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Space use and preferred places among domestic cats in Ås, south-eastern Norway

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Abstract

Cats are popular pets and are usually allowed to roam free when owners let them out of the house. The home range size of cats has been well studied, but we know very little about how cats use the space within their home range. In this study, I examine whether cats have preferred places within their home range where they spend a lot of time, and if so, where these are located. I also investigate whether several cats use preferred places and share them, or if they are largely occupied by a single individual. To achieve this, cat owners were recruited from four adjoining neighbourhoods in Ås, a small university town in south-eastern Norway. The aim was to recruit and track the outdoor movements of the entire cat population within this area. The cats were tracked with a GPS unit attached to a collar, and when they spent a lot of time in one area they would create a cluster of GPS fixes. These clusters from the tracking data would be identified as a preferred spot.

Results show that all cats had preferred locations within their home range where they spend a significant proportion of their time while outside. These preferred spots were close to home and most of their time was spent in gardens. Up to four cats could share a site, however, the most common was that only one cat used a site. Male cats travelled further than female cats, had their preferred spots more spread out and shared more sites. Older cats moved less than younger cats and spent more time in one place, whereas younger cats walked more between sites they used.

These findings suggest that wildlife living in urban areas and using gardens have a high risk of encountering cats and are more exposed to cat predation.

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Introduction

Humans have had cats (*Felis catus)* as partners since prehistoric times (Ottoni et al., 2017). Since then they have become increasingly popular as pets and today they are the world´s most abundant predator as there are around 600 million cats globally (Kays et al., 2020) and around 770 000 in Norway (Braastad, 2021). This translates to a very high density of domestic cats within residential areas around the world. For example, in the UK the density was found to be between 132-1580 cats/km^2 (Sims et al., 2008) and in the US above 200 cats/km^2 (Lepczyk et al., 2004). The density of cats can be higher than populations of other similar predators because humans provide food and shelter (Kays et al., 2020). This may carry significance for much of the local wildlife and the ecosystem around them.

Cats are opportunistic hunters that hunt small mammals (Barratt, 1997), birds (Pavisse et al., 2019), reptiles (Medina et al., 2011), amphibians and invertebrates (Hernandez et al., 2018). Predation from cats has increased the mortality rate for many birds and amphibians (Pavisse et al., 2019, Hernandez et al., 2018) and cats are in fact connected to 63 extinctions and threaten 230 species globally (Doherty et al., 2016). Cats on oceanic island have contributed to 33 (13.9%) of the global bird, mammal and reptile extinctions (Medina et al., 2011). Feral cats kill an estimated 1.4-4.0 billion birds and 6.3-22.3 billion mammals annually in the US, whereas owned cats appear to have a smaller impact on wildlife (Loss et al., 2013).

Domestic cats are more regulated than feral, as they are fed by their owners and often dependent on being let in or out of the house. However, cats are usually allowed to roam free, and they can choose where they want to be and for how long. The kind of habitat the cat spends time in affects potential prey species and how abundant they are (Barratt, 1997). As most cats hunt between dusk and dawn (Hernandez et al., 2018), the timing of the cat´s release can also affect prey species. Even when not hunting, cats can affect wildlife by creating a landscape of fear that leads to reduced foraging and reproduction, and increased vulnerability to other predators (Loss and Marra, 2017, Preisser et al., 2005). The ecological impact of cats is increasingly studied with focus on the effects of owned cats (e.g. Hall et al., 2016, Roetman et al., 2018, Thomas et al., 2014, Horn et al., 2011). In Norway, a project named “Kattesporet” (Cat tracks) which this study is a part of, uses citizen scientists and

Global Positioning System (GPS) units to track cats and this gives information about their space use.

Investigating cat home ranges have revealed some information about their space use. Most cats spend their time in the vicinity of their owner's house, rarely venturing more than 100 m from home (Thomas et al., 2014, Barratt, 1997, Hanmer et al., 2017, López-Jara et al., 2021, Kays et al., 2020, Bischof et al., 2022). However, the size of the home range depends on the individual cat (Coughlin and van Heezik, 2015) as gender and age can affect ranging behaviour, with males having larger home ranges than females, and younger cats (2-7 years) having larger home ranges than older cats (>8 years) (Hall et al., 2016). Sometimes male cats can have overlapping home ranges with other males, while females usually do not share their home range with other females, but can occasionally share with males (Barratt, 1997). Home ranges are also affected by cat density as urban cats have smaller home ranges than suburban cats (Hanmer et al., 2017, Hall et al., 2016, Kays et al., 2020). Neighbouring cats generally do not have overlapping home ranges, while cats from the same residence and related cats can have overlap regardless of gender (Barratt, 1997).

Within the home ranges there may be specific locations that cats use more than the rest of the home range. When a tracked cat spends a lot of time in one location, more GPS fixes will be registered at this location creating a cluster of location fixes. These clusters of location fixes therefore indicate sites where cats like to hang out for longer periods of time. For feral cats these sites can be lairs that are used often (Roshier and Carter, 2021). Domestic cats show a similar pattern, but cats living in an urban setting have a high chance of encountering each other (Hall et al., 2016) and popular cat hotspots can be used by more than one cat (Flockhart et al., 2016). This means that cats may need to share popular hunting and resting places (Barratt, 1997). However, to my knowledge no studies have investigated an entire cat population´s usage of preferred places.

How cats use their environment when outside can help elucidate their impact on local wildlife. It is therefore important to understand how cats use their home ranges. However, few studies have investigated cat space use of their home ranges (Roshier and Carter, 2021). In this study, I attempt to rectify this shortfall by 1) examining whether cats have preferred areas where they hang out, and if so, how far are these sites from their home and in what kind of habitat are they located, and 2) do several cats use preferred places and share them or are they largely occupied by a single individual. I hypothesise that cats have preferred areas within their home range where they spend much of their time. Further, I hypothesise that the cats spend most of their time close to home and in gardens, and that the sharing of potential preferred areas will depend on sex and relatedness. Results are discussed in relation to previous findings, and I also provide some comments on conservation implications.

Methods

Study area

The study was conducted in Ås, a small town (inhabitants: 10 725, area: 4,73 km^2) (SSB, 2021) in south-eastern Norway, during May 2021. It is a university town, consisting of a large campus, residential areas, and a town centre largely surrounded by agricultural fields and production forests (NIBIO, 2020). The town is also dissected by a railroad. The average minimum and maximum temperature during May 2021 was 8.3°C and 15.1°C (NKS, 2022), respectively.

The chosen study site was around 1 km^2 and consisted of four neighbourhoods. Three of these were on the west side of the railway and one on the east side. The only direct connection between the neighbourhoods on either side of the railway was a pedestrian tunnel.

Recruiting participants

Participants were recruited from the chosen neighbourhoods primarily through information flyers posted in their postboxes, but some participants were contacted directly. Information about the project was also posted on a local social-media group. Lastly, personal communication with residents was used to encourage recruitment and interest in the project.

Once recruited, cat owners were required to submit two forms. First, the owners had to fill in a registration form containing contact information and address, cat name, number of cats and how much time their cat spent outdoors. Once the owner was registered, they received a more detailed survey regarding cat gender, morphometrics and habits (Appendix A). They were also asked if they wanted a wildlife camera installed in their garden. Lastly, owners were encouraged to send in pictures of their cats that could be used to identify the cats appearing on the wildlife cameras later.

GPS units

A week before the tracking started the GPS units were delivered to participants. The model used was i-gotUGT120 GPS produced by Mobile Action Technology, Inc., Taiwan, which has been used in previous cat studies (Hanmer et al., 2017, Sarfi, 2020, Kisen, 2021, Wu, 2020, Bachmann, 2020). These GPS units weigh around 26g. The tracking data is stored on the unit and needs manual download using the program @Trip PC.

The GPS units were delivered with a brief instruction on how to use them and information about the project. The package with the GPS units also included a charger and a collar. All participants had the same type of collar and those with multiple cats had collars in different colours to tell them apart, so each cat had their own GPS unit. The GPS was to be turned off and recharged while the cat was indoors to avoid positions from inside the home. When a cat was let out the owner was asked to turn on the GPS unit and check if it had connection to a satellite. The GPS was set to have a position fix every 30 seconds.

The cat tracking started 1st May and lasted until 29th May 2021. A project e-mail address and a phone number were available to the participants in case they had any questions during the tracking period. Participants were visited once during the sampling period to download data and check that the GPS unit was functioning. Talking with the owners revealed that the GPS was not always on the cat when it was outside, and not always off when the cat was inside.

Wildlife cameras

The participants that agreed to wildlife cameras had them installed in their garden. The cameras were of the models Browning Dark Ops HD Pro trail Camera BTC-6HDP, Browning BTC-6HDPX Dark Ops HD Pro and Browning Specs Ops Full HD. These were installed in 49 suitable gardens. Some gardens were not suitable because they were too small or had nowhere to place the cameras. The cameras were installed about 0.5 m above ground at a suitable place in consultation with the owners. Both privacy of the participant and the neighbours, and likelihood of capturing cats were taken into consideration when placing the cameras. What was not considered was growth of plants as the cameras were placed before the growth season, and therefore some cameras were overgrown by the end of the month.

The cameras were motion sensitive and took a 10-second-long video if triggered. They were placed one week after the project started and taken down after five weeks. The cameras had an SD memory card, but these varied in size (8-32 GB). This meant that not all the cameras were filming for the entire survey period as the cameras with smaller SD cards filled up before the end.

The information on the wildlife cameras was processed in three ways. The first thing to check was if there were any cats or other animals in the video. Videos with plants moving in the wind or humans were deleted. Then I checked if the cats in the videos were wearing a collar, as all participating cats were supposed to wear the collar every time they went outside. Finally, I attempted to identify the cats. To identify which tracked cat appeared in the video I compared cats in the video with pictures of the participating cats submitted by the owners. The cats that never had a collar on were identified as non-participating cats and had to be identified based on appearance. These cats were separated into different colours: black & white, black, brown, orange, calico, grey, striped, and white. Then the cats were compared to each other regardless of which camera they appeared on. Some cats were hard to identify because of bad videos or only viewed from one angle on one camera, making it difficult to compare it to stills of a similar cat from a different angle. Pure-coloured black cats were especially hard to separate and were therefore regarded as different cats unless they had a collar. When each cat was identified it got a unique ID. The non-participating cats had to be identified to assess how many cats that were not tracked were using the area. This could then be used to estimate how many cats in the population were included in the study.

Data analysis

R version 1.4.1103 (R Core Team, 2021) was used to analyse the data.

The GPS data were pre-processed following methods outlined in Bischof et al., (2022) and recommendations by Gupte et al. (2022) and Morris and Conner (2017). In short, positions with an elevation outside 0-300 m above sea level were removed. The first two days of tracking were removed (in case the introduction of a collar with GPS unit initially affected cat behaviour), as were positions for the day when the GPS check-up happened. Lastly, the positions with an estimated horizontal position error (EPHE) $\geq$ 5000 were removed.

To assess whether cats preferred specific locations within their home range, I identified GPS position clusters from the individual cat tracks. A cluster of position fixes indicates a location that a cat spends a lot of consecutive time. The R-package GPSeqClus (Clapp et al., 2021) was used to identify the clusters for each cat and make cluster calculations. The GPS position clusters were calculated based on a minimum of 10 or more GPS fixes that were created in a 10 m radius from the first GPS point. The radius of 10 m was chosen because the GPS units had a position error of 10 m (Morris and Conner, 2017). Therefore, the lower end of the distribution with shorter duration of clusters were not included in the analyses. The duration of clusters was calculated based on cluster start time and ending time. Centroids were created based on the average distance between the points in the cluster. Positions that were inside a cat´s home were removed, because I was not interested in indoor activities, only when the cats were outdoors. The clusters created by cats could subsequently be mapped and show where the cats were in relation to houses, other cats, and habitat types. It could also show if cats shared the same space.

To see how many cats shared a space, a raster was created that stack position clusters from each cat on top of each other. For each cell in the grid, it would be counted if a cat had a cluster inside or not. If a cluster was there, it would only be counted as one, regardless of how many clusters one cat had inside the cell. The grids from all the cats were stacked on top of each other and revealed how many cats shared the place located in one cell. A weakness with the raster is that two cats can have a cluster next to each other, but the grid division can place them in two separate cells. To counteract this, both 10 m x 10 m and 20 m x 20 m resolutions were investigated to see how different resolutions affected the number of overlapping clusters.

To better understand what affected cat space use, different linear regression models were created. These models tested if a predictor variable had a significant effect on the response variable. Further, a-priori linear candidate models were created and then tested with Akaike Information Criteria (AIC) to select the model that best explains the data. A full list of all the different predictor variables tested for each response variable is in Table 1.

Table 1. *Response variables and predictor variables used for linear regression models and a-priori candidate models.*

Response variable	**Predictor variables tested**
Average time outdoors	Cat gender, Cat age, Maximum distance (m) to home, Preferred spot´s average duration (seconds), Proportion of time spent in a preferred spot
Proportion of time spent in urban habitat	Cat age, Average distance (m) between a cat´s position and it´s home, Preferred spot´s average duration (seconds), Maximum distance (m) between a cat´s position and it´s home
Average distance (m) between a cat´s position and it´s home	Cat age, Cat gender
Maximum distance (m) between a cat´s position and it´s home	Cat age, Cat gender
Number of clusters	Cat age, Cat gender
Proportion of time spent in a preferred place	Cat age, Cat gender, Average distance (m) between a cat´s preferred spot´s and it´s home, Preferred spot´s average duration (seconds), How a cat is released (manual release, free access to cat door, and limited access to cat door), Proportion of time spent in urban habitat
Average duration of time in a preferred place (seconds)	Cat age, Cat gender, Average distance (m) between a cat´s preferred spot´s and it´s home, Average time outdoors (minutes), Proportion of time spent in a preferred spot, Maximum distance (m) between a cat´s position and it´s home
Maximum distance (m) between a cat´s preferred spot´s and it´s home	Cat gender, Proportion of time spent in a preferred spot
Average distance (m) between a cat´s preferred spot´s and it´s home	Cat gender, Proportion of time spent in a preferred spot

Results

Participants and their cats

GPS units were delivered to 82 households with a total of 100 cats. However, eight cats rejected the collar and could not participate, leaving 92 cats from 74 households. One GPS unit was lost during the month and had to be replaced.

Most households had one cat (n=57), but 16 residences had two cats, and one had three cats. The sex ratio was very even, with 42 females and 44 males. Six cats were not gendered. Most (n=90) of the cats were neutered. Average cat age was 6.4 ±0.36 (SE) years with a range from

1-15 years (Table 2). Many cats had to be let in and out by their owners (n=60), but 26 had a cat door and 24 of these always had free access to the outdoors. The remaining two cats had limited access with the owner closing the door at specific times.

Wildlife cameras

In total, 49 wildlife cameras were installed. Of these, only two did not have any videos of cats. After identifying the cats in the videos as either participating or not, it was estimated that 73% of the cats using the area had been tracked.

Table 2. *A summary of pet cat age and outdoor space use data, including minimum (Min), maximum (Max), mean, and standard error (SE) values for different variables.*

	Min	Max	Mean	SE
Cat age years	1	15	6.36	0.36
Average time spent outdoors (minutes)	6.21	1091.68	503.77	23.46
Average distance to home (m)	4.06	881.02	49.53	11.46
Max distance to home (m)	47.65	3383.52	352.13	46.06
Proportion of time in urban habitat	0.39	1	0.91	0.011
Proportion of time in a preferred place	0.70	0.96	0.86	0.00
Average time spent in a preferred place (seconds)	987.22	4182.57	1855.05	62.69
Average time spent in a preferred place converted to minutes	16.45	69.7	30.91	1.04
Number of clusters created	33	988	418.75	21.86
A preferred spot´s average distance to home (m)	6.19	945.03	59.66	13.47
A preferred spot´s max distance to home (m)	37.58	3381.51	315.87	45.75

General space use

The estimated average time spent outside per day for all cats was 503±23.46 (SE) minutes, with a range of 6.21-1091.68 minutes (Table 2). While different variables were tested, only age and time spent in a preferred place affected the duration of time spent outside (Table 3-4). Younger cats spent more time outdoors than older cats, and the time spent outside was positively correlated with time spent in a preferred location (Figure 1, Table 4).

Table 3. *Four different a-priori candidate models for response variable "average time outdoors (minutes)" with the lowest AIC values. The chosen model is marked in bold.*

Response variable	Candidate model	Prediction variables	R^2	F-statistics	P value	AIC
Average time outdoors (minutes)	Model 1	Age + Gender + preferred spot avg. duration[1]	0.2703	9.26 on 3 and 75 DF	2.769e-05	1057.25
	AIC selected model	**Age + Gender + Max. dist. home[2] + preferred spot avg. duration[1]**	**0.2924**	**7.643 on 4 and 74**	**3.277e-05**	**1056.82**
	Model 3	Age + Gender + Max. dist. home[2] + Preferred spot avg. duration[1] + Prop. preferred spot[3]	0.3059	6.435 on 5 and 73 DF	5.255e-05	1057.29
	Model 4	Age + Max. dist. home[2] + Preferred spot avg. duration[1]	0.2603	8.799 on 3 and 75 DF	4.525e-05	1058.32

[1] "preferred spot avg. duration" = preferred spot´s average duration (seconds)

[2] "Max. dist. home" = maximum distance (m) between a cat´s position and it´s home

[3] "Prop. preferred spot" = proportion of time spent in a preferred spot

Table 4. *Results of the AIC chosen linear regression model (the model selected in Table 3) for response variable "average time outdoors (minutes)". The significant values are marked in bold.*

	Estimate	Std. Error	T value	Pr(>|t|)
(Intercept)	209.33	86.35	2.424	0.0178 *
Cat gender	-72.29	43.97	-1.644	0.1044
Cat age	**-15.09**	**6.40**	**-2.356**	**0.0211 ***
Max. dist. home[1]	0.072	0.04	1.519	0.1330
Preferred spot avg. duration[2]	**0.22**	**0.04**	**5.133**	**2.22e-06 *****

[1] "Max. dist. home" = maximum distance (m) between a cat´s position and it´s home

[2] "preferred spot avg. duration" = preferred spot´s average duration (seconds)

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

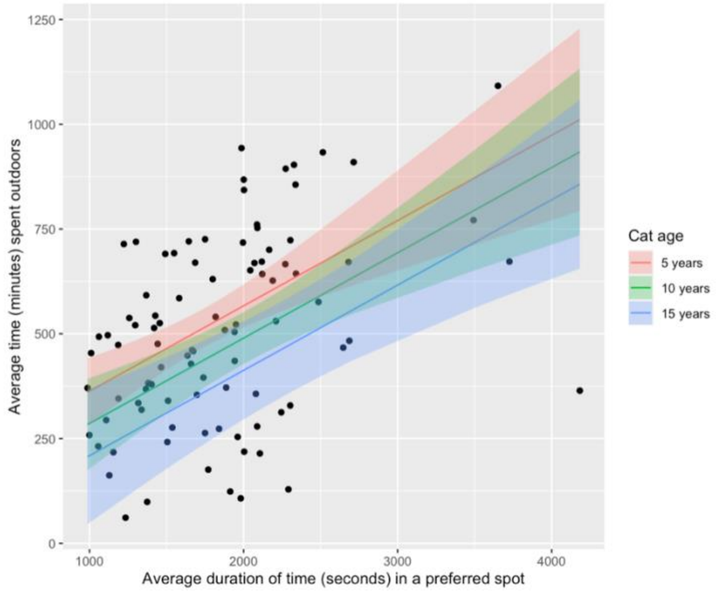

Figure 1. Linear regression model with a 95% CI displaying the relationship between average duration of time (seconds) in a preferred spot, average time (minutes) spent outdoors for the ages 5, 10 and 15 years.

Cats spent most of their time in urban habitats, with 15 cats spending 100% of their time and 20 cats spending ~99% of their time in urban habitats (Figure 2). Of the cats spending all their time in urban habitat most were female (n=10) (Figure 2). However, gender had no significant effect on time spent in urban habitats (F-statistic: 1.35 on 1 and 84 DF, p-value: 0.2485). The linear regression model showed that a cat´s average distance to home best explained the proportion of time it would spend in urban habitat (Table 5-6). The cats that travelled farthest also spent the least amount of time in urban habitats (Figure 3). Age also had a significant effect on how much time a cat spent in urban habitats (Table 5-6), with older cats spending more time in urban habitats than younger cats (Figure 4).

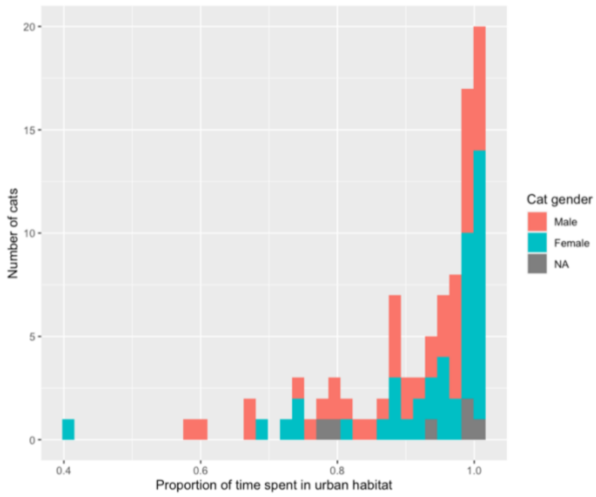

Figure 2. A histogram showing the gender of cats and how many spent different proportions of time in urban habitat. As 20 cats spent ~0.99 in urban habitat the figure shows more cats in 1.0 than the actual number (n=15).

Table 5. *Four different a-priori candidate models for response variable "proportion of time spent in urban habitat" with the lowest AIC value, and a model for age. The chosen model is marked in bold.*

Response variable	Candidate model	Prediction variables	R^2	F-statistics	P value	AIC
Proportion of time spent in urban habitat	Model 1	Age + Avg. dist. home[1] + Preferred spot avg. duration[2] + Age×Avg. dist. home[1]	0.3835	11.51 on 4 and 74 DF	2.559e-07	-138.8167
	Model 2	Age + Avg. dist. home[1] + Age×Avg. dist. home[1]	0.3514	13.54 on 3 and 75 DF	3.772e-07	-136.7983
	AIC selected model	**Avg. dist. home[1]**	**0.2261**	**26.3 on 1 and 90 DF**	**1.666e-06**	**-155.4795**
	Model 4	Max. dist. home[3]	0.1451	15.28 on 1 and 90 DF	0.0001793	-146.3231
	Age as predictor model	Age	0.07112	5.896 on 1 and 77 DF	0.01751	-112.4282

[1] "Avg. dist. home" = average distance (m) between a cat´s position and it´s home

[2] "Prop. preferred spot" = proportion of time spent in a preferred spot

[3] "Max. dist. home" = maximum distance (m) between a cat´s position and it´s home

Table 6. *Results of the AIC chosen linear regression model (the model selected in Table 5) for response variable "proportion of time spent in urban habitat", and linear regression model with response variable "proportion of time spent in urban habitat" and predictor variable "age". Significant values are marked in bold.*

Model		Estimate	Std. Error	T value	Pr(>|t|)
AIC model	(Intercept)	9.378e-01	1.164e-02	80.556	< 2e-16 ***
	Avg. dist. home[1]	**-4.972e-04**	**9.696e-05**	**-5.128**	**1.67e-06 *** **
Age as predictor variable model	(Intercept)	0.850889	0.027024	31.486	<2e-16 ***
	Cat age	**0.009029**	**0.003718**	**2.428**	**0.0175 ***

[1] "Avg. dist. home" = average distance (m) between a cat´s position and it´s home

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

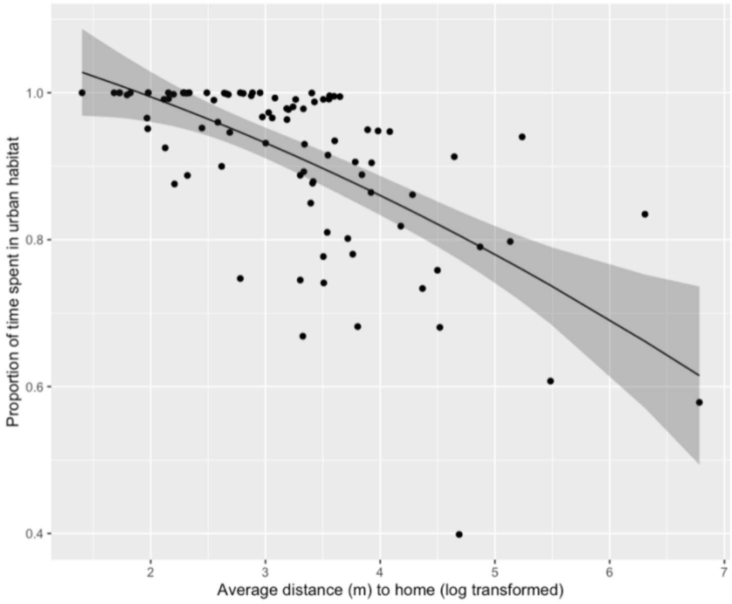

Figure 3. Log transformed linear regression with 95% CI, shows the relationship between how much time a cat spends in urban habitat and the average distance (m) between a cat and it´s home.

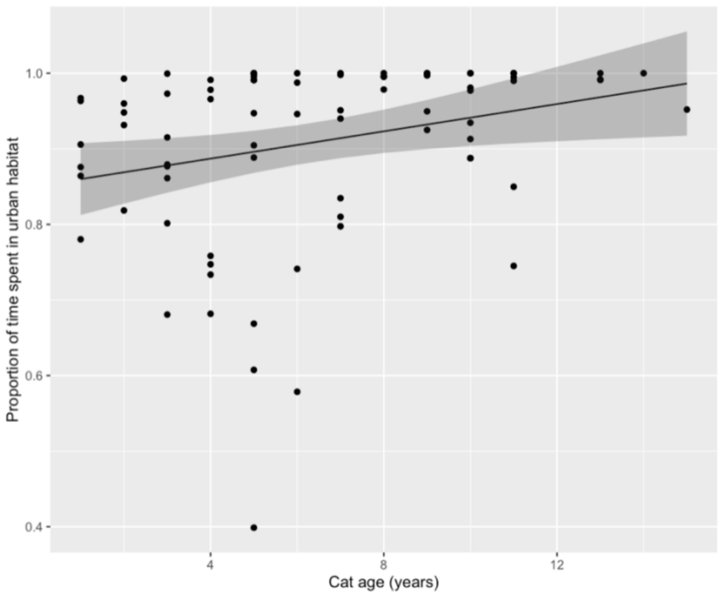

Figure 4. Linear regression with a 95% CI showing the relationship between a cat´s age (years) and the amount of time it spends in urban habitats.

Cats did not travel far from home, as most cats had a low average distance making the mean distance for all cats 50 m ±11.46 (SE) (Table 2). While the range was 4-881 m, only a few cats (n=3) had an average distance above 250 m (Appendix B, Figure B1A). The range was greater for maximum distance between a cat and a home, ranging from 48-3384 m (Table 2). The mean for maximum distance to a cat´s home was 352 m ± 46 (SE) (Table 2). Only four cats that had a maximum distance above 1000 m (Appendix B, Figure B2B).

All the cats that had the highest average and maximum distances travelled were males (Figure 5). There was a significant effect between gender and maximum distance travelled as well as for average distance travelled (Table 7). Age did not have a significant effect on either maximum distance travelled (F-statistic: 0.989 on 1 and 77 DF, p-value: 0.3231) nor average distance (F-statistic: 0.3486 on 1 and 77 DF, p-value: 0.5566).

Table 7. *Linear regression models with response variables "average distance (m) to home" and "maximum distance (m) to home" with predictor variable "gender". Significant values are marked in bold*

Response variable	Prediction variables	R^2	F-statistics	P value	
Avg. dist. home[1]	Gender	0.04556	4.01 on 1 and 84 DF	0.04847	
Max. dist. home[2]	Gender	0.08393	7.696 on 1 and 84 DF	0.00682	
Model		**Estimate**	**Std. Error**	**T value**	**Pr(>|t|)**
Avg. dist. home[1] model	(Intercept)	73.81	16.77	4.401	3.14e-05 ***
	Cat gender	**-48.05**	**24.00**	**-2.002**	**0.0485 ***
Max. dist. home[2] model	(Intercept)	480.28	66.06	7.270	1.71e-10 ***
	Cat gender	**-262.23**	**94.53**	**-2.774**	**0.00682 ****

[1] "Avg. dist. home" = average distance (m) between a cat´s position and it´s home

[2] "Max. dist. home" = maximum distance (m) between a cat´s position and it´s home

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

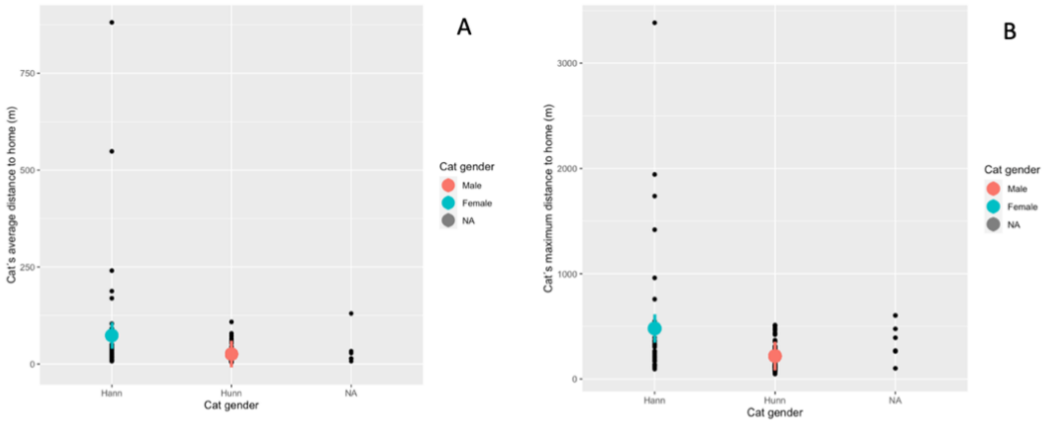

Figure 5. Linear regression with 95% CI for cat gender and A) average distance (m) between a cat and home, and B) maximum distance (m) between a cat and home.

Preferred places

The number of GPS position clusters created by a cat varied from 33-988 clusters created by a cat and the mean number was 419± 21.86 (SE) (Table 2). The distribution of clusters created between the genders was even (Appendix B, Figure B2), with no significant effect of gender on the number of clusters created (F-statistic: 0.3701 on 1 and 84 DF, p-value: 0.5446). Age on the other hand had a significant effect, where older cats created fewer clusters than younger cats (Figure 6, Table 8).

Table 8. *Linear regression model with response variables "number of clusters" with predictor variable "age". Significant values are marked in bold.*

Response variable	Prediction variables	R^2	F-statistics	P value	
Number of clusters	Age	0.05247,	4.264 on 1 and 77 DF	0.04229	
Model		**Estimate**	**Std. Error**	**T value**	**Pr(>|t|)**
	(Intercept)	508.722	46.412	10.961	<2e-16 ***
	Cat age	**-13.187**	**6.386**	**-2.065**	**0.0423 ***

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

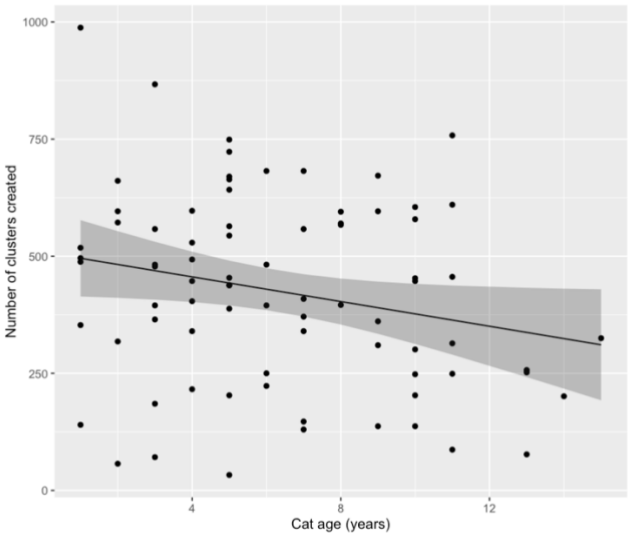

Figure 6. Linear regression with 95%CI showing the relationship between cat age (years) and number of clusters created.

Most cats (n=47) spent between 80-90% of their outdoor time in a preferred place (Table 2, Appendix B, Figure B3), and this was affected by several variables. There was no significant difference between the genders on how much time they spent in a preferred place (F-statistic: 3.628 on 1 and 84 DF, p=0.06). However, there was a significant relationship between the proportion of time a cat spent in a preferred spot, average time (seconds) spent in a preferred spot and proportion of time a cat spent in urban habitat (Table 9-10). Cats that had a high average time in preferred spots also had a high proportion of time spent in preferred spots and spent a lot of time in urban habitat (Figure 7). The effect of age was also tested and had a significant effect on the proportion of time spent in a preferred spot (Table 9-10). Older cats spent more of their time in a preferred spot than younger cats (Figure 8).

Table 9. *Four a-priory linear regression models for response variable "proportion of time spent in a preferred spot". The model chosen from AIC values is marked in bold.*

Response variable	Candidate model	Prediction variables	R^2	F-statistics	P value	AIC
Proportion of time spent in a preferred place	Model 1	Age + Preferred spot avg. dist. home[1] + Preferred spot avg. duration[2] + Age×Preferred spot avg. dist. home[1]	0.7456	54.21 on 4 and 74 DF	2.2e-16	-317.2520
	Model 2	How released[3] + Preferred spot avg. dist. home[1] + Preferred spot avg. duration[2]	0.6653	40.25 on 4 and 81 DF	2.2e-16	-325.4461
	Model 3	Preferred spot avg. dist. home[1] + Preferred spot avg. duration[2]	0.6672	89.23 on 2 and 89 DF	2.2e-16	-352.1406
	AIC selected model	**Preferred spot avg. dist. home[1] + Preferred spot avg. duration[2] + Prop. urban[4]**	**0.7362**	**81.85 on 3 and 88 DF**	**2.2e-16**	**-371.4931**
	Age model	Age	0.08786	7.417 on 1 and 77 DF	0.00799	

[1] "Preferred spot avg. dist. home" = average distance (m) between a cat´s preferred spot´s and it´s home

[2] "preferred spot avg. duration" = preferred spot´s average duration (seconds)

[3] "how released" = manual release, free access to cat door or limited access to cat door

[4] "prop. urban" = proportion of time spent in urban habitat

Table 10. *Results of the AIC chosen linear regression model (the model selected in Table 9) for response variable "proportion of time spent in urban habitat", and linear regression model with response variable "proportion of time spent in urban habitat" and predictor variable "age". Significant values marked in bold.*

Model		Estimate	Std. Error	T value	Pr(>|t|)
AIC selected model	(Intercept)	5.934e-01	2.985e-02	19.881	< 2e-16 ***
	Preferred spot avg. dist. home[1]	-2.770e-05	2.816e-05	-0.984	0.328
	Preferred spot avg. duration[2]	**6.591e-05**	**5.889e-06**	**11.192**	**< 2e-16 *****
	Prop. urban[3]	**1.612e-01**	**3.361e-02**	**4.795**	**6.58e-06 *****
Age model	(Intercept)	0.826275	0.013474	61.323	< 2e-16 ***
	Cat age	**0.005049**	**0.001854**	**2.723**	**0.00799 ****

[1] "Preferred spot avg. dist. home" = average distance (m) between a cat´s preferred spot´s and it´s home

[2] "preferred spot avg. duration" = preferred spot´s average duration (seconds)

[3] "prop. urban" = proportion of time spent in urban habitat

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

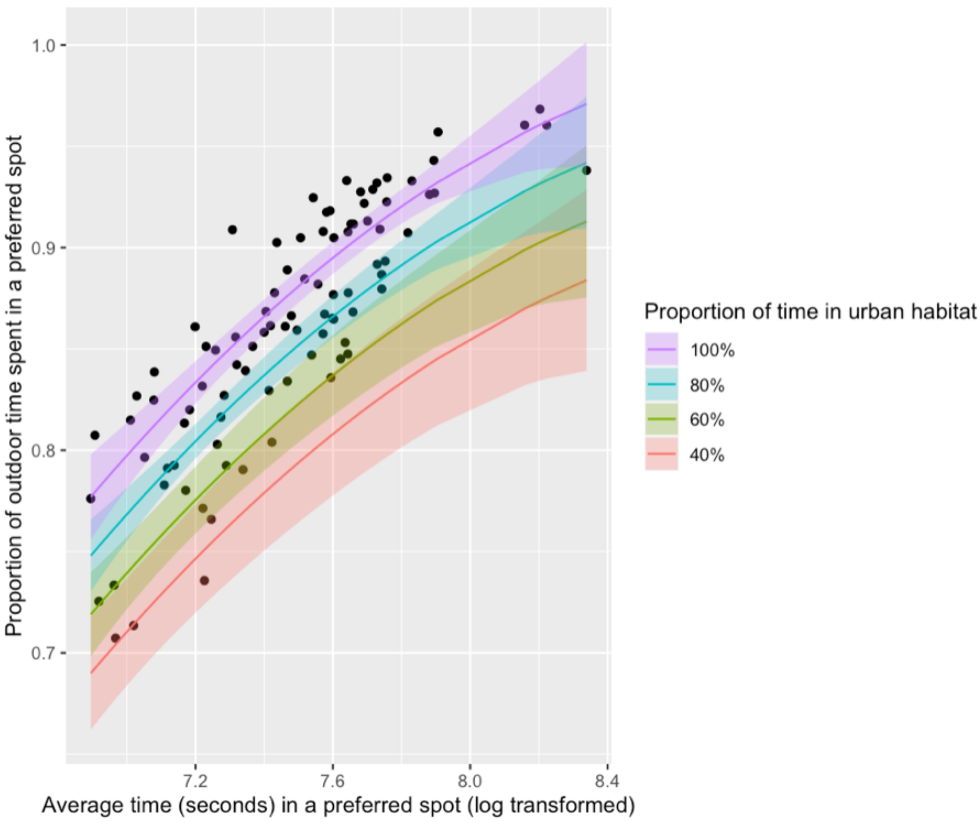

Figure 7. Linear regression with 95% Ci showing the relationship between average time (seconds) in a preferred spot (log transformed), proportion of outdoor time spent in a preferred spot and proportion of time in urban habitat.

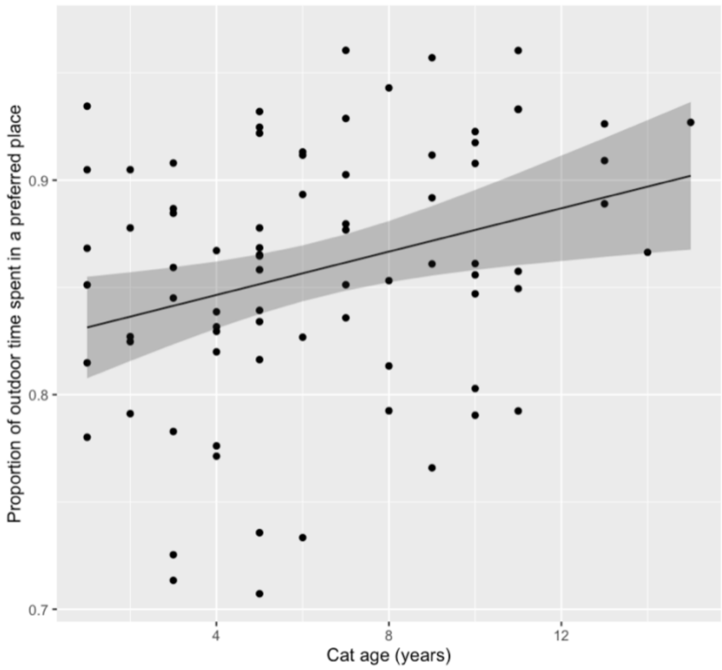

Figure 8. Linear regression with 95% CI showing relationship between cat age (years) and proportion of time spent in a preferred place.

The average time spent in a preferred spot varied from 16-70 minutes with a mean of 31minutes ±1.04 (SE) for the entire study period (Table 2). Few cats (n= 4) spent more than 3000 seconds (50 minutes) on average in a preferred place, and all of these (except one not gendered) were female (Appendix B, Figure B4). However, there were no significant differences between the genders (F-statistic: 1.365 on 1 and 84 DF, p= 0.246).

Different variables were tested for the response variable “average duration of time in a preferred place (seconds)”. The AIC chosen model was one with the predictor variables “age”, “average time spent outdoors (minutes)” and “proportion of time spent in a preferred spot”, with an interaction for the two latter ones (Table 11). While all the predictor variables were significant, “average time spent outdoors (minutes)” had a lower p-value (0.017) than the other variables (Table 12). “Cat age”, “proportion of time spent in a preferred place” and the interaction between “proportion of time spent in a preferred place” and “average time spent outdoors (minutes)” had a positive effect on “average duration of time in a preferred place (seconds)” (Figure 9). “Average time spent outdoors (minutes)” was the only variable that had a negative effect on the response variable (Figure 9).

Table 11. *Four different a-priori linear models with response variable "average duration of time in a preferred place (seconds)". The model chosen from AIC values is marked in bold.*

Response variable	Candidate model	Prediction variables	R^2	F-statistics	P value	AIC
Average duration of time in a preferred place (seconds)	Model 1	Gender + Age + preferred spot avg. dist. home[1] + avg. time outdoors[2] + Prop. preferred spot[3]	0.7667	47.98 on 5 and 73 DF	2.2e-16	1113.801
	AIC selected model	**Age + avg. time outdoors[2] × Prop. preferred spot[3]**	**0.7867**	**68.24 on 4 and 74 DF**	**2.2e-16**	**1104.716**
	Model 3	Gender + preferred spot max. dist.[4] + avg. time outdoors[2] + Age + Prop. preferred spot[3]	0.765	47.53 on 5 and 73 DF	2.2e-16	1114.371
	Model 4	Age + avg. time outdoors[1] + Prop. preferred spot[3]	0.765	81.36 on 3 and 75 DF	2.2e-16	1110.392

[1] "Preferred spot avg. dist. home" = average distance (m) between a cat´s preferred spot´s and it´s home

[2] "avg. time outdoors" = average time spent outdoors (minutes)

[3] "Prop. preferred spot" = proportion of time spent in a preferred spot

[4] "preferred spot max. dist." = preferred spot´s maximum distance (m) to home

Table 12. *Results of the AIC chosen linear regression model (the model selected in Table 11) for response variable "average duration of time in a preferred place (seconds)". Significant values marked with bold.*

	Estimate	Std. Error	T value	Pr(>|t|)
(Intercept)	-1529.891	1044.840	-1.464	0.14737
Cat age	**23.093**	**8.585**	**2.690**	**0.00883 ** **
Avg. time. outdoors[1]	**-4.930**	**2.023**	**-2.437**	**0.01720 * **
Prop. preferred spot[2]	**3384.553**	**1220.925**	**2.772**	**0.00704 ** **
avg. time. outdoors : prop. preferred spot	**6.378**	**2.321**	**2.748**	**0.00753 ** **

[1] "avg. time outdoors" = average time spent outdoors (minutes)

[2] "Prop. preferred spot" = proportion of time spent in a preferred spot

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

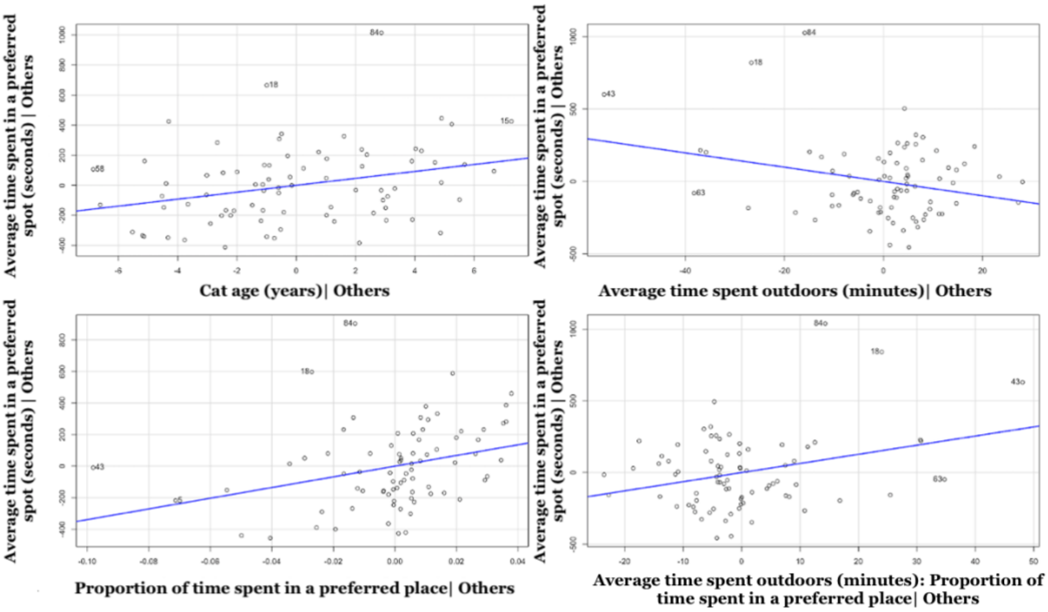

Figure 9. Linear regression with the response variable "average duration of time in a preferred place (seconds)" and predictor variables "age", "average time spent outdoors (minutes)" and "proportion of time spent in a preferred spot", with an interaction between "average time spent outdoors (minutes)" and "proportion of time spent in a preferred spot". "Others" are the remaining predictor variables held as a constant.

The preferred spots of cats were not far from home. The average cat went 60 m ±13.47 (SE) from home to spend time in a site, the range being 6-945m (Table 2). For maximum distances, the shortest was 38 m, the longest 3382 m and the mean 316 m ± 45.75 (SE) (Table 2). Few cats had an average distance for their preferred spots above 250 m (n=3), or a maximum distance above 1000 m (n=4) and all these cats were male (Appendix B, Figure B5).

Gender had a significant effect on a preferred spot´s maximum and average distance to home (Table 13). Male cats had preferred sites at a higher average and maximum distance to home than females (Figure 10). Cats that had a preferred spot at a high maximum and average distance from home spent less time there than cats that kept closer to home (Figure 11).

Table 13. *Linear regression models for the response variables "maximum distance (m) between a cat´s preferred spot´s and it´s home" and "average distance (m) between a cat´s preferred spot´s and it´s home". Significant values marked in bold*

Response variable	Prediction variables	R^2	F-statistics	P value	
Preferred spot max. dist.[1]	Gender	0.0737	6.683 on 1 and 84 DF	0.01146	
	Prop. preferred spot[2]	0.08589	F-statistic: 8.457 on 1 and 90 DF	p-value: 0.00458	
Preferred spot avg. dist.[3]	Gender	0.04905	F-statistic: 4.333 on 1 and 84 DF	p-value: 0.04042	
	Prop. preferred spot[2]				
Model		**Estimate**	**Std. Error**	**T value**	**Pr(>|t|)**
Preferred spot max. dist. home[1] and gender	(Intercept)	435.39	65.91	6.605	3.4e-09 ***
	Cat gender	**-243.84**	**94.32**	**-2.585**	**0.0115 ***
Preferred spot max. dist. home[1] and Prop. preferred spot[2]	(Intercept)	2175.0	640.8	3.394	0.00103 **
	Prop. preferred spot[2]	**-2158.9**	**742.4**	**-2.908**	**0.00458 ****
Preferred spot avg. dist. home[3] and gender	(Intercept)	89.54	19.71	4.543	1.84e-05 ***
	Cat gender	**-58.70**	**28.20**	**-2.082**	**0.0404 ***
Preferred spot avg. dist. home[3] and Prop. preferred spot[2]	(Intercept)	682.4	186.1	3.667	0.000415 ***
	Prop. preferred spot[2]	**-723.2**	**215.6**	**-3.354**	**0.001166 ****

[1] "Preferred spot max. dist. home" = maximum distance (m) between a cat´s preferred spot´s and it´s home

[2] "Prop. preferred spot" = proportion of time spent in a preferred spot

[3] "Preferred spot avg. dist. home" = average distance (m) between a cat´s preferred spot´s and it´s home

Significance codes: '***' =<0.001 '**'=< 0.01 '*' =<0.05

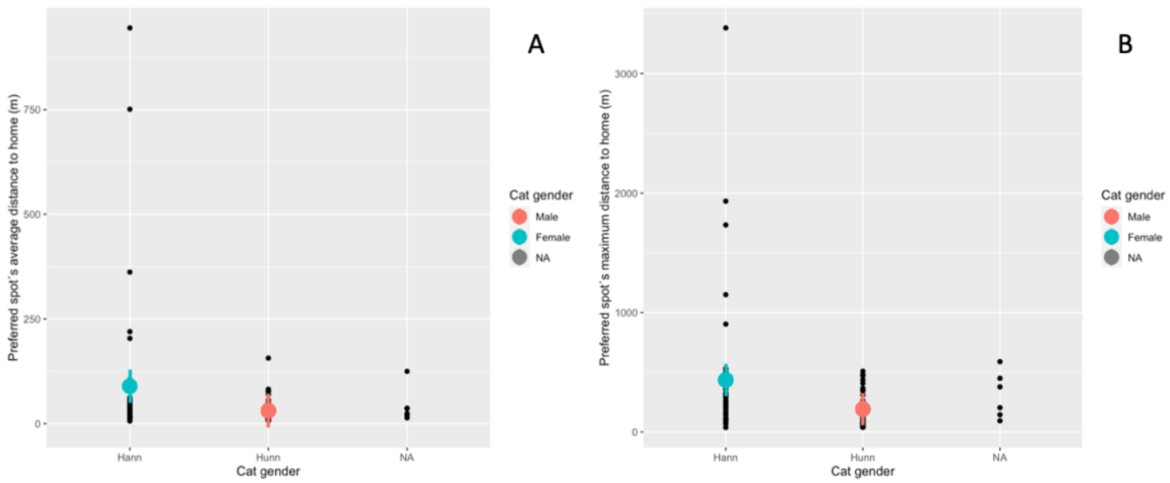

Figure 10. Linear regression with 95% CI showing the relationship between cat gender and (A) average distance (m) for their preferred place, and (B) maximum distance (m) for their preferred place.

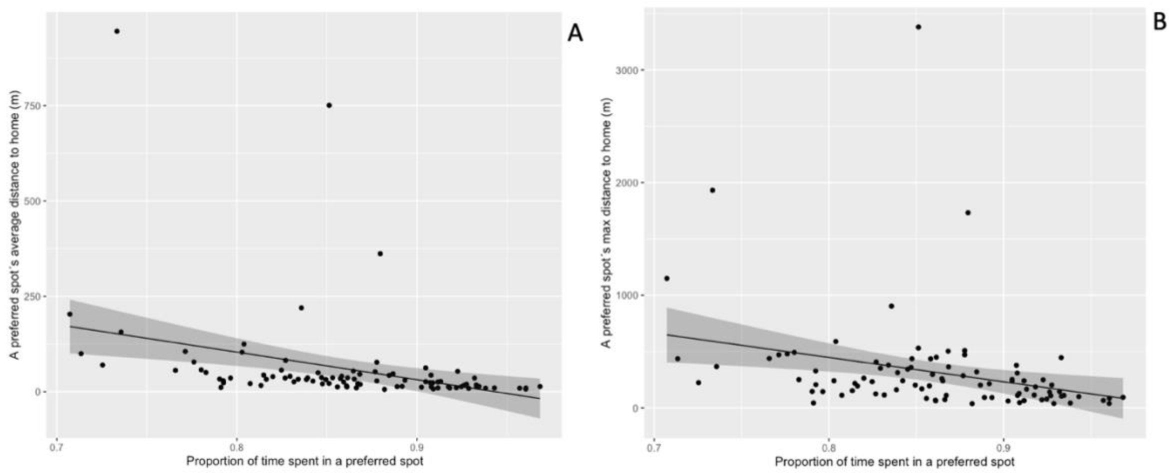

Figure 11. Linear regression with 95% CI showing the relationship between proportion of time spent in a preferred spot and (A) average distance (m) for their preferred place, and (B) maximum distance (m) for their preferred place.

Overlap of preferred places among cats

The cats spent most of their time in the neighbourhoods that were part of the study area (Figure 12 B). Only a few cats (n=4) were seen to be clearly outside the study area (colour-coded light blue, green, purple, and red, Figure 12). There was a particularly high amount of cat clustering close to the residential areas and some of those were overlapping (Figure 12).

A raster analysis showed how many cats shared a specific place. The maximum number of cats that share a place was four regardless of the raster size tested (Figure 13). The most common was that only one cat used the place (Figure 13). The most popular places were in the middle of neighbourhoods, while places outside the neighbourhoods usually only had one cat using the space (Figure 13). These cats were all males (Figure 14 A).

A separated raster for females and males showed a difference in space use (Figure 14). Females spend their time concentrated around their homes and they do not overlap much with other females (Figure 14 B). The highest number of overlaps for exclusively females was three, compared to males that had up to four cats using the same site (Figure 14). The males use more space and create more scattered clusters than the females (Figure 14).

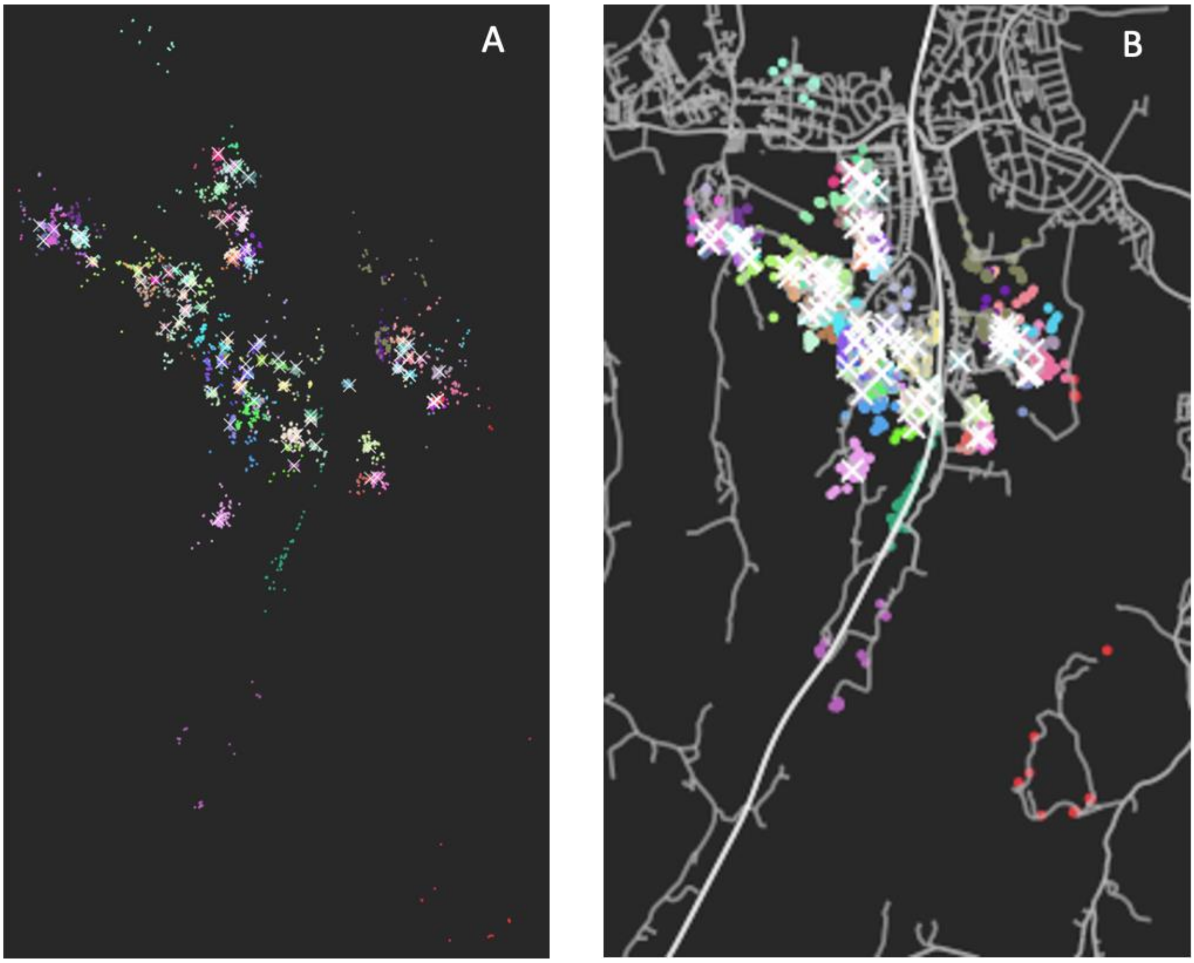

Figure12. The clusters created by cats from usage of the study area and surrounding areas. Cat homes (study area) are marked with a white ×. A) All the clusters created by cats each assigned a separate colour (note: the background map was excluded so the clusters would be more visible). B) The cluster centroids and buffers for each cat and their relation to human structures in the area. The white line represents the railway, the grey lines are roads.

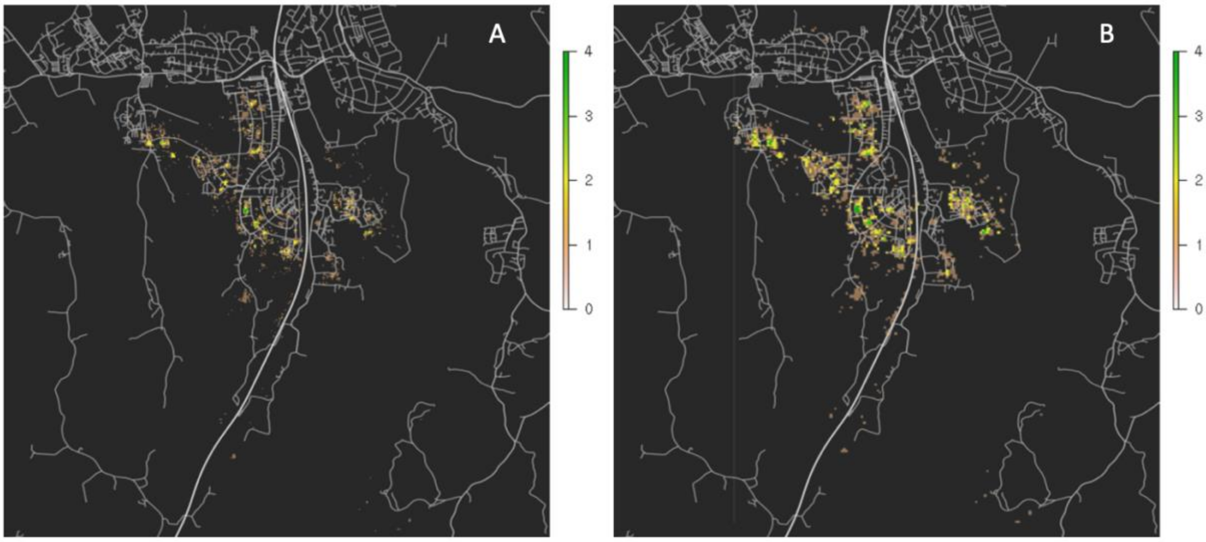

Figure 13. Raster showing the overlap of cat clusters, with the lowest number being 0 (transparent), and highest 4 (dark green). The raster is laid over a map with the white line representing the railway and roads as grey lines. Note: the raster positions are only approximate. A) Number of overlapping cells in the raster when resolution = 10 m. B) Number of overlapping cells in the raster when resolution = 20 m.

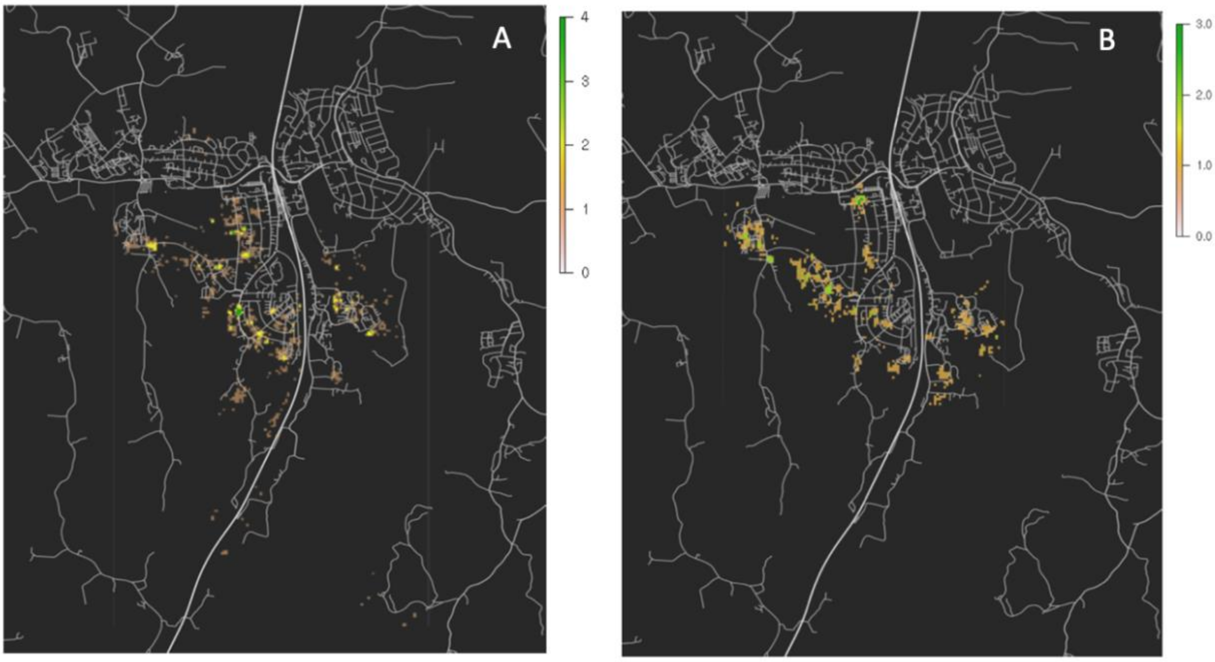

Figure 14. Raster showing the overlap of cat clusters, with resolution = 20 m. The raster is laid over a map with the white line representing the railway and roads as grey lines. Note: the raster positions are only approximate. A) A raster for only male cat clusters with the lowest number being 0 (transparent), and highest 4 (dark green). B) A raster for only female cat clusters with the lowest number being 0 (transparent), and highest 3 (dark green).

A plot showing the GPS fixes from a few cats illustrate how different cats can move (Figure 15). Most of the cats create clusters around their home and some further away (Figure 15A). However, the clusters created by two cats and colour-coded brown and blue are concentrated close to their home (Figure 15A). The cats colour-coded yellow and light green live in the same house and share several spots even far away from their house (Figure 15A). The cats living in the same house on a different road followed the same pattern as those in Figure 15A, these cats also shared spaces when outside (Figure 15B). Here the cats color-coded yellow and light green, as well as the cats color-coded blue and purple that live in the same house only shared space with their housemate (Figure 15B). The cat marked with blue went into the same areas as the neighbouring cat marked with green, but did not have the same overlap in space use as it did with the cat marked with purple (Figure 15B). An example on how much neighbouring cats can avoid each other is seen with the cats marked blue and red that walk in opposite directions (Figure 15C). They only share space around their neighbouring houses, but even then remain on opposite sites (Figure 15C).

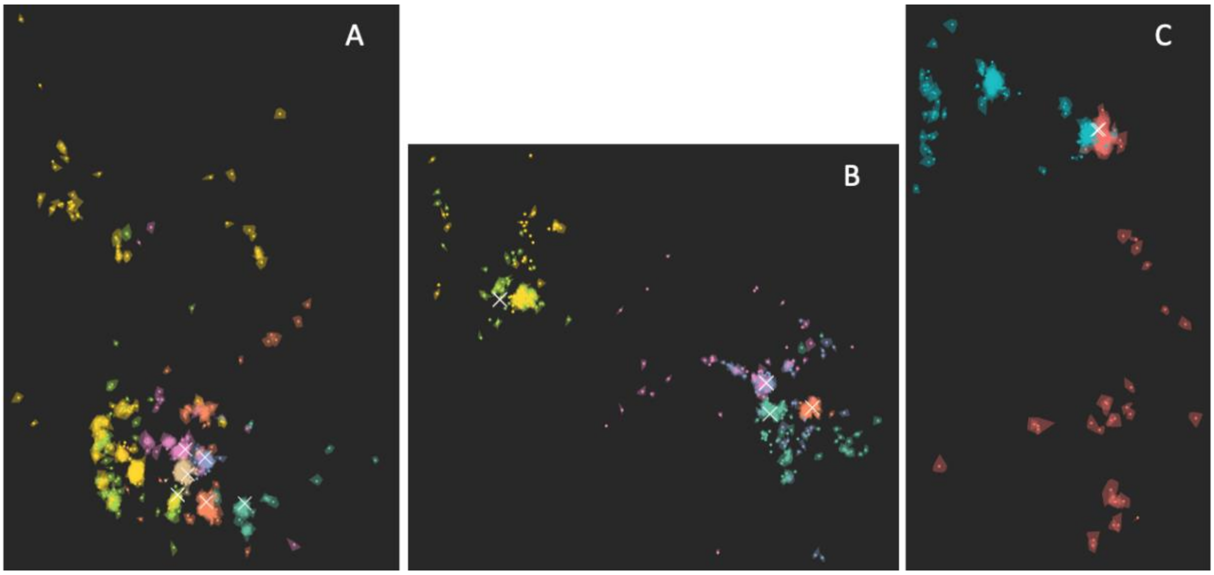

Figure15. Example cat cluster centrioles and buffer zone from three selected roads plotted. The cat homes are represented by a white ×. A) the movement patterns of seven cats from six homes, the green and yellow cats sharing a home. B) the movement pattern of six cats from four homes, the purple and blue cat sharing a home and the green and yellow one sharing a home. C) the movement pattern of two neighbouring cats (the × marks are on top of one another).

Discussion

The participants

To my knowledge, this is the first study to attempt to map an entire cat population within a neighbourhood, and managed to document the activities for at least 73% of the cat population (Bischof et al., 2022). Out of the 100 cats participating in the study, a total of 92 cats delivered enough data to be included in analyses. This is a higher completion rate than in previous studies conducted through "Kattesporet", where 72 of 110 cats completed (Sarfi, 2020). The reasons for the high completion rate can be that the instructions given to the citizen scientists had been simplified and were easier to understand. Cat owners in Ås may also have shown higher motivation for participating than other households scattered across the eastern counties of Norway in previous studies, as Ås is known for the university and several people with a relation to NMBU lived in the study area. In addition, the participants lived in the same neighbourhoods and participating might have created a feeling of togetherness, and not participating could make them feel left out.

Spatio-temporal movement

Cats spent most of their time within 250 m from their home. This is consistent with earlier findings (Barratt, 1997, López-Jara et al., 2021, Sarfi, 2020, Kays et al., 2020) and supports my first prediction that cats would stay close to home. The cat homes in my study area were in neighbourhoods, meaning that cats spent most of their time in urban habitats. Most cats (n=35) spent close to 100% of their time in urban habitats, and the mean proportion of time in urban habitat was 91%. This high use of gardens and other urban habitats have been documented in other studies as well (Thomas et al., 2014, Barratt, 1997, Hanmer et al., 2017, López-Jara et al., 2021). The cats that travelled farthest spent less time in urban habitats, as they likely went outside the neighbourhoods and into surrounding forests and other habitats.

There were only four cats that had a distance to home above 1000 m, and they were all neutered males. There was a significant effect of gender on how far away a cat travelled. However, not all males travelled long distances and there are in fact variable results regarding gender and home range size in previous research, with some studies finding a significant effect (Hall et al., 2016, Bachmann, 2020, Kays et al., 2020) and others not (Hanmer et al., 2017, Kisen, 2021). Other factors, such as the cat´s age, could also have affected travelled distance.

Younger cats spent more time outside and older cats spent more time in urban habitat. This means that younger cats travel farther and for longer periods than older cats. However, when tested for significance there was no relationship between age and how far a cat travelled. Yet, other factors that remain untested also may affect travel distances. For example, cats in suburban areas travel farther than urban cats (Hall et al., 2016, Hanmer et al., 2017, Kays et al., 2020, Kisen, 2021). However, the cats in my study were all from the same type of urban neighbourhood. Cat personality (Coughlin and van Heezik, 2015, Kisen, 2021) and access to food (Thomas et al., 2014) may also affect cat roaming. It is therefore difficult to precisely explain why these males travelled so far compared to the rest of the population.

Spatio-temporal habitat use

I found that cats spent between 80-90% of their time in preferred places, which supports my second prediction that cats would spend most of their time in preferred places. This is slightly higher than in a previous study conducted similarly to mine, where cats were found to spend 63% of their outdoor time in one place (Wu, 2020). However, this study did not look at an entire cat population, but several cats from different types of urban and rural locations. While it did not find a significant difference between residential types, the results can have been affected by the difference in the resident cat populations. This underlines the importance of looking at a single cat population with most of the cats included to gain accurate information. Furthermore, as no other studies have done this, it is difficult to know if the examined population in my study is an example of a typical or atypical cat population.

The sites of high visitation were located close to the cat´s home. Some cats had a very low average distance to their home, meaning that the cat had many sites around the house that it used frequently. Males had a significantly higher maximum and average distance between their home and a preferred site than females. This means that male cats travelled further to reach their preferred sites, which fits with findings that males have larger home ranges than females (Hall et al., 2016, Bachmann, 2020, Kays et al., 2020).

Home range studies give information on where the cats go. However, few studies have investigated how the cats use their home range. As cats have a loose home range that is patrolled (Feldman, 1994), looking at home range alone may not give correct information on how a cat uses an area. My data show that cats can travel far away from home to use sites for a prolonged time. However, cats that travel far to reach a preferred spot also spend less time in that site compared to sites closer to home. A previous study found that cats spent less time in forests if it was located far from their home (López-Jara et al., 2021). This means that distance between a cat's home and a site can affect how much time a cat spends there.

When cats become older, they move less around and have more preferred places that they spend time in. They spent less time walking between sites and that gives them a high average time in preferred places. The cats that had the highest proportion of time in a preferred place also travelled the shortest distance from home and spent more time in urban habitats, meaning that older cats spent their time close to home. In contrast, younger cats visited more places, spent less time in each of them, and had a lower proportion of time in preferred sites as they spent more time walking between places. Age has been documented to affect home range size, as older cats have smaller home ranges than younger cats (Sarfi, 2020, Kays et al., 2020, Hall et al., 2016, Kisen, 2021). This might create the assumption that older cats have a smaller impact on local wildlife, or that older cats use the outdoors less than younger cats. However, cats that spent a high proportion of time in a preferred spot also had a high duration of time in a preferred space, and so had a high average time outdoors. So even though old cats do not travel as much as younger cats, they still use sites outside and have the potential to affect wildlife.

Overlap between cats

Cat friendship affected how much they used the same places, partly supporting my third prediction that gender and kinship would affect how much different cats overlapped in their preferred places. Cats that came from the same house shared several places outside, even at a greater distance from their home. While it is unknown if these cats were related or not, that is probably irrelevant as unrelated cats can become friends and treat each other as family members when they live together (Alger and Alger, 1999, Crowell-Davis et al., 2004). The fact that related cats share a home range is already known (Barratt, 1997, Hanmer et al., 2017), so it is only logical that they would also share specific sites outside. While related cats can share places regardless of gender, unrelated cats do not necessarily do so.

Gender also affected whether cats shared places; male cats had more overlap and shared sites more than females shared sites. Whereas up to four male cats could share a site, only a maximum of three females shared sites. My results support previous findings that male cats travel farther than females (Hall et al., 2016, Bachmann, 2020, Kays et al., 2020). Male cats are bolder than females (Kisen, 2021), and that could explain why males travel more and have more opportunities to meet other cats than females have. Furthermore, a study on feral cats found that male cats that interacted with cats from other colonies had higher mating chances (Crowell-Davis et al., 2004). The cats I examined were domestic and neutered, and this means that the males should not be roaming after females and remain closer to food sources (Barratt, 1997). However, a meta-study found that desexing only affected males that were neutered as kittens before they had established a home range, and that neutering adult males did not change their home range size (Hall et al., 2016). Lastly, the fact that both males and females shared some sites means that there is likely more than cat kinship and friendship that decides if cats share places. In sum, these untested variables may explain my observed pattern.

The most popular sites, with the maximum of four cats sharing a site, were located where there were most houses. A higher housing density likely means a higher cat density (Lepczyk et al., 2004), and that could explain why the most popular sites were in places with a lot of houses. In addition, urban cats are more likely to meet other cats (Hall et al., 2016), and as cats do not travel far, the cats living on the same street in the middle of a neighbourhood probably have few options on where to go. Furthermore, cats also prefer spending time in gardens (Thomas et al., 2014, Barratt, 1997, Hanmer et al., 2017, López-Jara et al., 2021) and likely visit other cats´ gardens. A lack of food competition would assume less need for territories and can increase tolerance between the cats (Alger and Alger, 1999). Lastly, it is possible the cats share the site without even knowing it (Roshier and Carter, 2021). I was not able to test if the cats shared a site at the same time, so if the cats knew about each other is unknown.

While cats can share places, the most common was that only one cat used a site. This was particularly along the edges of the neighbourhoods where cats had more options on where to go. This means that as solitary hunters they tend to have little overlap in space use if possible (Barratt, 1997). The sharing of specific sites might be more out of tolerance and necessity rather than preference. These findings confirm my prediction that different factors would affect how cats share sites, with gender and kinship both having an effect.

How cat space use can affect wildlife

This assessment of cat spatio-temporal use of their surroundings reveals how a cat population utilises an urban area, and that most cats remain close to homes and in urban habitats. Although assessing hunting rates was beyond the scope of this study, the results provide information that can be used to understand how cats can impact wildlife. Even when cats had access to natural habitats they still preferred gardens (Hanmer et al., 2017). The time a cat spent at preferred sites decreased with increasing distance from their home. This means that wildlife in urban habitats have a higher risk of cat predation than wildlife in natural habitats (Kays et al., 2020, Lepczyk et al., 2004). These wildlife species consist of rodents (Barratt, 1997), ground dwelling birds and brush feeding birds (Lepczyk et al., 2004, Pavisse et al.,

2019) amphibians and invertebrates (Hernandez et al., 2018), and reptiles (Medina et al., 2011). While the most eager hunters show no preference for species type, prey with a weight beneath 100g is most common (Loyd et al., 2013).

Preferred sites mostly overlapped in areas where cats had limited choice of space, in the middle of the neighbourhoods. Potential prey species that use these sites have a higher chance of meeting a cat than species using sites at the edges of neighbourhoods. However, varying cat density does not affect the predation rate in urban habitats as they are generally high (Sims et al., 2008). Even when not hunting, the high number of cats can affect local wildlife species through creating a landscape of fear (Preisser et al., 2005, Loss and Marra, 2017). Cats can use sites important to local wildlife like around a bird feeder (Dunn and Tessaglia, 1994), and this can potentially affect the bird population by preventing birds from feeding and rearing their young.

It was not investigated what the cats were doing at their sites, but some educated guesses can be made. Studies on other felines such as cougar/mountain lion (*Puma concolor)* and bobcat (*Lynx rufus*) found that they created clusters at kill sites (Anderson Jr and Lindzey, 2003, Wilckens et al., 2016, Clark et al., 2014, Svoboda et al., 2013). As these larger felines are ambush predators like domestic cats, it is likely that cats also hunt in their sites which consequently creates a cluster of GPS fixes. Another possibility is that the cats use the sites as a shelter or resting place like feral cats (Roshier and Carter, 2021). While it is likely that cats use the sites for both hunting and resting, further studies are clearly needed to elucidate the activity of cats in these locations.

A future study could, for example, place a wildlife camera in identified places of high visitation to gain more knowledge of what cats do at these sites. As cat predation rate is difficult to calculate due to reliance on owners reporting hunting behaviour and cats eating their prey in the field (Lepczyk et al., 2004), placing a wildlife camera in cat hotspots can give a better understanding of cat predation. Alternatively, mounted cameras on the cats is also an option to examine cat predation (Loyd et al., 2013). However, it might be more expensive to outfit every cat in a population with both a GPS and a camera, than placing a wildlife camera at a popular site.

Cats are pets, and therefore management of them to reduce predation can be challenging. Few owners are in favour of cat management beyond neutering (McDonald et al., 2015). This is because some owners do not recognize that their pet can affect wildlife populations or do not think it is a problem (McDonald et al., 2015, Crowley et al., 2019, Lepczyk et al., 2004). Studies that include the cat owners, like this one, can increase knowledge and interest about the impacts cats have (Roetman et al., 2018). As my study demonstrates that cats do not travel far even when they have free access to the outdoors, it might encourage some owners to limit how a cat is allowed outdoors. Wildlife conservation, veterinary and animal welfare organizations all support having more restricted outdoor access for cats, and stronger legislation to prevent pet abandonment and restrict breeding licensing (Loss and Marra, 2017).

Conclusion

The results from this study reveal that cats have some places they spend more time in than others. These sites are located close to a cat´s home, as few cats travelled far from home. This also means that cats living in urban habitats with a high density of cats have limited space to roam, and therefore must share places. Up to four cats could share a specific site, but most common was that only one cat used a site. Male cats were more likely to share a site than females, and they also used more space. Cats from the same house shared sites when outside, and this was probably affected by kinship or friendship between those cats. Older cats did not travel far but used a lot of time in places around the house. As cats used gardens the most, it is wildlife living close to humans that are most at risk from cat predation (Kays et al., 2020, Lepczyk et al., 2004). My findings can encourage owners to limit their cat´s outdoor access because cats do not travel far anyway. However, management of cats is challenging due to cats being pets and regulations are unpopular (Crowley et al., 2019, Lepczyk et al., 2004).

Further studies should focus on tracking entire cat populations as much as possible. They should investigate the differences between entire populations of urban cats and rural cats. Furthermore, uncertainties from previous cat studies where findings are contradictory, such as if gender affects home range, should be re-examined by examining an entire population. My study showed that some males travelled much farther than the rest of the population, and similar males might have disproportionately affected the results in other studies.

Cat´s preferred places should also be investigated more. Cat home range alone does not necessarily give accurate information about cat space use. Some aspects that could be investigated include: looking at whether cats use their sites at the same time or different times, if time spent in a preferred place is affected by the presence/ absence of other cats, and activities at sites such as predation and resting. Furthermore, my findings should be tested against other populations of cats.

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Appendix A

The detailed survey asked participants the following questions:

Do you have a dog?

Cat´s age

Cat´s gender

Cat´s weight

Cat´s breed

Any health issues?

Is the cat sterilized?

Does the cat always have access to food or only at specific times?

Is the cat used to collars?

When is it most outside during the day?

How is the cat let out? Manually, unlimited cat door or a cat door that closes?

How often is the cat outside and for how long?

How long has the cat lived in the area?

How often does the cat bring home prey?

Does the cat use a litter box?

Appendix B

Histograms visualizing data (2 pages)

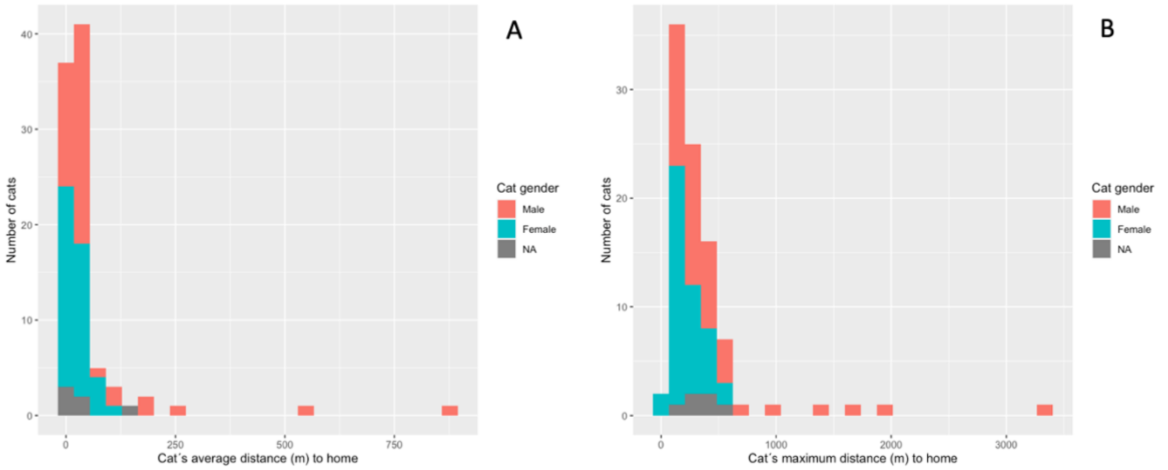

Figure B1. Histograms showing the number of cats, their gender, and their A) average distance to home (m), and B) maximum distance to home (m).

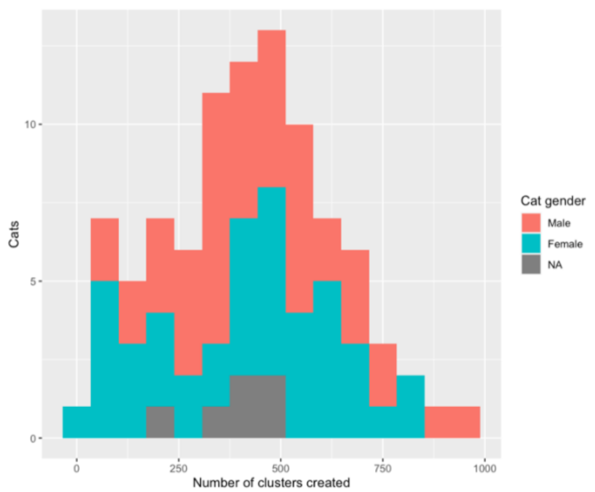

Figure B2. Histogram showing the number of clusters created by cats for each gender.

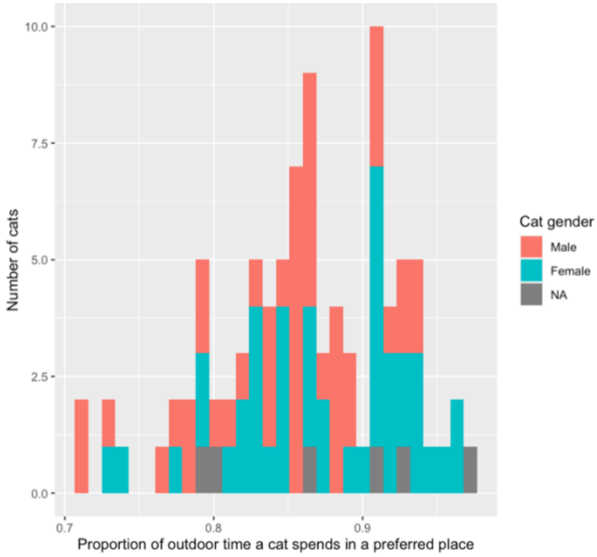

Figure B3. Histogram with proportion of outdoor time a cat spends in a preferred spot, number of cats and their gender.

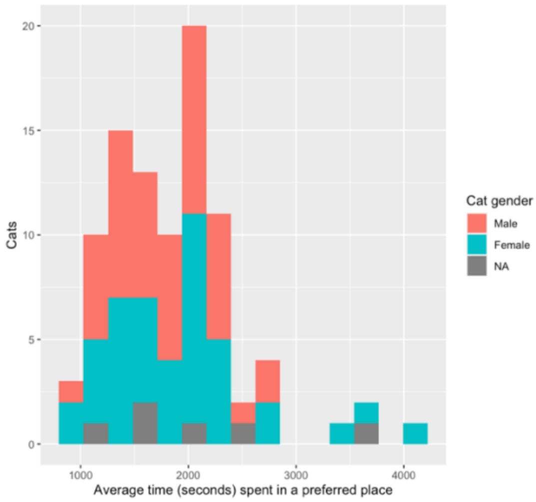

Figure B4. Histogram showing average time (seconds) a cat spent in a preferred place and number of cats, colour-coded by gender.

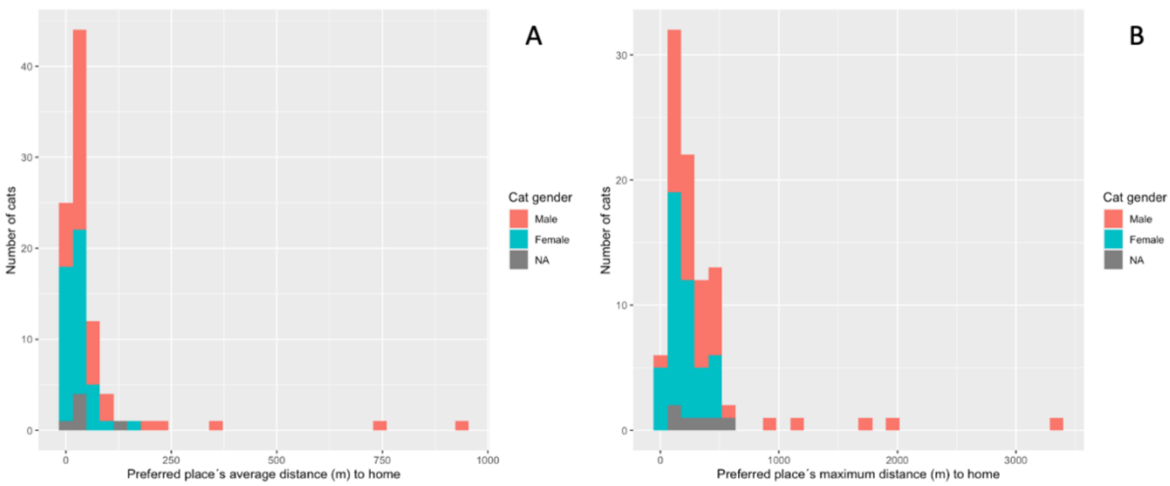

Figure B5. Histograms showing the number of cats, their gender, and their A) average distance (m) between home and a preferred place and B) maximum distance (m) between home and a preferred place.

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