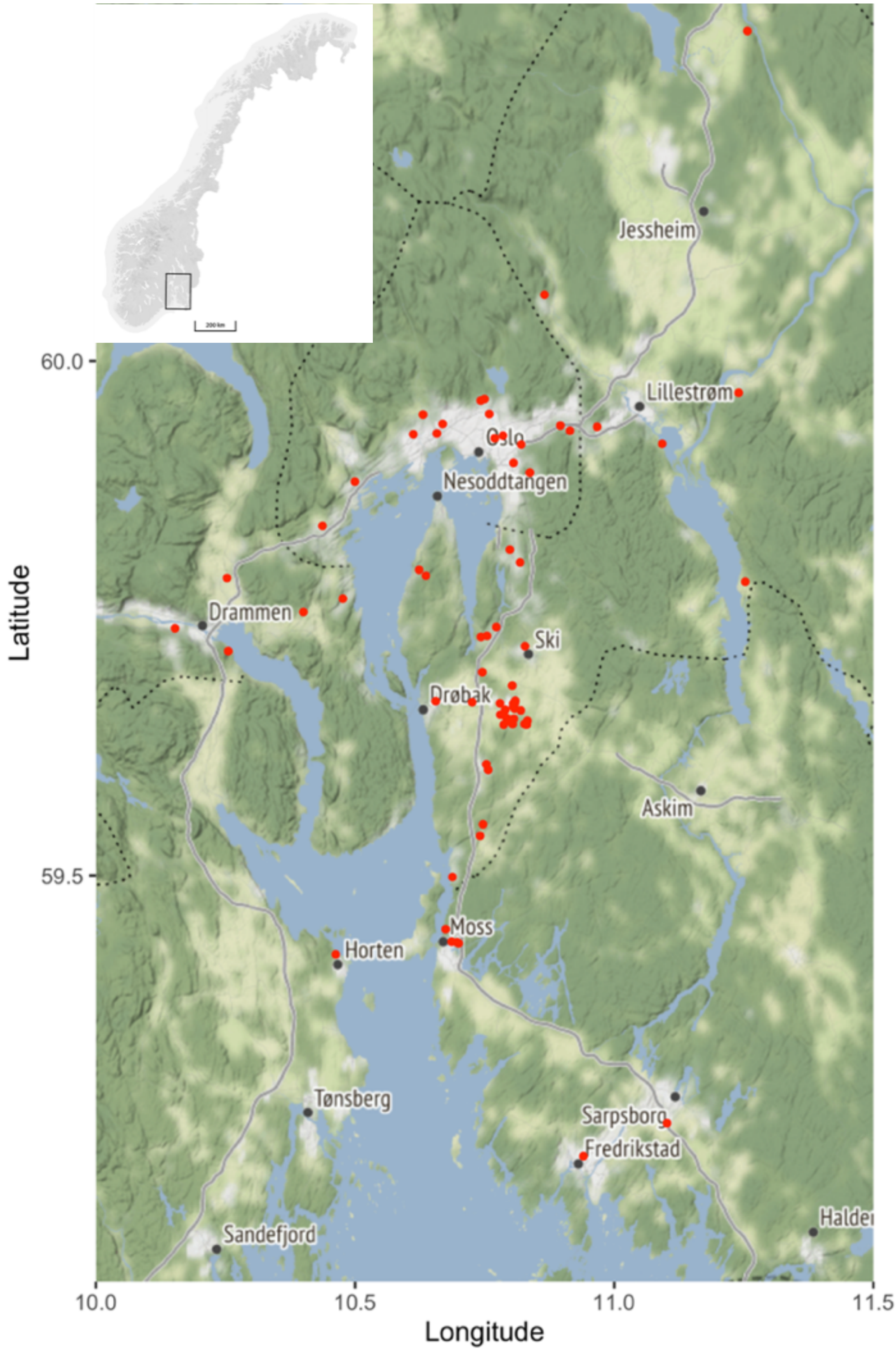


Figure 1: Map of the study area in south-eastern Norway, including camera trap sites marked with red. Inserted map from Norgeskart (Kartverket, 2020), and main map created with Rstudio (RStudio Team, 2020).

2.2. Data collection

2.2.1 Participants

An online registration form was used to recruit participants as part of a project studying domestic cats (KatteSporet), based at Norwegian University of Life Science (Appendix 1). The form was shared through social media. Written informed consent was obtained from all homeowners before participation in the project (Appendix 1). The participants included in the current study had to be willing to install a camera trap in their garden for one week (seven days). Due to a limited number of cameras, participants were limited to the south-eastern counties.

All participants who completed the online registration form were contacted by email. Participants residing outside the south-east, were asked to contribute in a later study period when expanding the project. The included participants were asked to answer a second form, a questionnaire (Appendix 2). The camera trap was then sent to each participant in custom made boxes along with detailed instructions on how to mount the camera in their garden (Appendix 4). A return postage slip was included in each package. All participants will be offered access to their videos when the data analysis and the project is completed.

2.2.2 Camera trapping

During the five-month study period, camera traps were installed in 71 private gardens (Figure 1). One camera was installed in each garden. The camera used in the study was Browning Dark Ops HD Pro (Figure 2). This camera has an 80 ft detection range, Illuma-Smart Technology that automatically adjusts IR Flash for night photos, and Smart IR video that allows a daytime video clip to keep recording as long as the camera detects movements up to two minutes. The camera settings were set in advance before sending it to the participants (Appendix 5). It was set to record 10 seconds videos, with a capture delay of 30 seconds and Smart IR on.

The participants were instructed to mount the camera trap in their garden, turn it on, and let the camera stay for one week (seven days). Additionally, they were asked to control that the camera was positioned correctly once a day. At the end of the trapping period, the camera was turned off and returned by mail using the return slip to the Norwegian University of Life Sciences for reviewing.

Figure 2: The camera that was used, Browning Dark Ops HD Pro. Pictures from browningtrailcameras.com (Browning Trial Cameras, 2020).

2.3. Data analysis

2.3.1 Review of data

For every site camera ID, site ID, address, location, municipality, type of area, latitude, longitude, start and end date was registered. Every camera was allocated a unique camera ID number. Because some cameras were used several places, it was necessary to know which ones were used where. The camera ID was therefore combined with a site ID to provide a unique participant identification. Location was retrieved from postal area in the address, and this was also used to find the belonging municipality. Type of area was retrieved from the second questionnaire, where the participants answered if they lived in rural, residential or city area. To find the latitudes and longitudes for the different camera sites, Kartverket's Norgeskart was used (Kartverket, 2020), where the address provided from the participant form was entered.

The videos from the camera traps were manually reviewed. All videos containing humans were immediately deleted for privacy. For every video date, time, time of day, temperature, species, number of animals on the video and activity was registered. Start and end date of trapping was registered equivalent to the first and last video recorded. Date, time and temperature were registered from the videos. Fourteen of the cameras reset between when we set them and when they were installed. This led to wrongly recorded date and time on the videos and a day/night variable was added based on whether the camera was in day or night mode. For the identification of species, relevant literature was used (Bjärvall & Ullström, 1997; Svensson et al., 2010). In addition, the number of animals and activity (stationary/eating/moving) was registered.

2.3.2 Statistical analysis

All statistical analyses in this study were performed using Rstudio for macOS Version 1.2.1335 (RStudio Team, 2020). A single-season site occupancy model was used to estimate species occupancy (psi/ψ) and detection probabilities (P). A p-value < 0.05 was considered to indicate a statistically significant difference.

The site info data and camera data was loaded into Rstudio. In addition to the variables already described, the total number of days at each camera trap site was added, before merging the two datasets. During merging of the two datasets 20 of the records disappeared. This was 20 records of cats, and these were therefore not included in further analysis. The day of detection was added to the dataset, allocated from one to the number of trapping days.

The dataset was organised for occupancy analysis. For every species at every site for every day, 0 = not detected, 1 = detected, and NA = camera not in use this day. Type of area was added as a site covariate, where residental and city area was merged to urban. "unmarkedFrameOccu" was used to organize detection and non-detection data along with the covariate. From the summary of "unmarkedFrameOccu" the maximum and mean number of observation per site was registered. Then, when running the model for each species the number of sites with at least one detection was given. The species detected at less than three sites were excluded.

These models were runned for every species:
m1 <- occupancy probability and detection probability with no covariates
m2 <- effect of area type on occupancy probability
m3 <- effect of area type on detection probability
m4 <- effect of area type on both occupancy probability and detection probability

AICc for the different models were compared (Appendix 6). The lowest AICc is considered the best fitted model. Where ΔAICc < 2, the models can be equally used. These model results were compared and checked for significant p-values. If the model with higher AICc did not have a significant p-value that was lower than the comparing model, the model with the least covariates were chosen. The models provided estimates of occupancy and detection probability.

3. Results

3.1 Data summary

Of the 307 homeowners that were interested in participating in the study, 71 completed the camera trapping in their garden. Figure 3 shows the flow chart of the selection process including the reasons of exclusion. Based on the information the homeowners gave, 50 lived in residential areas, 4 in city areas and 17 in rural areas.

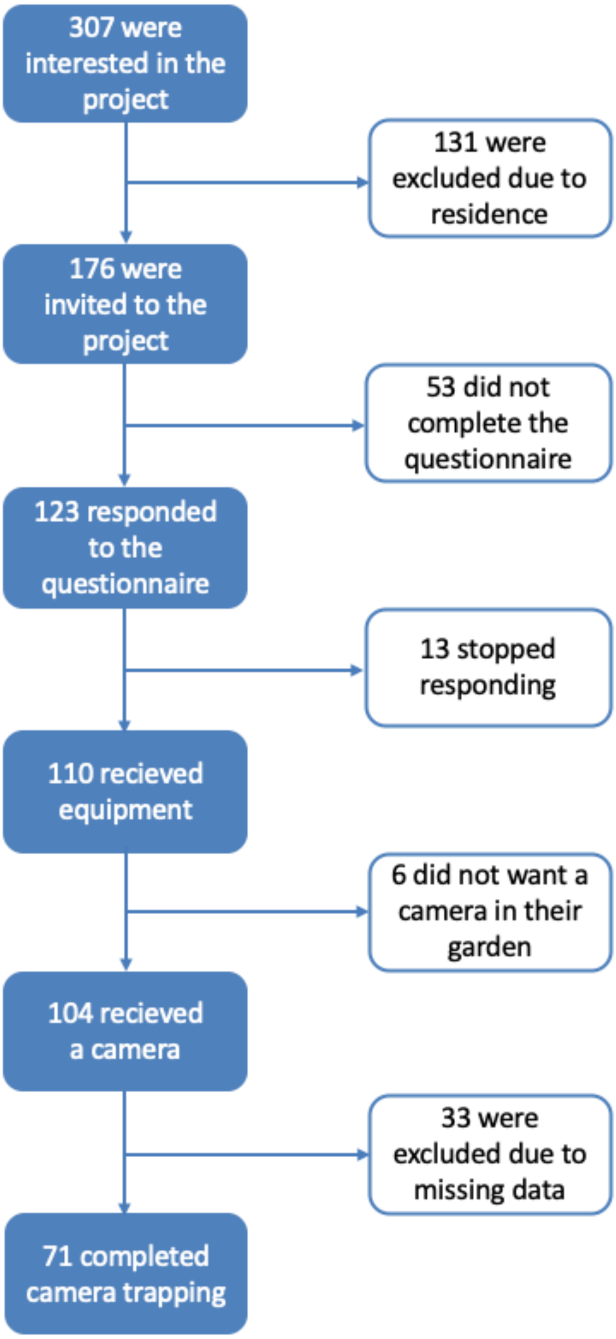


Figure 3: An illustration of the recruitment and selection process of participants, including the reasons for exclusion and dropout.

After the removal of videos containing humans, the 71 camera traps yielded 3193 wildlife detection events. Examples of detected species are shown in Figure 4. According to the written instructions, the camera traps were supposed to record for seven days. However, the time span varied, and the camera traps recorded from 1-29 days with an average of 8 days.

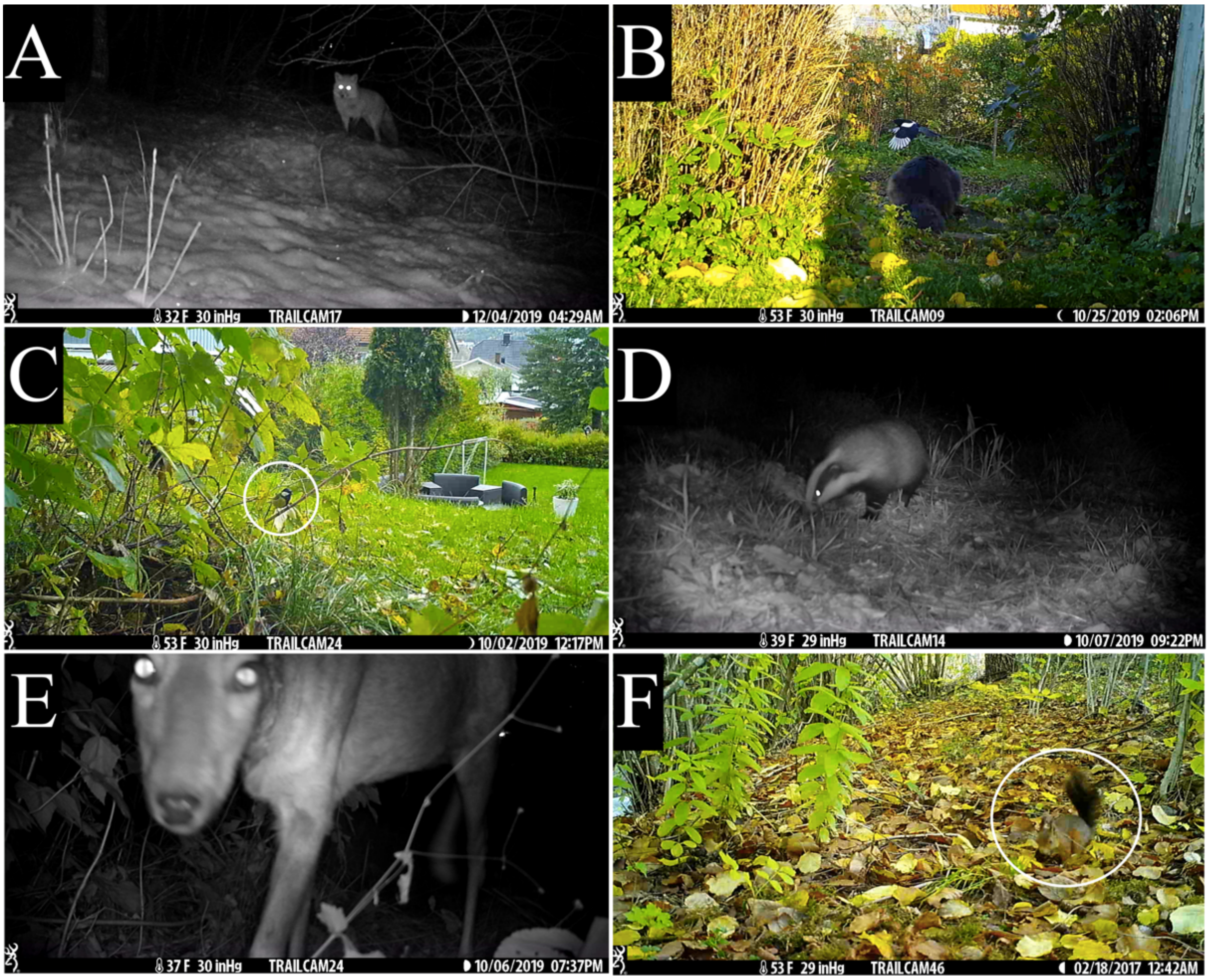


Figure 4: Examples of wildlife caught on camera. Images taken from camera trap videos showing red fox (A), domestic cat and common magpie (B), great tit (C), European badger (D), roe deer (E) and red squirrel (F).

3.2 Species richness

Seven mammals were captured on camera: European badger (*Meles meles*), domestic cat (*Felis catus*), domestic dog (*Canis lupus familiaris*), mice (*Mus ssp.*), red fox (*Vulpes vulpes*), red squirrel (*Sciurus vulgaris*) and roe deer (*Capreolus capreolus*), in addition to several birds (Table 1). The most frequently captured species was the domestic cat (1172 detections), while the most frequently captured wild mammal was roe deer (115 detections). Most of the identified mammal species (Table 1) occurred in both urban and rural areas, apart from the domestic dog and mice that were not registered in rural areas. All identified bird species detected at more than three sites (Table 1) occurred in both urban and rural areas. None of the identified bird species detected at less than three sites (Table 1) occurred in both urban and rural areas.

*Table 1: Summary of the video recordings from 71 gardens with installed camera traps, in south-eastern Norway. *The 20 records of cats that disappeared during merging, are only included in total.*

Mammal species	Number of detections			Sites with at least one detection
	Urban	**Rural**	**Total**	
European badger (*Meles meles*)	14	23	37	8
Domestic cat (*Felis catus*)	944	263	1227*	60
Domestic dog (*Canis lupus familiaris*)	10	0	10	5
Mice (*Mus spp.*)	9	0	9	4
Red fox (*Vulpes vulpes*)	11	4	15	4
Red squirrel (*Sciurus vulgaris*)	12	5	17	5
Roe deer (*Capreolus capreolus*)	105	50	155	19
Bird species				
Common blackbird (*Turdus merula*)	6	1	7	4
Common magpie (*Pica pica*)	274	34	308	37
Common wood pigeon (*Columba palumbus*)	18	0	18	2
European blue tit (*Cyanistes caeruleus*)	6	0	6	2
European robin (*Erithacus rubecula*)	2	0	2	2
Great spotted woodpecker (*Dendrocopos major*)	0	1	1	1
Great tit (*Parus major*)	26	4	30	11
Spotted nutcracker (*Nucifraga caryocatactes*)	5	0	5	1
Other	253	31	284	22

Six videos contained multiple species (four cat/birds, one cat/badger, one roe deer/bird). In one, a badger walking past (Figure 5A), then a few seconds later a cat enters the picture and is clearly looking in the badger's direction (Figure 5B).

Figure 5: Still image from video where (A) a badger is moving past and (B), a cat is looking in the direction the badger is moving.

In another video, a cat is moving carefully and staying close to the ground, while a common magpie (*Pica pica*) flies by (Figure 6).

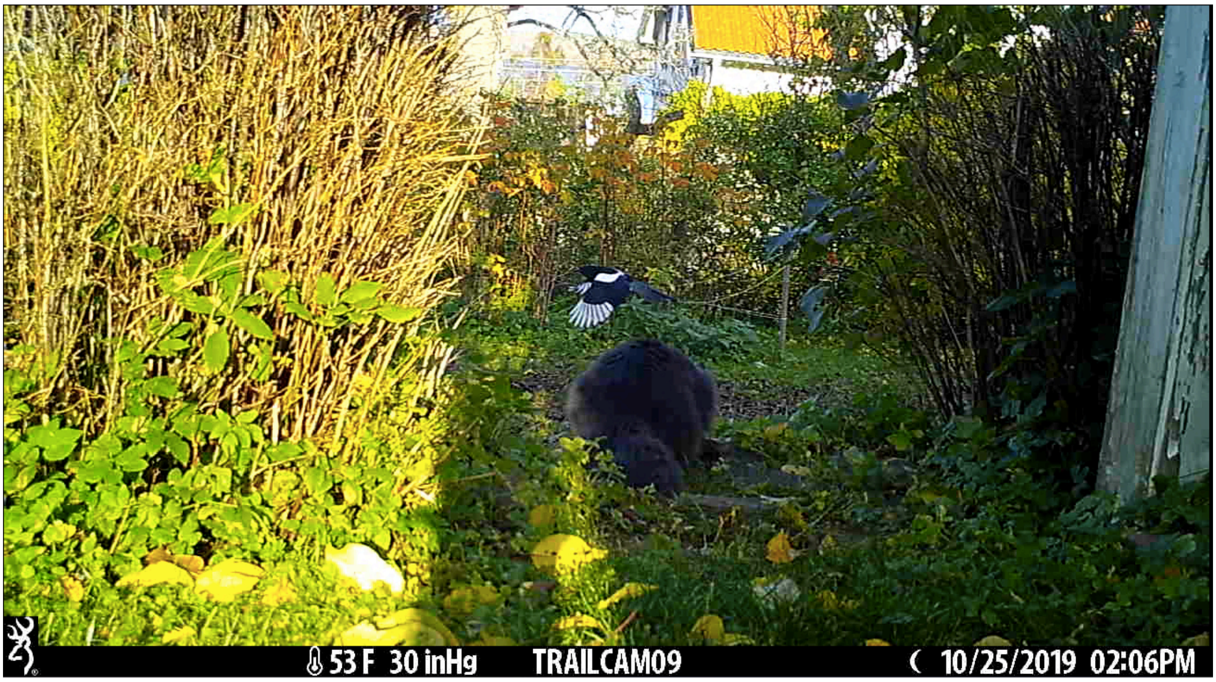


Figure 6: Still image from video where a cat stays close to the ground while a common magpie is flying past.

3.3 Occupancy analysis

After choosing the top models, it was only for two species, domestic cat and common magpie, that the first model without covariates was not chosen (Appendix 6). Domestic cat and common magpie had a significant difference in detection probability between urban and rural areas (Table 2). The detection probability for both species was higher in urban areas. There was no significant difference in occupancy between urban and rural areas for any of the other species.

Table 2: Estimates of occupancy and detection probability from occupancy models. 95% confidence interval in parentheses. When the urban and rural values are equal only one value is presented. The statistical significance level was set to p-value < 0.05. The results with p-value < 0.05 between urban and rural areas are marked in bold.

Species	Occupancy (Psi)		Detection probability (P)	
	Urban	Rural	Urban	Rural
European badger (*Meles meles*)	0.169 (0.080-0.323)		0.151 (0.087-0.251)	
Domestic cat (*Felis catus*)	0.879 (0.770-0.940)		**0.617 (0.568-0.663)**	**0.5031 (0.408-0.598)**
Domestic dog (*Canis lupus familiaris*)	0.322 (0.034-0.866)		0.032 (0.005-0.178)	
Mice (*Mus spp.*)	0.083 (0.027-0.229)		0.153 (0.049-0.389)	
Red fox (*Vulpes vulpes*)	0.120 (0.034-0.345)		0.084 (0.029-0.220	
Red squirrel (*Sciurus vulgaris*)	0.092 (0.037-0.210)		0.202 (0.113-0.333)	
Roe deer (*Capreolus capreolus*)	0.301 (0.198-0.429)		0.304 (0.233-0.384)	
Common blackbird (*Turdus merula*)	0.109 (0.026-0.363)		0.095 (0.019-0.364)	
Common magpie (*Pica pica*)	0.631 (0.487-0.754)		**0.355 (0.296-0.418)**	**0.104 (0.050-0.203)**
Great tit (*Parus major*)	0.237 (0.116-0.425)		0.137 (0.064-0.269)	

4. Discussion

The purpose of the current study is to investigate what animals can be found in private gardens in south-eastern Norway, and if there is a difference in the occurrence of species between urban and rural areas. To my knowledge, this is the first study to perform camera trapping in private gardens in Norway and an analysis of data from 71 gardens is presented. A variety of mammals and birds were identified; seven mammals and eight birds were identified to species, in addition to several other birds. Furthermore, the difference in species that occurs in urban and rural areas was investigated and compared.

4.1 Species richness

Species richness was higher in urban areas, and when only looking at species detected at more than three sites, the species richness was similar in both urban and rural areas. My first hypothesis that rural areas would contain more species than urban areas was therefore not supported. The uneven distribution of cameras between urban and rural areas may have had an impact on this, so the results should be interpreted with caution. Domestic cat, with 1127 detections, was the most frequently registered mammal and most commonly detected species overall. Participants recruited to this study were all homeowners with cats, and the high detection of cats was therefore expected. The domestic cat is a major predator and may pose a significant threat to birds and small mammals (Goddard et al., 2010; McDonald et al., 2015). Several videos showed cats together with another species, where one can see that the cat is curious and possibly in hunting mode. One can argue that this may have an impact on the species richness in the homeowners gardens, which is discussed as a cause of concern for some species populations (Goddard et al., 2010; McDonald et al., 2015). However, this was not investigated in this study.

The most frequently detected wild mammal was roe deer with 155 detections. Roe deer are widespread and common throughout the study area (Bevanger, 2018). They prefer deciduous and coniferous forests in the vicinity of agricultural areas, but can also enter urban gardens (Bevanger, 2018). The frequent detection of roe deer is therefore in an alignment with previous knowledge. In addition, the European badger, red squirrel and red fox were detected. The European badger is a common species throughout southern Norway. It is an adaptable species that can live in different habitats, but it prefers deciduous, scrub or mixed forests in the vicinity of cultivated land (Bevanger, 2015). However, in some areas it is also a common feature of urban landscapes, where they can utilize anthropogenic (Gomes et al., 2019). Red squirrels occur across most of Norway. They are diurnal, staying in the trees most of the time and occur in all forest districts (Østbye & Frafjord, 2018). They frequently visit bird feeders during the winter (Jokimäki et al., 2017) and can also take advantage of cherry and hazel trees in domestic gardens during the autumn (personal observation). However, their occurrence and visits to private gardens may be related to the surrounding landscape as they are likely dependent on a nearby wood for food, cover and sleeping sites (Jokimäki et al., 2017). This aspect was not assessed in the current study. The red fox is a generalist species found along the coast, inland, in the lowlands and in the mountains (Eide, 2018). However, cities and towns are also attractive habitats, where the red fox can feed on waste from humans (Eide, 2018). Because mice were not detected to species and some dogs were on a leash, they are not discussed.

In sum, all the mammal species detected in this study were expected. The most surprising result was perhaps a species that was not detected – the European hedgehog (*Erinaceus europaeus*). In Norway, the hedgehog lives mainly along the coast from Bergen to Østfold, with varying densities in different counties (Johansen, 2019), but several observations are registered in the study area (Artsdatabanken, 2020). The European hedgehog is originally a deciduous forest species, but is now found primarily in cultural landscapes with agriculture, towns and cities (Johansen, 2020). The absence of this species from video material collected in this study was therefore unexpected. Hedgehog numbers have been declining in some European countries, and may be negatively influenced by badgers and red foxes (Pettett et al., 2018). However, with the limited sample size in this study it is not possible to provide any conclusions. This indicates the need of further studies.

The most detected bird was the common magpie with 308 detections. Common magpie distribution is closely linked to humans and follows human settlement throughout the country, and the species is well adapted to the urban environment (Husby, 2020). As a generalist species food items includes anthropogenic food (Krystofkova et al., 2011). In addition, great tit (*Parus major*), common wood pigeon (*Columba palumbus*) and common blackbird (*Turdus merula*) were detected. The great tit is evenly distributed in suitable biotopes throughout Norway. It is primarily a deciduous forest bird, but is very adaptable and flexible in its habitat choice, and is common in gardens and park areas (Hauge, 2020). There are dense populations of common wood pigeon in south-eastern Norway. The species nests both in larger contiguous forest areas and in smaller forest deposits close to cultural landscapes, but recently it has started to move into the cities (Viker, 2020). The common blackbird occurs in most of southern Norway. It is common in cultivated land and developed areas, in addition to gardens and parks in cities and towns and is one of the most common birds in gardens and parks in Norway (Pedersen, 2020). Other bird species, such as European blue tit (*Cyanistes caeruleus*), European robin (*Erithacus rubecula*), great spotted woodpecker (*Dendrocopos major*) and spotted nutcracker (*Nucifraga caryocatactes*) were detected at less than three sites, and were therefore not included in the analysis. This also applied to the common wood pigeon, although detected 18 times, it was only detected at two sites. This could perhaps suggest a patchy distribution. Most of the detections were of large-bodied birds and many smaller bird species were not identifiable in the video material. It is possible that camera traps give a bias towards detecting larger bird species and species that more readily use the ground to forage.

4.2 Occupancy analysis

The domestic cat and common magpie had a significantly higher detection probability in urban than rural areas. However, the study revealed no significant difference in occupancy between urban and rural areas for any of the detected species. My second hypothesis that rural areas will have higher occupancy than urban areas was therefore not supported. However, as previously mentioned the results should be interpreted with caution, due to the uneven distribution of cameras between urban and rural areas. Cats in urban areas may occur at higher densities than rural cats due to a higher density of houses, and in turn cat owners, in urban areas. Urban areas also likely contain more roads and fewer natural food sources, potentially constraining cat home ranges and making the cat stay closer to the owner's house and garden (Thomas et al., 2014), in turn making them more readily detected by camera traps. The successful colonization of urban habitats by the common magpie could be because of greater supply or better availability of food (Krystofkova et al., 2011). The closeness to humans may be explained by the protection they give against any predators that are more shy than the common magpie (Husby, 2020).

In Norway, natural habitats are never far away. This may be a reason for the similar occupancy in urban and rural areas observed in the current study. Even in Oslo, the capital of Norway, large contiguous forest areas are only minutes away and the city contains several large parks. The fact that natural areas are so close can have an impact on wildlife. They may allow wildlife to migrate in and out of the urban environment or support home ranges that overlap urban and natural areas (Gallo et al., 2017). The size and number of green areas in the urban environment will likely determine whether it can fully support populations of particular wildlife species within its limit (Gallo et al., 2017). However, the number of gardens investigated were limited, so the results should be interpreted with caution.

4.3 Methodological considerations

The project received great interest, which eased the recruitment process. Based on the interest in this project, one can argue that there are good opportunities of doing further studies in this field.

The equipment was delivered to the participants by mail, which efficiently reached a high number of participants. However, as the participants mounted the camera traps on their own using written instructions, they may have chosen a less than ideal spot for the camera (e.g., facing their front door where humans were frequently observed) or installed the camera wrongly (e.g. too high/low). In future studies, one could improve the quality of the camera mounting by on-site training of the homeowners (Katrak-Adefowora et al., 2020). However, this would require a lot more time, travel and effort. Another solution for this challenge could be a digital training.

A camera trap is also limited by its fixed location and may only show a specific part of the garden depending on the garden size. As this could lead to missed detections, it is a possibility that the data analysis in this study was influenced. A possible solution for the challenge of missed detections is to place several camera traps which covers the whole garden. Other studies have used skilled individuals to register wildlife in gardens (Akinnifesi et al., 2010). However, the use of on-site human observers could introduce observer bias, and likely influence the detection of nocturnal and shy species (Bischof et al., 2014). The use of camera traps can therefore be a strength in this study, as it provides detailed information without on-site human observers (Bischof et al., 2014).

To increase the efficiency of research efforts and research results, statistical power analysis can be used (Steidl et al., 1997). A power analysis can estimate the samples necessary to achieve a high probability of detecting biologically significant effects (Steidl et al., 1997). Another reason for calculating statistical power a too large sample size which can lead to unnecessary use of resources (Charan & Kantharia, 2013). An increased sample size increase statistical power which increases the probability of finding an effect (Steidl et al., 1997). The lack of finding an effect in this study may be due to the sample size as a power analysis was not performed, or because there was no actual effect. The results should be interpreted with caution.

The effect of covariates on wildlife occupancy and detection probability, in addition to area, could be investigated further. For example, size of garden, landscape context (e.g. distance of garden from roads, parks and natural habitats) and season could be assessed. An interesting aspect would also be to examine the influence of domestic cat detection probability and occupancy on wildlife detection and occupancy, and whether any such interactions occur between different wildlife species.

5. Conclusion

In this study, the use of citizen scientists and camera traps to investigate wildlife use of private gardens in urban and rural areas was successful. A variety of mammals and birds were detected, and the species richness was higher in urban areas. The occupancy analysis showed that the domestic cat and common magpie had a significantly higher detection probability in urban than rural areas, whereas the study revealed no significant difference in occupancy between urban and rural areas for any of the detected species. My findings suggest that gardens are important for wildlife both in urban and rural areas. Such observations should be considered when planning new urban landscapes. For future studies, I suggest investigating the effect of additional covariates on wildlife occupancy and detection probability.

6. References

Akinnifesi, F. K., Sileshi, G. W., Ajayi, O. C., Akinnifesi, A. I., de Moura, E. G., Linhares, J. F. P. & Rodrigues, I. (2010). Biodiversity of the urban homegardens of São Luís city, Northeastern Brazil. *Urban Ecosystems*, 13 (1): 129-146. doi: 10.1007/s11252-009-0108-9.

Artsdatabanken. (2020). *Artskart: Piggsvin - Erinaceus europaeus*. Available at: https://artskart.artsdatabanken.no/app/#map/422388,6831668/4.11556352749467/background/greyMap/filter/%7B%22TaxonIds%22%3A%5B31113%5D%2C%22IncludeSubTaxonIds%22%3Atrue%2C%22Found%22%3A%5B2%5D%2C%22Style%22%3A1%7D (accessed: 2020.08.08).

Bevanger, K. (2015). *Grevling Meles meles (Linnaeus, 1758)*: Norsk institutt for naturforskning. Available at: https://www.artsdatabanken.no/Pages/182509/Grevling (accessed: 2020.08.08).

Bevanger, K. (2018). *Rådyr Capreolus capreolus (Linnaeus, 1758)*: Norsk institutt for naturforskning. Available at: https://artsdatabanken.no/Pages/179482 (accessed: 2020.08.08).

Bischof, R., Hameed, S., Ali, H., Kabir, M., Younas, M., Shah, K. A., Din, J. U. & Nawaz, M. A. (2014). Using time-to-event analysis to complement hierarchical methods when assessing determinants of photographic detectability during camera trapping. *Methods in Ecology and Evolution*, 5 (1): 44-53. doi: 10.1111/2041-210x.12115.

Bjärvall, A. & Ullström, S. (1997). *Pattedyr - Alle Europas arter i tekst og bilde*. Oslo: Cappelen Damm.

Browning Trial Cameras. (2020). *DARK OPS HD PRO X*. Available at: https://browningtrailcameras.com/products/dark-ops-hd-pro-x (accessed: 2020.07.30).

Burton, A. C., Neilson, E., Moreira, D., Ladle, A., Steenweg, R., Fisher, J. T., Bayne, E. & Boutin, S. (2015). Wildlife camera trapping: a review and recommendations for linking surveys to ecological processes. *Journal of Applied Ecology*, 52 (3): 675-685. doi: 10.1111/1365-2664.12432.

Charan, J. & Kantharia, N. D. (2013). How to calculate sample size in animal studies? *Journal of pharmacology & pharmacotherapeutics*, 4: 303-6. doi: 10.4103/0976-500X.119726.

Eide, N. E. (2018). *Rødrev Vulpes vulpes (Linnaeus, 1758)*: Norsk institutt for naturforskning. Available at: https://artsdatabanken.no/Pages/180936 (accessed: 2020.08.08).

Gallo, T., Fidino, M., Lehrer, E. W. & Magle, S. B. (2017). Mammal diversity and metacommunity dynamics in urban green spaces: implications for urban wildlife conservation. *Ecological Applications*, 27 (8): 2330-2341. doi: 10.1002/eap.1611.

Goddard, M. A., Dougill, A. J. & Benton, T. G. (2010). Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology & Evolution*, 25 (2): 90-98. doi: 10.1016/j.tree.2009.07.016.

Gomes, D. J., Wierzbowska, I. A., Bevanger, K., O'Mahony, D. T. & Rola, K. (2019). Diet of the European badgers (Meles meles) in urban and rural areas of Norway. *European Journal of Wildlife Research*, 66 (1): 7. doi: 10.1007/s10344-019-1347-6.

Hauge, K.-O. (2020). *Kjøttmeis Parus major*: Norsk ornitologisk forening. Available at: https://www.birdlife.no/fuglekunnskap/fugleatlas/index.php?art_id=92 (accessed: 2020.08.08).

Husby, M. (2020). *Skjære Pica pica*: Norsk ornitologisk forening. Available at: https://www.birdlife.no/fuglekunnskap/fugleatlas/index.php?art_id=164 (accessed: 2020.08.08).

Johansen, B. S. (2019). *Piggsvin*: Store norske leksikon. Available at: https://snl.no/piggsvin (accessed: 2020.08.08).
Johansen, B. S. (2020). *Piggsvin Erinaceus europaeus (L., 1758)*: Norsk zoologisk forening. Available at: http://www.zoologi.no/artsfakta/pattedyr/piggsvin/faktaark/tekst/20120315153938308 (accessed: 2020.08.11).
Jokimäki, J., Selonen, V., Lehikoinen, A. & Kaisanlahti-Jokimäki, M.-L. (2017). The role of urban habitats in the abundance of red squirrels (Sciurus vulgaris, L.) in Finland. *Urban Forestry & Urban Greening*, 27: 100-108. doi: https://doi.org/10.1016/j.ufug.2017.06.021.
Kartverket. (2020). *Norgeskart*. Available at: http://norgeskart.no/.
Katrak-Adefowora, R., Blickley, J. & Zellmer, A. (2020). Just-in-Time Training Improves Accuracy of Citizen Scientist Wildlife Identifications from Camera Trap Photos. *Citizen Science: Theory and Practice*, 5: 8. doi: 10.5334/cstp.219.
Krystofkova, M., Fousova, P. & Exnerova, A. (2011). Nestling diet of the Common Magpie (Pica pica) in urban and agricultural habitats. *Ornis Fennica*, 88 (3): 138-146.
Langvatn, R. (2019a). *Elg*: Store norske leksikon. Available at: https://snl.no/elg (accessed: 2020.08.15).
Langvatn, R. (2019b). *Hjort*: Store norske leksikon. Available at: https://snl.no/hjort (accessed: 2020.08.15).
Linkie, M., Dinata, Y., Nugroho, A. & Haidir, I. A. (2007). Estimating occupancy of a data deficient mammalian species living in tropical rainforests: Sun bears in the Kerinci Seblat region, Sumatra. *Biological Conservation*, 137 (1): 20-27. doi: 10.1016/j.biocon.2007.01.016.
MacKenzie, D. I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A. & Langtimm, C. A. (2002). Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, 83 (8): 2248-2255. doi: 10.2307/3072056.
MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L. & Hines, J. E. (2006). *Occupancy Estimation and Modeling : Inferring Patterns and Dynamics of Species Occurrence*. Amsterdam: Elsevier.
McCallum, J. (2013). Changing use of camera traps in mammalian field research: habitats, taxa and study types. *Mammal Review*, 43 (3): 196-206. doi: 10.1111/j.1365-2907.2012.00216.x.
McDonald, J. L., Maclean, M., Evans, M. R. & Hodgson, D. J. (2015). Reconciling actual and perceived rates of predation by domestic cats. *Ecology and Evolution*, 5 (14): 2745-2753. doi: 10.1002/ece3.1553.
McDonald, R. I., Kareiva, P. & Formana, R. T. T. (2008). The implications of current and future urbanization for global protected areas and biodiversity conservation. *Biological Conservation*, 141 (6): 1695-1703. doi: 10.1016/j.biocon.2008.04.025.
Norsk institutt for bioøkonomi. (2020a). *Arealressursstatistikk Oslo*. Available at: https://kart13.nibio.no/arealressursstatistikk/xml_filer/2019/03_arstat_2019.xml (accessed: 2020.07.08).
Norsk institutt for bioøkonomi. (2020b). *Arealressursstatistikk Vestfold og Telemark*. Available at: https://kart13.nibio.no/arealressursstatistikk/xml_filer/2019/38_arstat_2019.xml (accessed: 2020.07.08).
Norsk institutt for bioøkonomi. (2020c). *Arealressursstatistikk Viken*. Available at: https://kart13.nibio.no/arealressursstatistikk/xml_filer/2019/30_arstat_2019.xml (accessed: 2020.07.08).

Norsk institutt for bioøkonomi. (2020d). *Treslag i Norge*: Norsk institutt for bioøkonomi. Available at: https://www.nibio.no/tema/skog/skoggenetiske-ressurser/treslag-i-norge (accessed: 2020.07.08).

Norsk Klimaservicesenter. (2020). *Observasjoner og værstatistikk*. Available at: https://seklima.met.no/observations/ (accessed: 2020.07.09).

Norsk ornitologisk forening. (2020). *Fugler ved foringsplassen*. Available at: https://www.fuglevennen.no/aktiviteter/foringsplassen/ (accessed: 2020.08.12).

O'Connel, A. F., Nichols, J. D. & Karanth, K. U. (2011). *Camera Traps in Animal Ecology: Methods and Analyses*. Tokyo: Springer.

Pedersen, F. H. (2020). *Svarttrost Turdus merula*: Norsk ornitologisk forening. Available at: https://www.birdlife.no/fuglekunnskap/fugleatlas/index.php?art_id=203 (accessed: 2020.08.08).

Pettett, C. E., Johnson, P. J., Moorhouse, T. P. & Macdonald, D. W. (2018). National predictors of hedgehog Erinaceus europaeus distribution and decline in Britain. *Mammal Review*, 48 (1): 1-6. doi: 10.1111/mam.12107.

Rovero, F., Zimmermann, F., Berzi, D. & Meek, P. (2013). "Which camera trap type and how many do I need?" A review of camera features and study designs for a range of wildlife research applications. *Hystrix-Italian Journal of Mammalogy*, 24 (2): 148-156. doi: 10.4404/hystrix-24.2-6316.

RStudio Team. (2020). *RStudio: Integrated Development for R* (Version 1.2.1335). Boston, MA. Available at: http://www.rstudio.com/.

Statistisk sentralbyrå. (2020a). *Befolkningen*. Available at: https://www.ssb.no/befolkning/faktaside/befolkningen (accessed: 2020.07.08).

Statistisk sentralbyrå. (2020b). *Population and land area in urban settlements*. Available at: https://www.ssb.no/en/befolkning/statistikker/beftett/ (accessed: 2020.07.09).

Steidl, R. J., Hayes, J. P. & Schauber, E. (1997). Statistical Power Analysis in Wildlife Research. *The Journal of Wildlife Management*, 61 (2): 270-279. doi: 10.2307/3802582.

Svensson, L., Mullarney, K. & Zetterström, D. (2010). *Gyldendals store fugleguide - Europas og middelhavsområdets fugler i felt*. 4 ed. Oslo: Gyldendal Fakta.

Thomas, R. L., Baker, P. J. & Fellowes, M. D. E. (2014). Ranging characteristics of the domestic cat (Felis catus) in an urban environment. *Urban Ecosystems*, 17 (4): 911-921. doi: 10.1007/s11252-014-0360-5.

Toms, M. P. & Newson, S. E. (2006). Volunteer surveys as a means of inferring trends in garden mammal populations. *Mammal Review*, 36 (4): 309-317. doi: 10.1111/j.1365-2907.2006.00094.x.

Viker, M. (2020). *Ringdue Columba palumbus*: Norsk ornitologisk forening. Available at: https://www.birdlife.no/fuglekunnskap/fugleatlas/index.php?taxon_id=4782 (accessed: 2020.08.08).

Østbye, E. & Frafjord, K. (2018). *Ekorn*: Store norske leksikon. Available at: https://snl.no/ekorn (accessed: 2020.08.08).

Appendix

Appendix 1: Registration form

Påmeldingsskjema:

Katter er populære kjæledyr. I Norge er det anslått at 400.000 husholdninger eier cirka 767.000 katter. Disse kattene kan godt virke godt tamme og forutsigbare, men mye av oppførselen deres er faktisk et mysterium for oss. Mange av kattens mysterier er knyttet til dens atferd mens den er ute. Vi åpner døra og den går over dørterskelen og blir borte. Hvor den går og hva den gjør, vet vi ikke.

I dette prosjektet ønsker vi å finne ut mer om dette ved å bruke GPS til å registrere katters aktiviteter utendørs, samt installere viltkameraer i eiernes hager. Prosjektet skal stimulere til fascinasjon og nysgjerrighet for forskning og vitenskap blant barn og unge. Vi skal engasjere familier med barn i vitenskapelig forskning og demonstrere viktigheten av resultatene til samfunn og miljø. For å stimulere interessen for forskning og vitenskap skal barna selv utføre forskningen og få innblikk data som viser kattens bevegelser.

NB! Vi ønsker kun katter som er vant til å være ute. Innendørs katt skal ikke slippes ut for dette studiet.

Eksperimentet varer i én uke fra du mottar utstyr og setter i gang. Oppgaven din som katteeier i løpet av denne eksperimentuken er å sørge for at GPS er skrudd på og sitter festet i halsbåndet til katten når den er utendørs.

Om dette er noe som ikke passer, kan du allikevel fylle ut resten av skjemaet slik at vi kan kontakte deg ved en senere anledning om du ønsker dette.

- Jeg har tid og anledning til å delta i prosjektet nå.
- Jeg har ikke anledning nå, men ønsker å eventuelt kontaktes senere.

- Kontaktinformasjon
    - Navn på forelder:
    - Epost:
    - Telefonnummer:
    - Adresse:
    - Har dere hage?
        a) Ja
        b) Nei
- Om barnet som skal delta
    - Et av målene med prosjektet er øke barn og unges interesse for forskning. Barna i prosjektet skal bidra aktivt inn i forskningen. Husholdningen må derfor ha minst et barn i skoletrinnet 6-10.
    - Barnets alder:
- Om katten som skal delta
    - Hvor ofte er katten din ute? I gjennomsnitt.
        a) Sjeldnere enn en gang om dagen
        b) En gang om dagen
        c) To ganger om dagen
        d) Tre ganger om dagen eller oftere
    - Når katten din er ute, hvor lenge er den vanligvis ute? I gjennomsnitt.
        a) Mindre enn 5 timer
        b) 5-10 timer
        c) 11-20 timer
        d) Mer enn 20 timer
    - Et viltkamera har sensorer som registrerer bevegelse. Dette gjør at det filmer bare når det er bevegelse foran kameraet. Er du interessert i å plassere viltkamera i hagen som filmer katten din og annet dyreliv der?
        a) Ja
        b) Nei

Informasjon

Ved å trykke på "Submit" godtar du at NMBU lagrer disse dataene, og kontakter deg per e-post eller telefon.

Appendix 2: Questionnaire

Spørreskjema: Informasjon om katten din

Takk for at du vil bidra på vårt forskningsprosjekt! Før vi starter med selve dataregistreringen, behøver litt mer informasjon om katten din.

- Navn (eier):
- Epost:
- Om katten
    - Last opp et bilde av katten. NB! Bildet må være uten mennesker. Ved å laste opp bildet gir du NMBU tillatelse til å bruke bildet i forbindelse med omtale av prosjektet.
    - Alder (år):
    - Kjønn
        - Hann
        - Hunn
    - Er den sterilisert/kastrert?
        - Ja
        - Nei
    - Dersom det er en usterilisert hunnkatt, går den på p-piller?
        - Ja
        - Nei
    - Vekt (kg):
    - Rase:
    - Personlighet
        - Utforskende
        - Forsiktig
- Kattens helse
    - Er den vaksinert?
        - Ja
        - Nei
    - Har den hatt noen sykdommer?
        - Nei
        - Ja
    - Hvis ja, hvilke?

- Vaner og rutiner
    - Hvordan mates katten?
        - Fri tilgang
        - Porsjoner
    - Er den vant til å ha på seg halsbånd?
        - Ja
        - Nei
- Utegang
    - Hva slags type område bor dere i?
        - Landlig
        - Boligfelt
        - By
    - Når på døgnet er katten ute? (Flere alternativer er mulig)
        - Morgen
        - Dagtid
        - Kveld
        - Natt
    - Hvordan slippes katten ut?
        - Fri tilgang til utearealer via katteluke
        - Begrenset tilgang til utearealer via katteluke (katteluken låses en viss periode av døgnet)
        - Eier slipper katten inn og ut
    - Hvor ofte pleier katten å ta med byttedyr hjem?
        - Daglig/nesten daglig
        - Ukentlig
        - Månedlig
        - Sjelden/aldri
    - Hvor mange andre katter pleier dere √• se i omr√•det? *
        - 0-5
        - 6-10
        - 11 eller flere
    - Andre relevante opplysninger eller kommentarer (for eksempel: gravid, har kattunger, nylig operert, under medisinsk behandling)?

Informasjon

Ved å trykke på "Submit" godtar du at NMBU lagrer disse dataene og bruker dem i forskningsprosjektet.

Appendix 3: Welcome flyer

Takk for at du og katten din vil være med på å bidra til spennende forskning!

I dette prosjektet kartlegges kattens bevegelser utendørs ved hjelp av GPS. Det eneste du som bidragsyter trenger å gjøre er å sørge for at katten din har på seg påslått GPS når den er ute, og noterer til hvilke tider du setter GPS-en av og på katten.

Vedlagt finner du alt du trenger for å sette i gang:

- GPS-enhet m/ ladekabel
- Halsbånd
- Viltkamera m/ stropp (hvis du takket ja til dette)
- Skjema for tidsregistrering
- Norgespakke returlapp

Eksperimentet varer i én uke fra første gang du slipper ut katten med GPS i halsbåndet. For at resultatet skal bli så nøyaktig som mulig anbefaler vi at du setter deg nøye inn i instruksjonene som ligger vedlagt i mailen (eller på link her: http://tiny.cc/katt), og at du er konsekvent på å samle inn data hver dag.

Når eksperiment-uken er over sender du utstyret tilbake til oss på NMBU via den ferdig betalte Norgespakke-løsningen.

Spørsmål? Ikke nøl med å ta kontakt på kattesporet@nmbu.no

Vennlig hilsen gjengen i Kattesporet

KATTE-SPORET

Appendix 4: Camera instructions

Hvordan samle data med viltkamera

Et viltkamera har en sensor som registrerer bevegelse. Når noe beveger seg innenfor sensorens "synsfelt" vil kameraet begynne å filme i en liten stund. Formålet med å utplassere viltkamera er å fange opptak av annet dyreliv i området, og det er derfor viktig at det settes opp i en vinkel der det ikke filmer mennesker.

Installering og aktivering

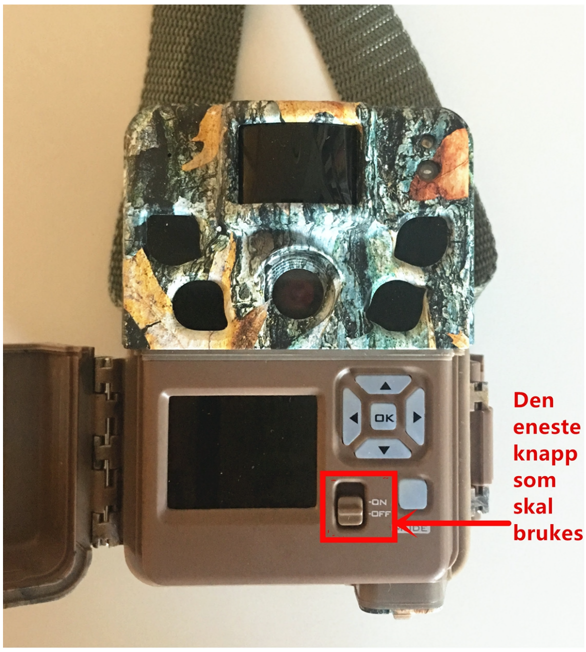
- Viltkameraet plasseres på egen eiendom på et tre eller lignende i knehøyde (ca 40-50 cm)
- Sørg for at kameraet plasseres et sted hvor det ikke er menneskelig aktivitet, men hvor katten kanskje ferdes. Bruk sjekkliste nede til å unngå ugunstig plassering.
- Forsøk å vinkle kameraet på en slik måte at det får et stort synsfelt uten å samtidig få meg seg "unødvendig" aktivitet fra mennesker e.l.
- Bruk vedlagt stropp for å feste kameraet. Sørg for at at det vinkles rett frem.
- Skru på kameraet først etter at det er ferdig plassert. Etter at kamera er skrudd på vil du ha 10 sekunder på å flytte deg vekk fra sensoren.

Videoopptak
Kamera har batterikapasitet for en hel uke og trenger ikke noen videre styringer. Se til kameraet en gang daglig for å kontrollere at det står i riktig vinkel.

Fjerning og tilbakelevering
Når du har fullført en ukes registrering kan du skru av kameraet og pakke det ned i medført emballasje før du leverer tilbake til oss.

Et godt utplassert viltkamera vender ikke mot:

- Vei
- Fortau
- Veranda
- Lekeplass/huske e.l.
- Garasje/innkjørsel
- Stier og ferdselsveier i hagen



Appendix 5: Camera settings

Table A 1: Showing the chosen camera settings that was set in advance.

Camera settings	
Date	MM/DD/YYYY
Time	TT:TT AM/PM
Mode	Video
Capture delay	30s
Video quality	High
Video length	10s
Smart IR	On
Night Exp	Long Range
Temp Unit	F
Info Strip	On
SD Management	Off
Motion Test	OK
Name	TRAILCAM##
Default settings	OK
Software Upgrade	OK

Appendix 6: Model selection

Table A 2: The model selection based on AICc for each species. Models are numbered as explained in the methods. Showing the number of estimated parameters (K), the information criterion requested (AICc), the appropriate ΔAICc depending on the information criteria selected, the level of support (AICcWt), the cumulative Akaike weights (Cum.Wt) and log-likelihood (LL) for each model. Chosen model is marked with.*

Species	Model	K	AICc	Δ AICc	AICcWt	Cum.Wt	LL
European badger	1*	2	140.87	0.00	0.55	0.55	-68.35
	3	3	142.91	2.04	0.20	0.74	-68.28
	2	3	143.02	2.14	0.19	0.93	68.33
	4	4	145.04	4.17	0.07	1.00	68.22
Domestic cat	3*	3	749.98	0.00	0.47	0.47	-371.81
	4	4	751.16	1.18	0.26	0.74	-371.28
	1	2	752.21	2.22	0.16	0.89	-374.01
	2	3	752.92	2.94	0.11	1.00	-373.28
Domestic dog	1*	2	69.78	0.00	0.54	0.54	-32.80
	3	3	71.73	1.95	0.20	0.74	-32.68
	2	3	71.93	2.15	0.18	0.92	-32.79
	4	4	73.61	3.84	0.08	1.00	-32.50
Mice	1*	2	61.72	0.00	0.50	0.50	-28.77
	3	3	63.09	1.37	0.25	0.75	-28.37
	2	3	63.90	2.17	0.17	0.91	-28-77
	4	4	65.25	3.52	0.19	1.00	-38.32
Red fox	3	3	71.57	0.00	0.3	0.3	-32.61
	2	3	71.58	0.00	0.3	0.6	-32.61
	1*	2	71.61	0.03	0.3	0.9	-33.72
	4	4	73.82	2.25	0.1	1.0	-32.61

Table A2 cont.

Species	Model	K	AICc	Δ AICc	AICcWt	Cum.Wt	LL
Red squirrel	3	3	103.12	0.00	0.34	0.34	-48.38
	4	4	103.50	0.38	0.28	0.62	-47.45
	1*	2	103.67	0.55	0.26	0.87	-49.75
	2	3	105.09	1.97	0.13	1.00	-49.36
Roe deer	1*	2	288.03	0.00	0.48	0.48	-141.93
	2	3	289.33	1.30	0.25	0.73	-141.49
	3	3	290.05	2.02	0.17	0.90	-141.85
	4	4	291.25	3.22	0.10	1.00	-141.32
Common blackbird	1*	2	57.79	0.00	0.55	0.55	-26.81
	3	3	59.89	2.11	0.19	0.74	-26.77
	2	3	59.96	2.17	0.19	0.93	-26.80
	4	4	61.84	4.05	0.07	1.00	-26.62
Common magpie	3*	3	481.44	0.00	0.74	0.74	-237.54
	4	4	483.58	2.14	0.25	1.00	-237.49
	2	3	493.10	11.66	0.00	1.00	-243.37
	1	2	494.73	13.30	0.00	1.00	-245.28
Great tit	*1	2	132.67	0.00	0.52	0.52	-64.24
	3	3	134.62	1.96	0.20	0.72	-64.13
	2	3	134.75	2.08	0.19	0.91	-64.19
	4	4	136.12	3.45	0.09	1.00	-63.76

Appendix 7: Model results

Table A 3: Results from the top model that emerged during AIC-based model comparison for each species. It shows the estimates, with standard error (SE), z-score and p-value, of occupancy (psi) and detection probability (p) for each model, and intercept Area:urban compared with Area:rural. A blank cells indicates that the parameter was not included and was therefore not estimated. The statistical significance level was set to p-value < 0.05. The results with p-value < 0.05 between urban and rural areas are marked in bold.

Species	Parameter		Estimate	SE	z	P(>|z|)
European badger	psi	Intercept	-1.59	0.435	3.66	0.000248
		Area:rural				
	p	Intercept	-1.72	0.321	-5.38	7.66e-08
		Area:rural				
Domestic cat	psi	Intercept	1.98	0.394	5.03	4.8e-07
		Area:rural				
	p	Intercept	0.475	0.103	4.6	4.28e-06
		Area:rural	-0.463	0.221	-2.1	**3.61e-02**
Domestic dog	psi	Intercept	-0.743	1.33	-0.559	0.577
		Area:rural				
	p	Intercept	-3.42	0.962	-3.55	0.000383
		Area:rural				
Mice	psi	Intercept	-2.41	0.608	-3.96	7.55e-05
		Area:rural				
	p	Intercept	-1.71	0.644	-2.66	0.00783
		Area:rural				
Red fox	psi	Intercept	-1.99	0.688	-2.89	0.00383
		Area:rural				
	p	Intercept	-2.39	0.572	-4.17	3.01e-05
		Area:rural				
Red squirrel	psi	Intercept	-2.29	0.491	-4.66	3.13e-06
		Area:rural				
	p	Intercept	-1.38	0.347	-3.96	7.49e-05
		Area:rural				
Roe deer	psi	Intercept	-0.843	0.284	-2.97	0.00296
		Area:rural				
	p	Intercept	-0.83	0.183	-4.53	5.84e-06
		Area:rural				

Table A3 cont.

Species	Parameter		Estimate	SE	z	P(>|z|)
Common blackbird	psi	Intercept	-0.843	0.284	-2.97	0.00296
		Area:rural				
	p	Intercept	-0.83	0.183	-4.53	5.84e-06
		Area:rural				
Common magpie	psi	Intercept	0.534	0.299	1.79	0.0741
		Area:rural				
	p	Intercept	-0.598	0.136	-4.39	1.15e-05
		Area:rural	-1.560	-0.423	-3.69	**2.28e-04**
Great tit	psi	Intercept	-1.17	0.441	-2.65	0.00808
		Area:rural				
	p	Intercept	-1.84	0.431	-4.28	1.86e-05
		Area:rural				

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