Influence of garden structure and surrounding landscape on the presence of wildlife in Umeå

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Swedish University of Agricultural Sciences, SLU
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Abstract

Around the world cities are growing. Expansion and densification often take place at the expense of urban greenspace, the most common habitat for urban wildlife. Even though gardens take up a significant amount of the city's green space, there are no general guidelines on how to manage garden to support local wildlife. Increased knowledge about habitat selection of wildlife in gardens is therefore needed, to improve the management of these spaces to support local wildlife. In this study, I used a mixed method approach with a survey and camera trapping on 145 locations in Umeå, Northern Sweden. To improve our understanding on how wildlife uses gardens, I tested three hypotheses for six wildlife species using a generalized linear mixed model. I expected that gardens containing wildlife friendly features would have a higher wildlife visitation frequency, and my results showed a positive correlation for red fox. I also assumed that gardens with a more natural vegetation structure would have a higher wildlife visitation frequency, which I didn't find support for. I also expected that the wildlife visitation frequency would increase with natural habitat in the surrounding. My results showed the opposite, where the visits of red fox and magpies were less frequent if there was natural habitat existing in the surroundings.

Keywords: urban, habitat selection, urban wildlife, garden, citizen science, Vulpes vulpes, Pica pica, wildlife gardening, wildlife friendly features, vegetation structure, greenspace

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Abbreviations

GIS	Geographic information system
EPA	Swedish Environmental Protection Agency
IPBS	Intergovernmental science-policy platform on biodiversity and ecosystem services
PIR	Passive infrared
SLU	Swedish University of Agricultural Sciences
WRI	Wildlife resources index

1. Introduction

Around the world cities are growing rapidly. Today there are more people living in urban areas than in rural areas (UN DESA 2019). In Sweden 85% of the population lives in urban areas (SCB 2015). The process of urbanization has created many challenges in our cities, such as air pollution, soil pollution, water pollution, an increase of invasive species, and loss of local indigenous species (Tarsitano 2006). We are today globally losing local indigenous species biodiversity due to habitat loss and fragmentation (McKinney 2006). This in turn causes disruption of ecosystem services and can poses a threat to human well-being (Smith et al. 2005). According to the IPBES report Bongaarts, J. (2019), exploitation is one of the major causes for species extinction.

Expansion and densification are a natural way to adapt to a growing population. The growth of cities often comes at the expense of the urban 'greenspace'. Greenspaces are important for urban wildlife since they improve the connectivity and are enabling dispersal between different habitats within urban environments (Beninde et al. 2015). I define the term 'greenspace' based on Taylor & Hochuli (2017) suggestions as `less developed land in the urban environment that consists of vegetation covered by trees, bushes, grass and flowers including parks, gardens, roadsides, railway sides, golf courses, cemeteries, forest groves, nature reserves and green corridors`. Greenspaces have been found to be the most common habitat for wildlife in urban environments (Beninde et al. 2015). Since greenspaces often lack protection, these surfaces are often subject to new exploitation, even though it is known that exploitation is one of the major causes for species extinction (Bongaarts 2019). The ecological function of greenspaces in urban environments is highly influenced by the composition and structure of the vegetation, which are the most important factor determining habitat quality (Byrne 2007). How the vegetation structure of urban greenspaces is formed is highly dependent on how the greenspace is managed (Goddard et al. 2013; Kendal et al. 2012a).

Private gardens are an important element of the urban greenspace, since they collectively often represent the largest area of the urban greenspace in cities (van Heezik et al. 2012). A garden can be defined as a piece of land that consists of trees, grass, flowers and shrubs (van Heezik et al. 2012). Since the gardens' value to wildlife is significantly affected by management, many gardens do not contribute to the cities- and the global biodiversity as much as they have the potential to do.
Certain features have been reported to improve biodiversity in gardens for example: hedges, shrubs, large especially old trees, dead wood, fruit trees, berry bushes, herbal- and grassland, ponds, wetlands, flower beds, meadows and the non-use of pesticides (Johansson et al. 2002; Petersen et al. 2014). Implementing these wildlife friendly features could potentially support biodiversity.

Even though gardens are recognized as important habitats for urban wildlife, there are not many studies on what effect the garden characteristics and the surrounding landscape have on the habitat selection of urban wildlife. One study done showed that deciduous trees, plants with fruits or berries were positively associated with native bird species richness (Belaire et al. 2014). Another recently published study on wildlife friendly features, birds and mammals showed an abundance of mammals in gardens with water sources and supplementary food resources, but also a positive association between the numbers of predators and prey relative abundance in gardens (Hansen et al. 2020). Most other studies on gardens and wildlife have been done on the human attitudes towards gardening for wildlife (e.g., Goddard et al. 2013), rather than on what value different type of gardens have for wildlife. More broadly research on urban wildlife show a shared opinion on how wildlife has adapted to cities, there are both studies that indicate that urban ecosystem are balanced, since mammals have adapted to suburban areas (Parsons et al. 2018) and studies that have shown that other taxa have been heavily impacted by urbanization (McKinney 2006). In the UK, ecologists have examined the extent of wildlife friendly gardening and the study estimates that about 12.6 million households feed birds (Gaston et al. 2007). Since the existing research on urban wildlife has been done in individual cities and on individual species, large-scale studies from different cities are still needed, to better understand the urban wildlife and their ecology.

An increased knowledge about habitat selection of urban wildlife among different types of gardens could potentially give indications on how to better manage gardens and greenspaces to sustain urban populations and build more resilience in urban ecosystems. So, with this in mind the aim of this study is to gain a deeper understanding of how wildlife uses gardens in northern Sweden, and to investigate what influence the vegetation structure, amount of wildlife friendly features and the surrounding landscape has on the visitation frequency of wildlife. Here, I test the following three hypotheses: 1) Gardens that contain more wildlife friendly features will have a higher wildlife visitation frequency, 2) Gardens with a more natural vegetation structure will have a higher wildlife visitation frequency, and 3) Wildlife visitation frequency will increase with the amount of natural habitat in a 1km^2 radius around the garden.

2. Material and method

In this study, I have focused on factors that potentially increase or decrease the visitation frequency of wildlife in gardens. I have used a mixed method approach. Including quantitative research with camera-trapping (Parsons et al. 2018), GIS analysis in QGIS (version 3.10, QGIS Development Team 2009), and statistical testing using RStudio (version 1.3.1093 PBC, 2020). I also included qualitative research with a survey to get a better understanding about each garden's characteristics (Rodriguez & Moorman 2016; Nassauer et al. 2009).

2.1. The study area

The study was conducted in gardens located in Umeå municipality (63°49′ N 20°16′), in the county of Västerbotten in northern Sweden (figure 1). Umeå is Sweden's 13th largest city with a population of 128,901 inhabitants in 2019 (Umeå municipality 2020) which makes it the largest urban area in the municipality, followed by Holmsund, Hörnefors and Sävar. Umeå have grown with an average of 1,850 people per year the last years (Umeå municipality 2020). The vegetation consists of boreal forest dominated by European spruce, (*Picea abies*), Scots pine (*Pinus sylvestris*) and the deciduous trees, Birch (*Betula pendula*, *Betula pubescens*) and European aspen (*Populus tremula*).

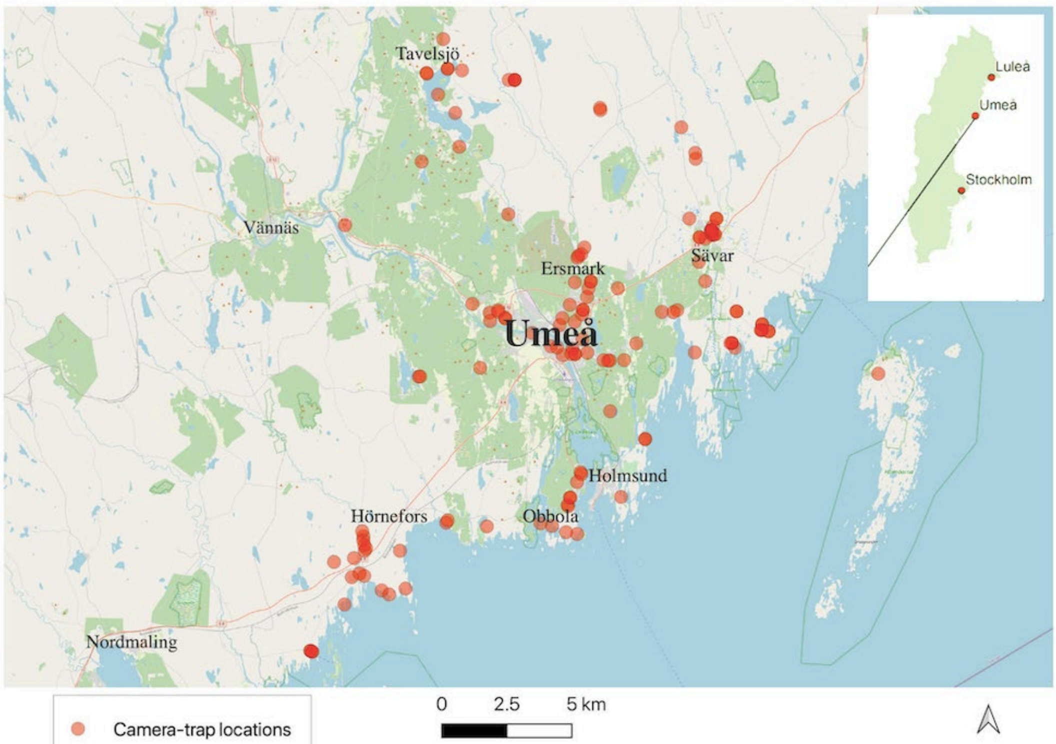

Figure 1. The red/orange dots are the 145 camera trap locations in the 'Meet your wild neighbours project'. Umeå.'Sorce: Base map and data from OpenStreetMap Foundation ©OpenStreetMap, and camera locations from ©Swedish University of Agricultural Sciences 2019-2020.

2.2. Camera trapping

I used the camera trapping from the citizen science project “Meet Your Wild Neighbours” to get information about wildlife visitation frequencies for different locations in Umeå municipality. The purpose of the “Meet your wild neighbours” project was to learn more about the wild animals in Umeå, and about the attitudes towards these animals. With the help of volunteers, we collected sampled in total 145 private gardens in Umeå (figure 1.). The camera sampling started in mid of September 2019 and continued until the beginning of November 2020 and each camera was sampling for one month. The volunteer used a “Reconyx Hyperfire HC500” camera with a PIR trigger, that they borrowed from SLU. The sensor was set on the highest sensitivity and shot tree images on “rapidfire” when the sensor was triggered, without any delay. The camera was also set to take a time lapse at noon and midnight, to control that the camera was working properly. The participants were asked to place the camera 40 cm above ground, in their own private domestic garden or on their private land. They were also told to not aim the cameras on public land, composts, bird-feeders or vegetable gardens, since that would potentially affect the visitation frequency. I measured visitation frequency as the number of observed wildlife corrected for the number of days the camera was active. Wildlife visitations were seen as independent events when there was more than 15 minutes between camera triggers (Parsons et al. 2018). I performed all classifications in the web-based open source application ‘Trapper’ (Bubnicki et al. 2016).

2.3. Survey

To understand what effect the numbers of wildlife friendly features and the amount of natural vegetation structure within the garden has on the visitation frequency of wildlife. The survey was sent out by email to the volunteers in the ‘Meet your wild neighbours project’ and was active for 31 days, to maximize the response rate three reminders were sent out at a seven-day interval to all the volunteers who had not responded. To produce the survey, I used the market research company Netigate and their online survey procurement service with the designed template’ ‘Netigate Galaxy’. The survey was funded by the research project ‘Meet your wild neighbours’. The survey included 18 questions (table. S 5.) and (table. S 6.) about garden characteristics, management regime and on how the volunteers interact with wildlife in their gardens (Goddard et al. 2013). The questions on management regimes were on how much percentage of their lawn was regularly mown and if they use pesticides or not. On the questions of garden characteristics, I included questions on which wildlife friendly features the gardens consist of, for example if they had nest boxes for birds, ponds, dead trees, trees higher than 2m, old trees, or hollow trees (Petersen et al. (2014), Johansson et al. (2002)). By doing this, I could get a wildlife resources index (WRI) that measures the number of wildlife-friendly features within the gardens (Goddard et al. 2013). I asked the volunteers to estimate the percentage of what their gardens consist of; built-up area, trees, shrubs, lawn, uncut lawn, and wild part with native natural vegetation. I also asked the volunteers to classify their gardens based on how natural the vegetation structure was, based on the four illustrations in (figure 2.) (Rodriguez & Moorman 2016; Nassauer et al. 2009).

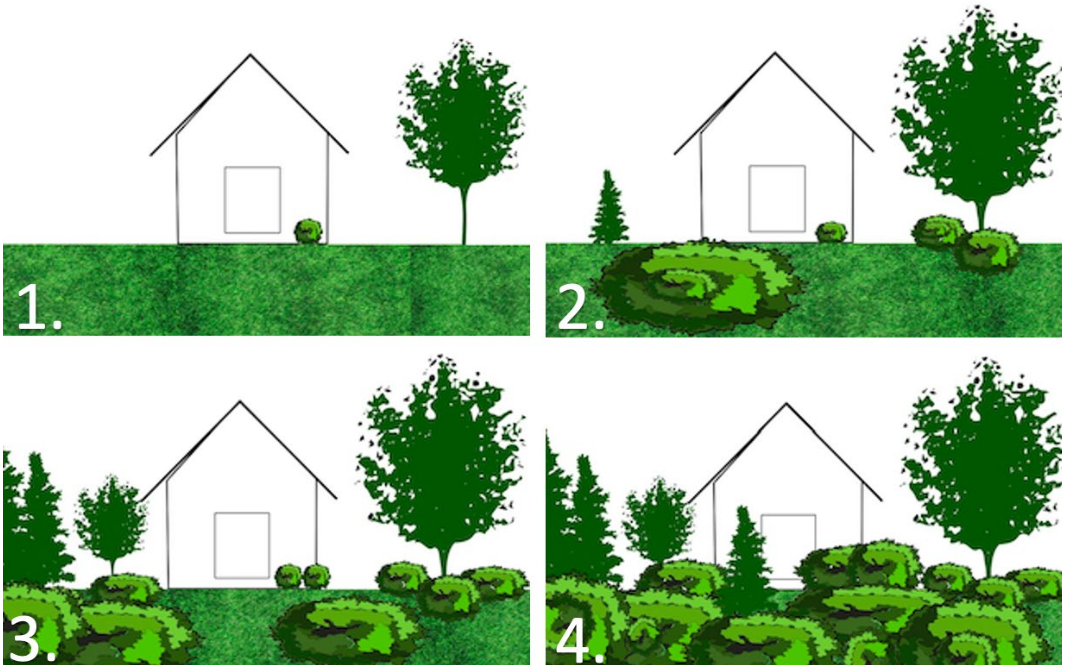

Figure 2 Illustration used to get information about the naturalness of each garden. Pictures represent a garden with 0-25% natural vegetation structure (1.), 26-50% natural vegetation structure (2.), 51-75% natural vegetation structure (3.), and 76-100% natural vegetation structure (4.) based on examples used by Rodriguez & Moorman (2016) and Nassauer et al. (2009). Illustrations by: Amanda Andersson, Sep 2020.

The questions on how the volunteers interact with wildlife in their gardens was for example; if they are doing supplemental feeding and how often, if they have free running animals, and about how much time they usually spent in their gardens during the growing season.

In total, 110 surveys were sent out. Since I didn't get answers from all volunteers, I classified the vegetation structures for the remaining gardens from camera trap images and satellite maps by estimating the percentage of canopy cover seen from the satellite images. Since some houses were under construction when the satellite images were taken, I could not classify these gardens in a sufficient way, so I had to exclude them from the analysis.

2.4. GIS-Analysis

After the data collection, a GIS analysis was performed. To answer the hypothesis if wildlife visitation frequency increases with the amount of natural habitat in a 1km^2 radius around the garden. I used the “generalized national land-cover map” from the Swedish EPA (www.naturvardsverket.se). I classified the data on the basis that clear-cuts (temporarily not forest), exploited land and water are "non-natural vegetation" and gave them the value 0. For forest, open natural areas and agricultural areas, I classified them as “natural vegetation” and gave them the value

1. I decided to count agricultural areas to the “natural vegetation” category since they appeal more as “natural vegetation” than “non-natural vegetation” to wildlife. I then calculated the proportion of natural vegetation in a 1km^2 buffer around each camera trap location.

2.5. Statistical analysis

To test my hypotheses, I applied a generalized linear mixed model (GLMM), with a Poisson distribution and a log-link function (log10) within the *lme4* package (Bates et al. 2015). In consideration that not all cameras were up to sampling the exact same number of days, I corrected for differences in camera trapping effort and added the (log10) of the number of camera trapping days as an offset to the model. I also corrected that some cameras took multiple measurements at the same location and added a random intercept per location. Since the ‘Meet your wild neighbours project’ started and was marketed in the autumn of 2019, more cameras were up sampling at the beginning of the project. Since I expected seasons to have an impact on how wildlife use gardens over the year, I corrected the differences between the seasons by grouping them into the four meteorological seasons: November 1 to April 30 (winter), May 1 to June 30 (spring), July 1 to August 31 (summer) and September 1 to October 31 (autumn). To test for the differences among seasons, I used a Tukey post-hoc test (Tukey). I tested models for individual species with a minimum of 45 observations from a minimum of 15 different locations to avoid issues of zero-inflation or model convergence. For species with sufficient data, I ran all the models separate per species and for each of the three covariates of interest for the three hypotheses. So, a model including the number of wildlife friendly features from (n = 111) locations for the first hypothesis. Then a model including the classification of natural vegetation structure from (n = 111) locations for the second hypothesis and last a model for the third hypothesis including the amount of natural habitat in a 1km^2 radius around (n = 118) locations. All models included season as a covariate to correct for potential differences in visitation frequency among seasons.

3. Results

After 13 months of camera trapping from 145 locations, 46,309 photos on animals were taken of 46 different species of birds and mammals (table. S1). The volunteers were asked to have the cameras up for sampling one month. Yet, not all cameras were active for one month with the shortest being up for 17 days and the longest for 78 days (due to the corona pandemic). This resulted in a mean sampling effort of 32 days. The wild species with sufficient data was Eurasian magpie (*Pica pica*) with 625 counts, roe deer (*Capreolus capreolus*) with 468, great tit (*Parus major*) with 116, mountain hare (*Lepus timidus*) with 96 counts, red fox (*Vulpes vulpes*) with 58 counts, and fieldfare (*Turdus pilaris*) with 52 counts, respectively (table. S 1). When running the model on great tit, I had convergence problems, so I had to remove the model of seasons for great tit.

3.1. Survey

For the survey, 71 surveys were completed resulting in a response rate of 66%. The questions from the survey on management regimes showed that none of the volunteers used pesticides in their gardens (table. S 2.) and that all had wildlife friendly features (table. S 3.). Moreover, 57% of the volunteers mowed 76-100% of their lawn regularly and 58% spent more than 5 hours/week in their garden during the growing season (table. S 2.). For garden characteristics, the results showed that 12 gardens had vegetation structure (1.), 25 vegetation structure (2.), 27 vegetation structure (3.) and 9 vegetation structure (4.) (figure 3.). From the questions on interactions with wildlife the results showed that 54% of the volunteers feed birds, and that 20% had a fence around their garden (table. S 2.).

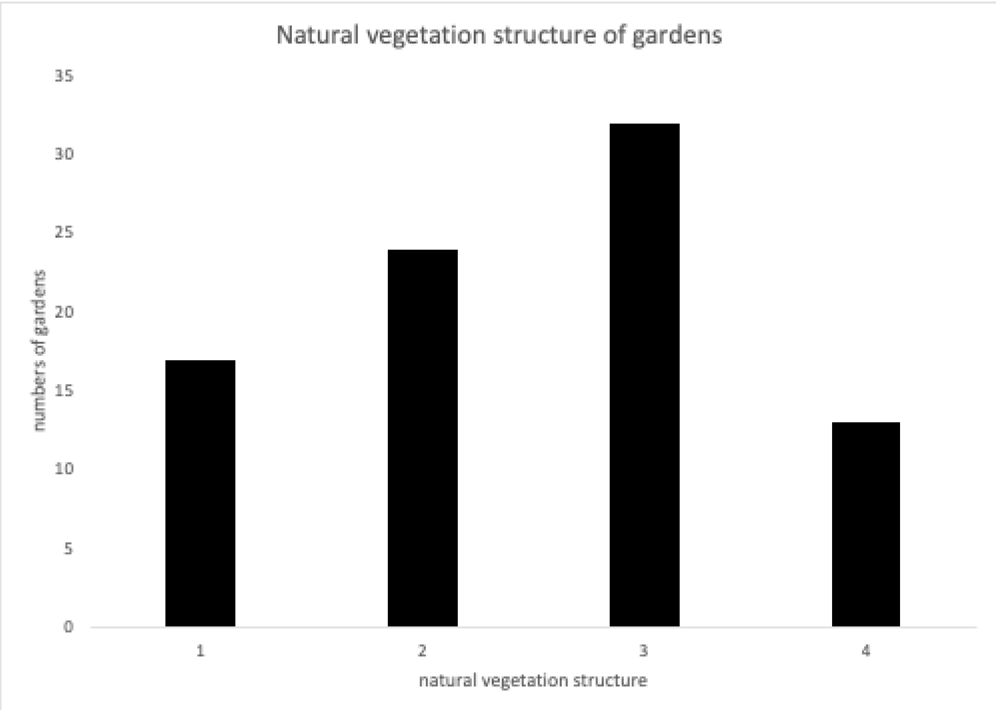

Figure 3. The number of gardens per type of vegetation structure based on the survey, 0-25% natural vegetation structure (1.), 26-50% natural vegetation structure (2.), 51-75% natural vegetation structure (3.), and 76-100% natural vegetation structure (4.).

The majority of gardens had a relatively high percentage of a natural vegetation structure (51-75%), while the most natural gardens (76-100%) had the lowest representation (figure 3.).

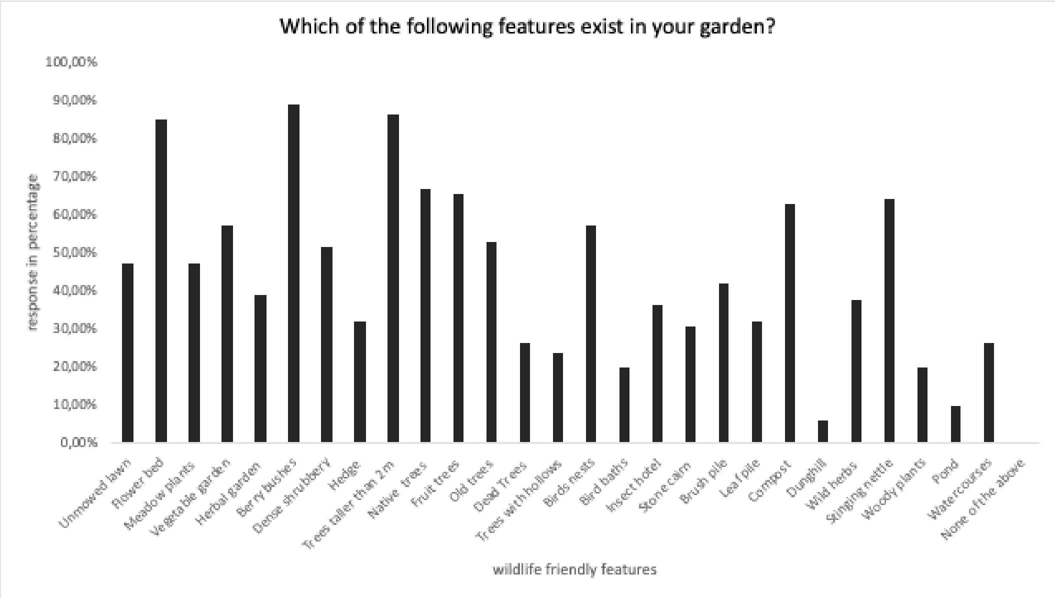

Figure 4. The percent of wildlife-friendly features in the gardens based on the survey.

The result from the survey showed that all gardens contained wildlife friendly features (figure 4.). The most common features were, trees taller than 2m, berry bushes and flower beds which more than 80% of the volunteers had in their gardens. In 60-80% of the gardens, native trees, fruit trees, compost and stinging nettles could be found. In 40-60% of the gardens, the volunteers had old trees, nest boxes for birds, unmown lawn, meadow plants, vegetable garden, dense shrubbery, and bush pile in their gardens. In 40-30% of the gardens, there was a leaf pile, hedge, wild herbs, herbal garden, insect hotel, and stone cairn. 30-19% of the gardens had woody plants, dead trees, trees with hollows, bird baths or watercourses could be found. The least common features in the gardens were pond that 9% of the volunteers had, and a dunghill that only 5% had.

3.2. Wildlife friendly features

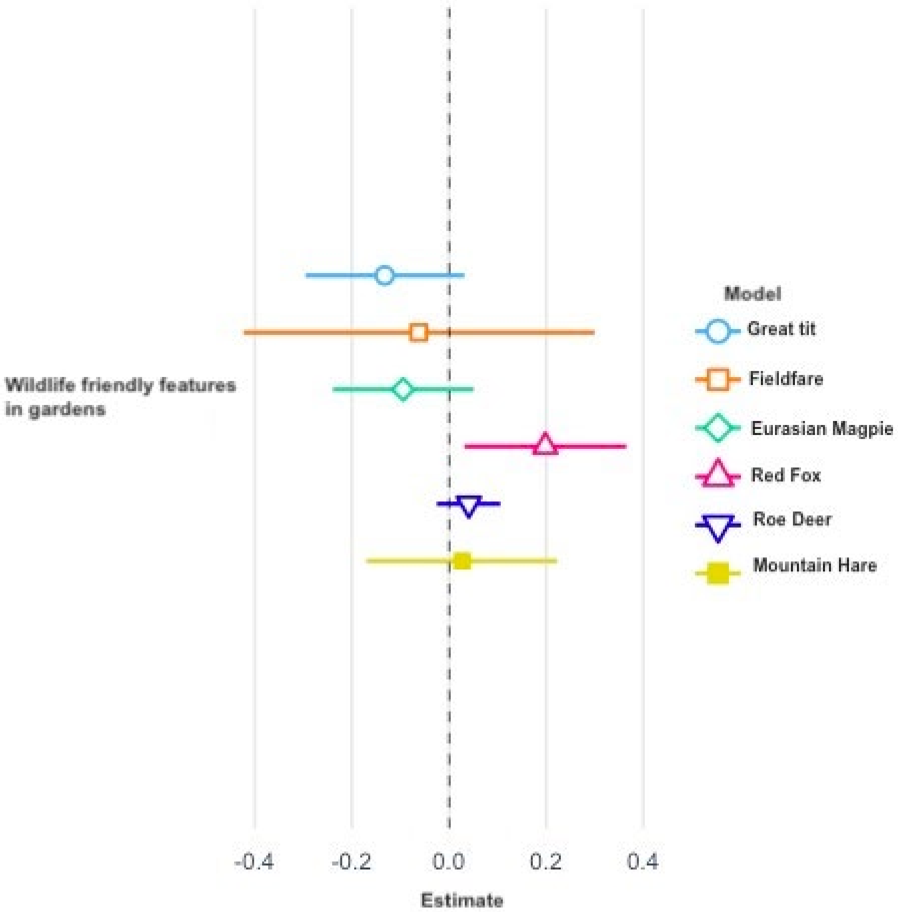

Figure 5. Coefficient plot of hypothesis 1.) wildlife visitation frequency increases with numbers of wildlife friendly features. species great tit, fieldfare, Eurasian magpie, red fox, roe deer, mountain hare, estimates show the regression coefficient and it's 95% confidence interval from a generalized linear mixed model (see methods for further details).

I did only find a correlation between the number of wildlife friendly features and the visitation frequency of wildlife for red fox (table S 4, figure 5.). The visitation frequency of red foxes increased with the number of wildlife friendly features (, beta = 0.17, p = 0.03; table S 4.).

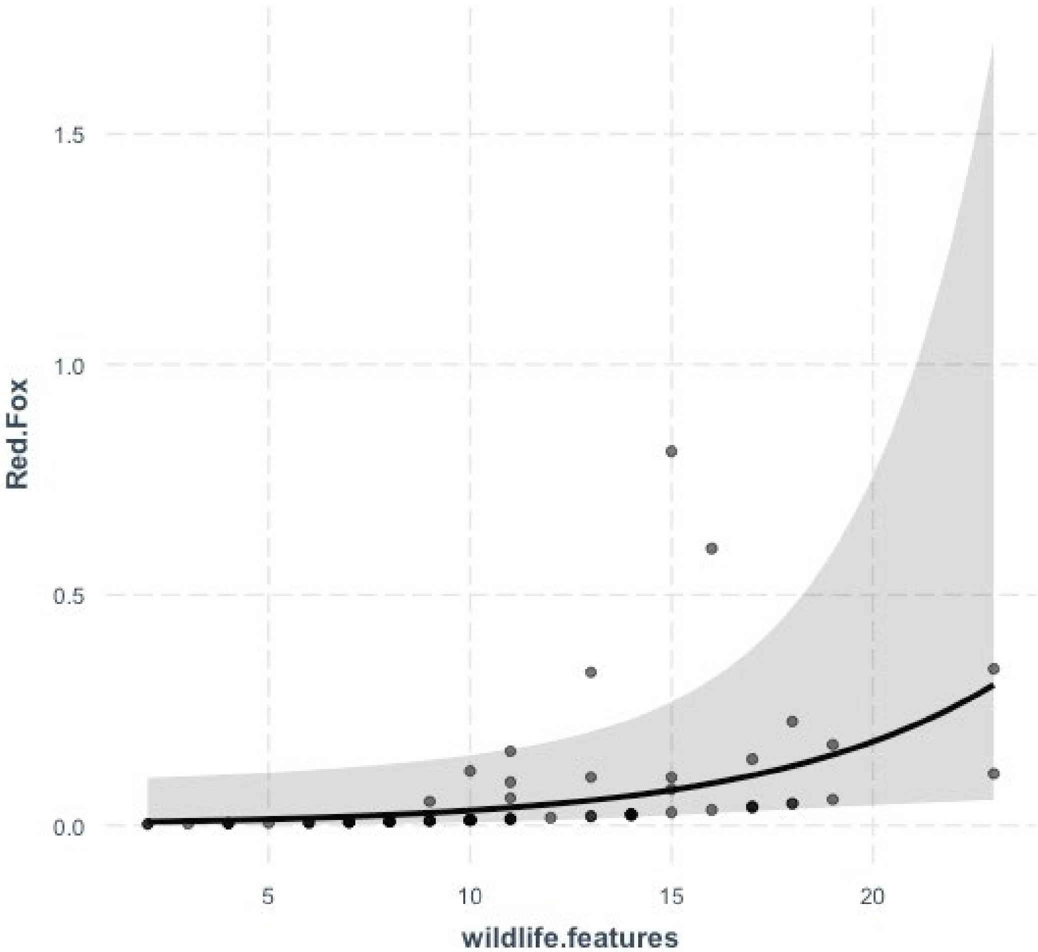

Figure 6. Partial residual plot of the estimates of visitation frequency by red fox and the number of wildlife features in gardens based on a generalized linear mixed model (see methods for more details).

I found a positive correlation between the visitation frequency for red fox and the numbers of wildlife friendly features in gardens (figure 6.).

3.3. Natural vegetation structure

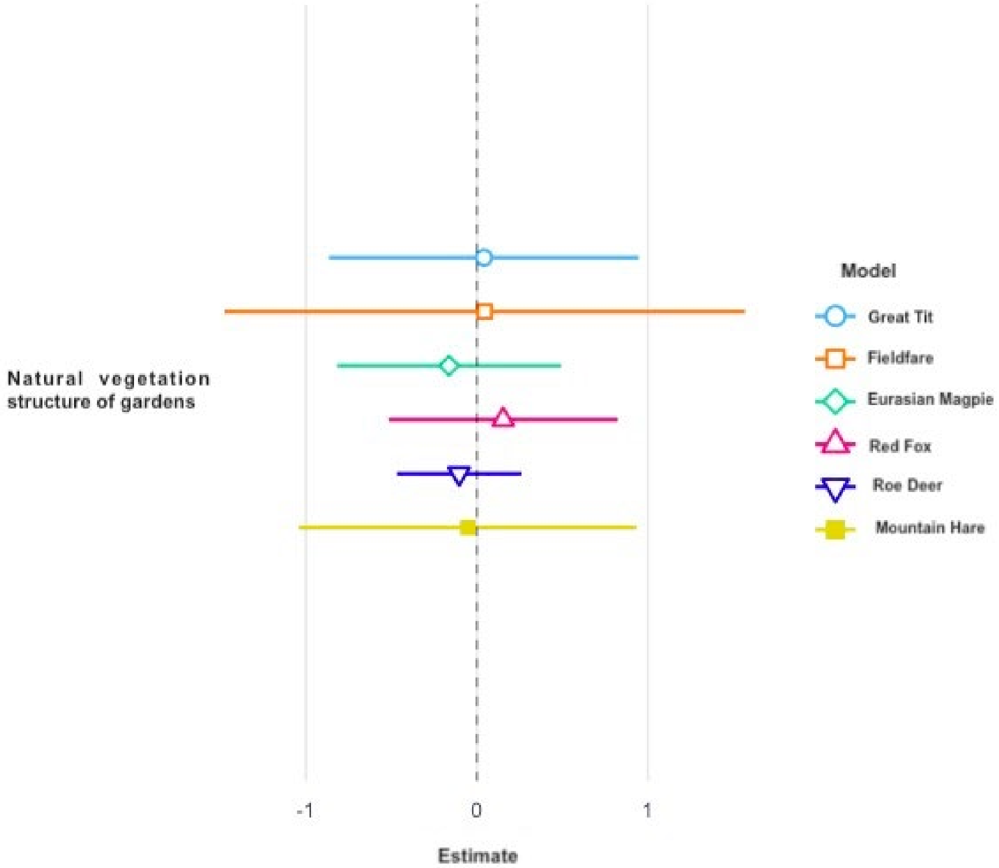

Figure 7. Coefficient plot of hypothesis 2.) wildlife visitation frequency increases with natural vegetation structure of garden, visitation frequency. Species great tit, fieldfare, Eurasian magpie, red fox, roe deer, mountain hare, estimates show the regression coefficient and it's 95% confidence interval from a generalized linear mixed model (see methods for further details).

The results showed that none of the species have a correlation between visitation frequency and the natural vegetation structure of a garden (table S 5, figure 7.).

3.4. Natural habitat in surroundings a 1km^2 radius around the garden

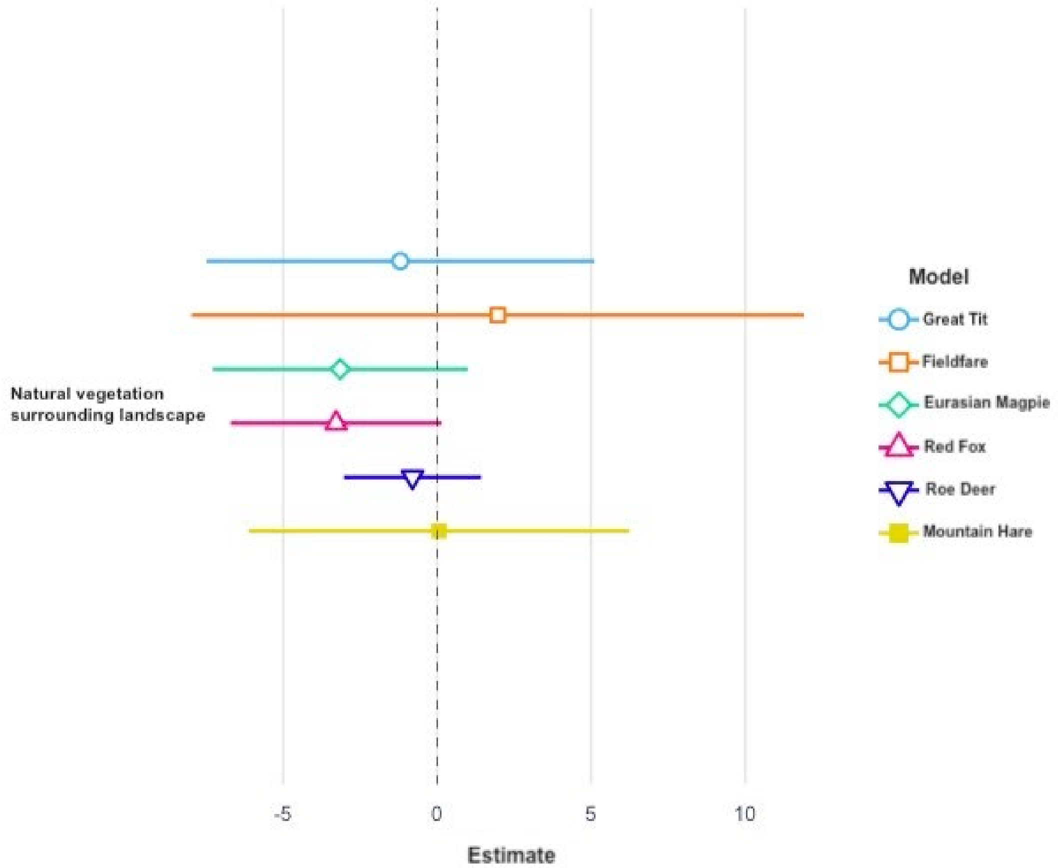

Figure 8. Coefficient plot hypothesis 3.) wildlife visitation frequency increase with natural habitat in a 1km2 radius around the garden, for species great tit, fieldfare, Eurasian magpie, red fox, roe deer and mountain hare, estimates show the regression coefficient and it's 95% confidence interval from a generalized linear mixed model (see methods for further details).

Except for magpie and red fox, none of the species showed a correlation between visitation frequency and the proportion of natural habitat in the surroundings of the camera location (table S 6, figure 8.). Magpie visitation frequency had a tendency to decrease with the proportion of natural vegetation, beta = -3.5 and p = 0.01 table S 6, figure 8.). Similarly, red fox visitation frequency decreased with the proportion of natural vegetation (beta = -4.0, p = 0.03; table S 6, figure 8.).

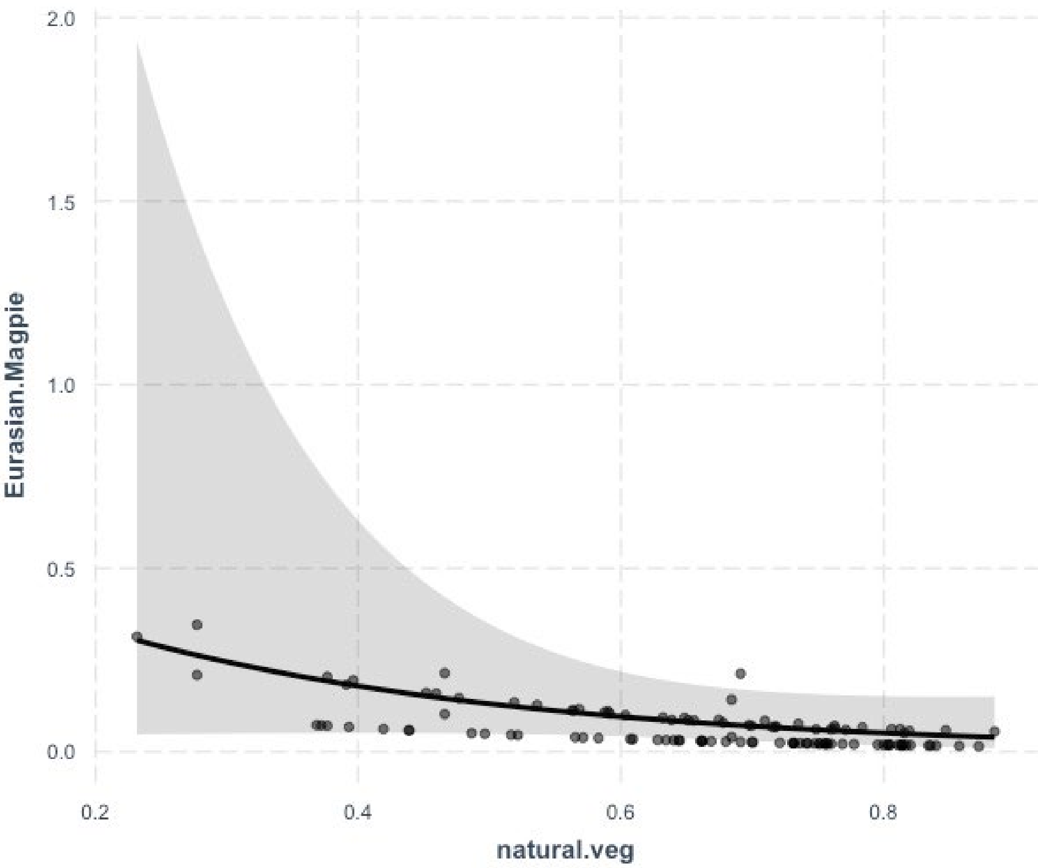

Figure 9. Partial residual plot of the estimates of visitation frequency by Eurasian Magpie as independent variable. Natural.veg as the dependent variable. The values in 'natural.veg' represent the average amount of natural vegetation in the surrounding landscape (1km2 buffer) around the camera locations, value 0 is the average of "non-natural vegetation" and value 1 is the average of "natural vegetation" based on a generalized linear mixed model (see methods for more details).

My results suggest a tendency to decrease in visitation frequency of Eurasian magpie with the amount of natural habitat in a 1km^2 radius around the gardens (figure 9.).

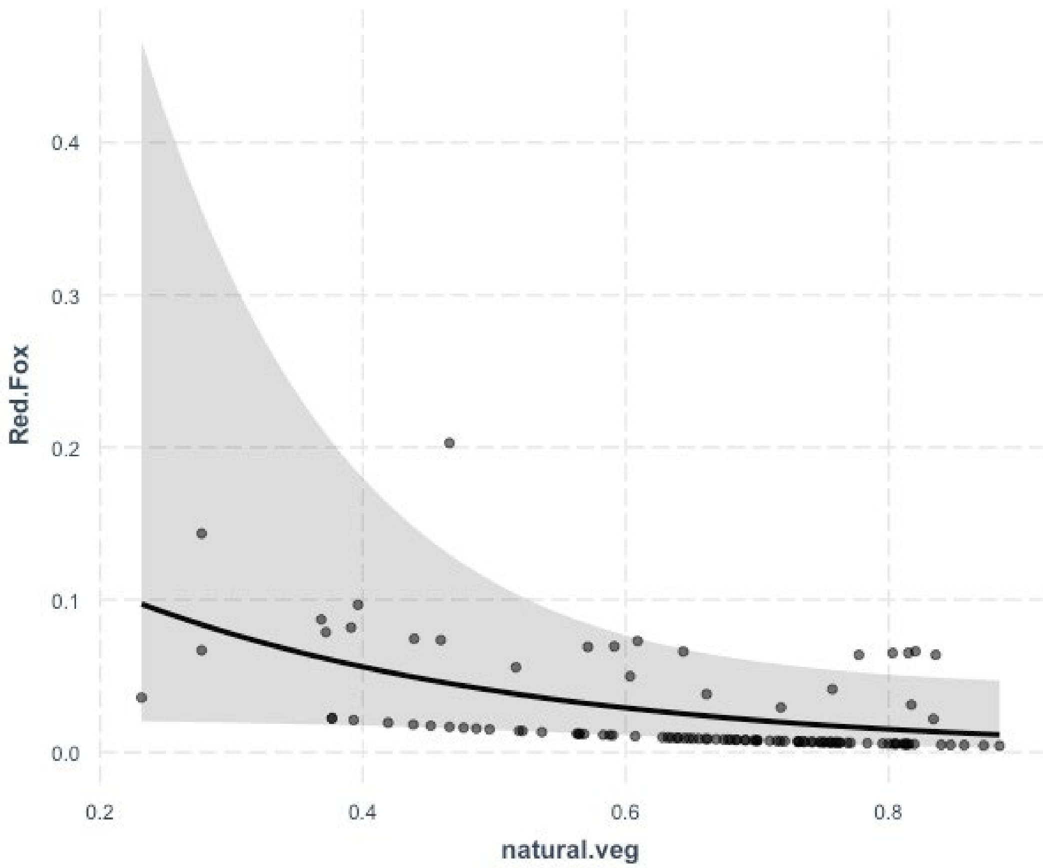

Figure 10. Partial residual plot of the estimates of visitation frequency by red fox as independent variable. Natural.veg as the dependent variable. The values in 'natural.veg' represent the average amount of natural vegetation in the surrounding landscape (1km2 buffer) around the camera locations, value 0 is the average of "non-natural vegetation" and value 1 is the average of "natural vegetation" based on a generalized linear mixed model (see methods for more details).

Visitation frequency of red fox decreased with the amount of natural habitat in a $1km^2$ radius around the gardens (figure 10.).

4. Discussion

Increased knowledge about habitat selection of urban wildlife can be used as a tool to manage greenspace to sustain urban wildlife populations and build more resilience in urban ecosystems. In this study, I have focused on the factors stated to increase the visitation frequency of wildlife in gardens. I have through qualitative- and quantitative data collection of citizen scientist volunteers been able to show that the visitation frequency of red fox was positively correlated with the amount of wildlife friendly features in gardens. I couldn't find any support for that gardens with a more natural vegetation structure would have a higher wildlife visitation frequency. In contrast, my results showed that the visitation frequency of magpies and red fox in gardens correlated negatively with the amount of natural habitat in a 1km2 radius around the garden. When testing my hypotheses, I only find pattern for red fox and magpie, which both are generalists and omnivorous species and not for any of the other studied species with more specialist characteristics.

This is one of the first studies on the subject in Europe. Most previous studies on gardens and wildlife have been done on the human aspect and attitudes towards gardens and wildlife (for example Goddard et al. 2013; Gaston et al. 2007; Rodriguez et al. 2016). The results of my study are similar to what has been previously observed before on attitudes, with a high participation in bird feeding (54%), which indicate a positive attitude towards having wildlife in gardens. Since few studies has been conducted on what value different types of gardens have for wildlife, I lack studies to compare my results too. I therefore encourage future studies on the subject. In this study, I have focused on the visitation frequency and habitat selection of urban wildlife in gardens, not the species richness. I will not discuss the human attitude or social consequences of wildlife in urban environments, since previous studies on the subject have covered this (e.g., Goddard et al. 2013; Gaston et al. 2007; Rodriguez et al. 2016).

For the hypothesis "gardens that contain more wildlife friendly features will have a higher wildlife visitation frequency than gardens that lack the abundance of such features", one previous study showed a positive correlation for native bird species (Belaire et al. 2014). In my study, I couldn't find a pattern for birds, which might be explained by the placement of the cameras (40cm above ground) that makes it harder to detect tree living birds. My results did show a positive correlation for red fox, which means that a high number of wildlife friendly features attracts red foxes. So, my hypothesis can be confirmed for red fox, but not for the other studied species. An explanation for this pattern could be that foxes are an opportunistic generalist species better adapted to urban environments, compared with the other studied species that had more specialist characteristics. Since generalist species are using a broader niche, they are more suited to adapt to the changing conditions in urban environments. Foxes are known to use a broad niche and to live in varied habitats, for example, in forests, grasslands and deserts. Their ability to adapt to changing conditions and different habitats is in their favour as well in urban habitats. Previous studies on urban foxes have shown that foxes are commonly associated with private gardens (Walter et al. 2018), where they utilize on anthropogenic food resources such as garbage and pet food. In natural environments, they feed on mainly rodents, birds and other small game species, but can also eat fruit, vegetables, insects, fish and reptiles. A study on urban red foxes in Switzerland showed that over half of their stomach content was of anthropogenic food resources (Contesse et al. 2002). Foxes success in urban environments is believed to be due to their opportunistic approach to food, safety from interspecific competition, and the safety of not being hunted (Walter et al. 2018). Studies by Rodewald & Gehrt (2014) on urban wildlife showed that species with a positive response to the urban environment often tend to be opportunistic, generalists and omnivorous with a high behavioural flexibility, which agrees to the behaviour of red fox, since red fox is stated to be one of the most adaptable carnivores (Bateman & Fleming 2012). My findings indicate that implementing wildlife friendly features in gardens is a tool for supporting urban foxes, and probably other urban wildlife species as well. Since an abundance of wildlife friendly features in gardens offers more resources, these gardens could be potential hotspots for prey species that attracts predators like foxes. Thus, this could be an explanation for the increase of foxes in gardens with wildlife friendly features. A previous study found that the number of predators using gardens had a positive association with prey relative abundance (Hansen et al. 2020).

Concerning vegetation structure and wildlife visitation frequency, previous studies have found a positive effect on birds with an increased proportion of understorey vegetation and large trees (Threlfall et al. 2016), but it has also been shown that omnivorous bird species have a negative response to vegetation cover (Lancaster and Rees, 1979). I didn't find a correlation between gardens with a more natural vegetation structure and the wildlife visitation frequency. The lack of patterns could be explained by the fact that the different studied species have specific factors that determine their visitation frequency, for example access to a specific type plant for food, or predator prey relationships. For example, studies investigated how wildlife in urban environments choose habitat after the absence of predators (Pettett et al. 2017). This is something I did not take into account, since I expected a general pattern with all studied species having higher visitation frequency in more natural gardens. However, the reason that I did not find a pattern might be due that I modelled the natural vegetation structure of as a linear response, while there might have been a nonlinear relationship. For future studies on how vegetation structure of gardens affects wildlife, I wouldn't suggest modelling it as a linear response, since I didn't find a linear relationship. It would also be interesting to perform a more detailed study on how specific types of urban vegetation effects specific species.

In contrast to the findings for my third hypothesis "wildlife visitation frequency increase with the amount of natural habitat in a 1km^2 radius around the gardens", previous studies showed that the number of fox sightings increased with an increasing area of private gardens, public parks and squares (Walter et al. 2018). My results showed the opposite, where visitation frequency of red fox and magpies decreased if there was a natural habitat within a 1km^2 radius around the gardens. When I compare my results to the study on fox sightings by Hansen et al. (2020), this study was done in a larger city, which does not have as good connectivity to the surrounding landscape into the urban areas as Umeå. An explanation to the difference could be the fact that Umeå has a good connectivity to the surrounding landscape and forest, for example by green corridors, the river and forest patches, which makes the urban greenspace in Umeå more available to foxes. In a city with less connectivity to the surrounding landscape, gardens will be more important for the urban wildlife, since the gardens could act as green oasis in otherwise homogeneous environments. Since Umeå has a relatively good connectivity to the surrounding landscape and many greenspaces. Thus, foxes can select between different greenspaces as habitats and will not be as dependent on gardens, as the foxes probably were in the study by (Hansen et al. 2020) in Vienna. My results indicate that foxes mainly used gardens with an abundance of wildlife friendly features that are situated in locations with little natural vegetation in the surroundings. This indicates that gardens are an important greenspace for foxes, where other vegetation is lacking. If a garden has a high proportion of natural vegetation in its surroundings and good connectivity to the surrounding landscape, for example, located in the forest, the garden will be less frequently visited by both magpies and red foxes. This indicates how important it is to protect areas with natural vegetation, in and around cities to sustain good connectivity to the surrounding landscape for urban wildlife. Earlier studies on the habitat selection of red foxes showed that they select habitat close to urban borders and avoid high-density housing (Duduś et al. 2014).

Magpies are strongly linked to human settlements and are so called hemerophile species (species that profit from the changes humans make in the environment) (Mullarney et al. 2009). Previous studies on habitat selection for magpies showed that the presence of magpie nests was positively correlated with the proportion of green urban areas, and negatively with forests, arable land and buildings. My results gave indications that magpies in Umeå were less frequently visiting gardens when other green spaces were available. If a garden has a high proportion of natural vegetation in its surrounding and for example is located in the forest, the garden will be less frequently visited by magpies and red foxes, probably due to habitat selection of areas with less human activity. In urban environments, there is an abundant availability of food that humans leave behind, and especially omnivores can take advantage of this resource and thrive within urban areas. Simply because they have a food selection behaviour that is directed towards eating everything that is available, not any specific resource. Because of this, omnivores have an advantage in urban environments, over specialist species that have to spend more time on searching for a specific type of food (Rodewald & Gehrt 2014). Thus, species that respond negatively to urban environments are often habitat specialists, which makes them more sensitive to human disturbance (Rodewald & Gehrt 2014). This is supported by studies on omnivorous birds on how they use supplemental feeding during the winter in urban environments (Lancaster and Rees, 1979). In this study, I only found patterns for the generalists and omnivorous species – red fox and magpie, which is an interesting result that gives indications on an unbalance in the urban ecosystem, where only generalist species seem to have adapted to. I therefore encourage to further investigate this pattern in other cities.

The fact that magpies and foxes seemed to use gardens if other greenspace were lacking, can be used as an argument for preserving greenspaces in cities.

Implementing greenspace in cities can be a potential future management tool, to prevent human wildlife conflicts, that may arise when wildlife enters gardens. Preserving greenspaces in cities will provide us with many ecosystem services.
For example, the fox will help humans with pest control when predating on pest species such as rats and rabbits. Greenspaces with trees and other vegetation will lower the temperature during hot seasons, binding carbon dioxide, remove pollutants from air and water Tarsitano (2006), taking care of rainwater Boverket (2019) and increasing the human wellbeing. In this sense, implementing more greensspaces with natural vegetation in urban areas will not only support wildlife and create more balance in urban ecosystems, but also gain humans in terms of ecosystem services.

Since most of the species lacked a clear pattern, this indicates that the patterns seem to be more complex than what could be explained by the simple methodological set up used in this study. The lack of patterns might be explained by the fact that I looked at the visitation frequency over a whole year, and the patterns were more season dependent, something I did not include in the model. Another explanation for the lack of clear patterns could be that many of the studied species have specific factors that determine their visitation frequency, which I didn't look at either. For example, for roe deer and hare the amount of edible vegetation to forage have a larger impact on habitat selection than connection to greenspace or shelter. So, if I had looked at more specific types of vegetation, based on the habitat requirements of each studied species, my results may have been different, since many species have specific factors that determine the habitat quality.

Regarding the used method, I did not look at connectivity of the gardens to the surrounding landscape, only on if natural vegetation was present in the surroundings, which might have played a role in the visitation frequency. Different elements in urban environments (for example roads and fences) generate barrier effects on species and will affect their movement (Underhill & Angold 2000). Another thing to have in consider for my results is that the sampling was not random but based on data collection of volunteers. This might have affected the results, since it was shown by the result from survey that many of the volunteers had a high interest in wildlife. For example, 54% of the volunteers fed birds in their gardens and none of them used pesticides. This indicates a high interest in wildlife and an environmental awareness. It's therefore possible that the volunteers already had adapted more wildlife friendly features in their gardens. To prevent this in future studies, marketing of similar projects could be directed more broadly, towards volunteers who do not already have an interest in wildlife, or by performing random sampling. In the survey, I asked questions about how much time the volunteers spend in their gardens, and also if they had pets, or a fence that could make it harder for wildlife to enter. These are all factors that I didn't take into account in my models and can be further explored in future studies.

In conclusions, I only found patterns for the generalists and omnivorous species – red fox and magpie. They seemed more prone to use gardens in areas that lack other greenspaces. Thus, with this study, I want to emphasize the importance of preserving greenspaces in urban planning. Secondly, where natural habitats are lacking, implementing wildlife-friendly features in gardens could be a tool to support urban foxes. Future studies are still needed on habitat selection and the specific requirements of species to give better guidelines on how gardens can be managed to support wildlife in urban environments.

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Maps

Geodata Generalized national land-cover map ©EPA

Geodata Base map OpenStreetMap Foundation ©OpenStreetMap

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Supplemental material

Table 1. Summary of all counted species in the ´Meet your wild neighbours project´.

Species	***Binomial name***	***Observed individuals***
Black headed gull	*Chroicocephalus ridibundus*	29
Bohemian waxwing	*Bombycilla garrulus*	1
Brambling	*Fringilla montifringilla*	12
Chaffinch	*Fringilla coelebs*	3
Chicken	*Gallus gallus domesticus*	92
Common blackbird	*Turdus merula*	21
Common Crane	*Grus grus*	2
Common Gull	*Larus canus*	37
Common Pheasant	*Phasianus colchicus*	4
Common wood pigeon	*Columba palumbus*	4
Domestic Cat	*Felis catus*	1018
Domestic Dog	*Canis familiaris*	198
Domestic Rabbit	*Oryctolagus cuniculus domesticus*	7
Eurasian Beaver	*Castor fiber*	1
Eurasian Blue Tit	*Cyanistes caeruleus*	2
Eurasian Elk	*Alces alces*	19
Eurasian Jay	*Garrulus glandarius*	2
Eurasian Magpie	*Pica pica*	625
Eurasian Oystercatcher	*Haematopus ostralegus*	5
Eurasian Red Squirrel	*Sciurus vulgaris*	65
Eurasian Tree Sparrow	*Passer montanus*	5
Eurasian Woodcock	*Scolopax rusticola*	2

European Badger	*Meles meles*	8
European mouflon	*Ovis aries musimon*	3
European Pine Marten	*Martes martes*	1
European Robin	*Erithacus rubecula*	25
Feral Pigeon	*Columba livia domestica*	2
Fieldfare	*Turdus pilaris*	52
Great Tit	*Parus major*	116
Greylag Goose	*Anser anser*	1
Hazel Grouse	*Tetrastes bonasia*	1
Hooded Crow	*Corvus cornix*	65
Mistle Thrush	*Turdus viscivorus*	2
Mountain Hare	*Lepus timidus*	96
Red Fox	*Vulpes vulpes*	58
Redwing	*Turdus iliacus*	2
Reindeer	*Rangifer tarandus*	13
Roe Deer	*Capreolus capreolus*	468
Song Thrush	*Turdus philomelos*	11
Spotted Nutcracker	*Nucifraga caryocatactes*	15
West European Hedgehog	*Erinaceus europaeus*	16
Western Capercaillie	*Tetrao urogallus*	3
Western Jackdaw	*Coloeus monedula*	13
White Wagtail	*Motacilla alba*	5
Yellow necked Field Mouse	*Apodemus flavicollis*	3
Yellowhammer	*Emberiza citrinella*	7

Table 2 Survey questions interactions wildlife.

In what surroundings Is your garden located?		***During the growing season, how much time is spent weekly in the garden?***	
Urban	*15,07%*	*<1h*	*4,11%*
Suburban	*21,92%*	*2h*	*10,96%*
Rural	*63,01%*	*3h*	*12,33%*
		4h	*15,07%*
		>5h	*57,53%*
Do you have fences around your garden?		***Do you use pesticides in your garden?***	
Yes	*20,55%*	*Yes*	*0,00%*
No	*79,45%*	*No*	*100,00%*
How often do you feed wildlife in your garden?		***Which domestic animals are present in your garden?***	
Daily	*13,11%*	*Dog*	*44,23%*
A few times a week	*4,92%*	*Cat*	*80,77%*
Weekly	*13,11%*	*Chickens*	*7,69%*
A few times a month	*11,48%*	*Rabbit*	*3,85%*
Monthly	*13,11%*	*Other*	*1,92%*
Less often	*4,92%*		
Never	*39,34%*		

Table 3. Survey questions number of wildlife features in gardens.

Which features can be found in your garden?

Unmowed lawn	*47,22%*	*Hedge*	*31,94%*
Flower bed	*84,72%*	*Trees taller than 2m*	*86,11%*
Meadow plants	*47,22%*	*Native trees*	*66,67%*
Vegetable garden	*56,94%*	*Fruit trees*	*65,28%*
Herbal garden	*38,89%*	*Old trees*	*52,78%*
Berry bushes	*88,89%*	*Dead Trees*	*26,39%*
Dense shrubbery	*51,39%*	*Trees with hollows*	*23,61%*
Compost	*62,50%*	*Birds nests*	*56,94%*
Dunghill	*5,56%*	*Bird baths*	*19,44%*
Wild herbs	*37,50%*	*Insect hotel*	*36,11%*
Stinging nettle	*63,89%*	*Stone cairn*	*30,56%*
Woody plants	*19,44%*	*Brush pile*	*41,67%*
Pond	*9,72%*	*Leaf pile*	*31,94%*
Watercourses	*26,39%*	*None of the above*	*0,00%*

Table 4. Summary statistic tests, hypothesis 1.) wildlife visitation frequency increases with numbers of wildlife friendly features in garden, in a generalized linear mixed model (GLMM), with a log-link function for corrections of camera trapping days (log10) and a Tukey post-hoc test for differences among seasons (Tukey).

Hypothesis	***Parameter***	***Parameter***	***Species bird***	***Binomial name***	***Estimate***	***z***	***p***	***AIC***
1	*Visitation frequency*	*Wildlife friendly features*	*Eurasian magpie*	*Pica pica*	*-0.09*	*1.27*	*0.20*	*368*
1	*Visitation frequency*	*Wildlife friendly features*	*fieldfare*	*Turdus pilaris*	*-0.06*	*-0.33*	*0.73*	*96*
1	*Visitation frequency*	*Wildlife friendly features*	*great tit*	*Parus major*	*-0.1*	*-1.5*	*0.11*	*105*
			Species mammal					
1	*Visitation frequency*	*Wildlife friendly features*	*roe deer*	*Capreolus capreolus*	*0.04*	*1.21*	*0.22*	*330*
1	*Visitation frequency*	*Wildlife friendly features*	*red fox*	*Vulpes vulpes*	*0.19*	*2.32*	*0.03 **	*108*
1	*Visitation frequency*	*Wildlife friendly features*	*mountain mare*	*Lepus timidus*	*0.02*	*0.26*	*0.78*	*136*

Table 5. Summary statistic tests, hypothesis 2.) wildlife visitation frequency increase with natural vegetation structure of garden, in a generalized linear mixed model (GLMM), with a log-link function for corrections of camera trapping days (log10) and a Tukey post-hoc test for differences among seasons (Tukey).

Hypothesis	***Parameter***	***Parameter***	***Species bird***	***Binomial name***	***Estimate***	***z***	***p***	***AIC***
2	*visitation frequency*	*natural vegetation structure*	*Eurasian magpie*	*Pica pica*	*-0.2*	*-0.7*	*0.44*	*471*
2	*visitation frequency*	*natural vegetation structure*	*fieldfare*	*Turdus pilaris*	*0.06*	*-0.07*	*0.93*	*128*
2	*Visitation frequency*	*natural vegetation structure*	*great tit*	*Parus major*	*0.04*	*0.08*	*0.92*	*158*
			Species mammal					
2	*visitation frequency*	*natural vegetation structure*	*roe deer*	*Capreolus capreolus*	*-0.06*	*-0.30*	*0.76*	*446*
2	*visitation frequency*	*natural vegetation structure*	*red fox*	*Vulpes vulpes*	*0.2*	*0.64*	*0.52*	*158*
2	*visitation frequency*	*natural vegetation structure*	*mountain hare*	*Lepus timidus*	*-0.19*	*-0.36*	*0.71*	*171*

Table 6. Summary statistic tests, hypothesis 3.) wildlife visitation frequency increase with natural habitat in a 1km2 radius around the garden, in a generalized linear mixed model (GLMM), with a log-link function for corrections of camera trapping days (log10) and a Tukey post-hoc test for differences among seasons (Tukey).

Hypothesis	***Parameter***	***Parameter***	***Species bird***	***Binomial name***	***Estimate***	***z***	***p***	***AIC***
3	*visitation frequency*	*natural habitat within a radius of 1 km2*	*Eurasian magpie*	*Pica pica*	*-3.2*	*-1.5*	*0.01*	*505*
3	*visitation frequency*	*natural habitat within a radius of 1 km2*	*fieldfare*	*Turdus pilaris*	*2.0*	*4.9*	*0.6*	*136*
3	*visitation frequency*	*natural habitat within a radius of 1 km2*	*great tit*	*Parus major*	*-0.8*	*-0.2*	*0.8*	*161*
			Species mammal					
3	*visitation frequency*	*natural habitat within a radius of 1 km2*	*roe deer*	*Capreolus capreolus*	*-0.6*	*-0.5*	*0.7*	*449*
3	*visitation frequency*	*natural habitat within a radius of 1 km2*	*red fox*	*Vulpes vulpes*	*-3.2*	*-1.8*	*0.05**	*186*
3	*visitation frequency*	*natural habitat within a radius of 1 km2*	*mountain hare*	*Lepus timidus*	*-0.01*	*-0.04*	*0.9*	*212*

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