Pollinators in Urban Landscapes

Local and landscape factors impact on pollinator species richness and abundance

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Abstract

Increasing human populations results in fast-growing urbanization. Natural and semi-natural landscapes are replaced with urban landscape features like roads, sidewalks, industrial and residential buildings. The remnants of the natural landscapes are left fragmented and are often managed by frequent mowing and trimming of the vegetation. This development has had a negative impact on pollinators such as bees and wasps. Bees and wasps are pollinating insects providing an ecosystem service that sustain the global food supply. Pollinators are important also in urban landscapes where their services are needed for ecological stability and biodiversity. This study compares 23 locations in Sollentuna municipality, to investigate if species richness and abundance of bees and wasps are correlated with local factors, landscape factors or both. The available food resources are measured in buffer zones with 200m radius. Local variables are: dead wood, exposed sand, extended edge zones, flowering plant species richness and unmanaged habitat. The result showed that the landscape factor of food availability was more important for the abundance of pollinators while local variables together with the landscape factor of food availability had a positive effect on the species richness.

Key words: Green infrastructure; insect conservation; urban biodiversity; ecosystem services; supporting services; urbanization

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Introduction

Ecosystem services are goods that nature provide which improves human well-being by meeting human demands. Ecosystem services are divided into four different categories: (i) provisioning services, e.g. food, water, timber and other goods that humans obtain from nature; (ii) regulating services maintain the functioning of nature and the livable environment such as keeping the water, air and soil clean from pollutants; (iii) supporting service like pollinators who support crop production; and (iiii) cultural services that provide humans with recreation, tourism and other experiences that contribute to physical and mental benefits (Crenna et al., 2017).

The supporting service that pollination contribute is a crucial life-support function for the ecological stability of the earth. Pollinators contribute to the maintenance needed for a great biodiversity and for ecosystem functions. Different insects, both wild and domesticated, pollinate over 80% of the wild plant species and up to 75% of the leading agricultural crops. Pollinating insects are fundamental in supporting the global ecological stability and food security. These pollinators contribute to the global food supply along with other essential assets and resources (Crenna et al., 2017, Lazaro et al., 2016).

The pollinating insects are undergoing a widespread decline at a global scale due to multiple interacting factors. The insects are vulnerable to anthropogenic activities, and several authors have documented regional declines in wild bee populations along with other pollinating insects around the world (Crenna et al., 2017, Balfour et al., 2018). The declines can be traced to a couple of different interactive factors including intensification of agricultural practices, climate change, introduction of exotic plants species, loss of forage and changes in land-use together with habitat loss due to urbanization. Urbanization cause habitat destruction, which is one of the main reasons of general species extinction. The human populations are growing in a rapid pace along with urban areas (Lerman et al., 2018, Choate et al., 2018, Fitch et al., 2019).

Natural or semi-natural landscapes turn into industrial, commercial and residential buildings, parking lots, roads, sidewalks etc., and the remaining natural landscapes get fragmented. Urban green spaces are rarely left with their natural vegetation, they are rather replaced with ornamentals and exotic plants and lawns. Limiting the native floral assets and altering the landscapes cause a negative effect on the local pollinators. The general maintenance of the green areas, such as mowing and trimming of the vegetation, disturbs the pollinators and contribute to a local decline. The fragmented landscapes and scarce food resources limit the pollinators to their nesting sites, making them reliant on the proximal food sources (Choate et al., 2018).

The decline in pollinators can have serious consequences and implications, especially for future generations. It poses a potential risk of the global food security and the natural ecosystems and its services. Not only will it have a negative effect on pollinator-dependent crops, and there by the future availability of food and goods, it will also impact the economy and agriculture that humans are dependent on. In urban landscapes the pollinators contribute to biodiversity and natural ecosystem functioning, which have been shown to be important for human mental and physical well-being (Crenna et al., 2017).

Background

Bees and wasps are a good example of pollinating insects that contribute to crucial ecosystem services. Flower-visiting bees and wasps are depending on the availability of food resources (Potts et al., 2003). Bees can be divided into three different groups, depending on their nesting habits; aboveground nesters, belowground nesters and cleptoparasites (bees who lay eggs in other insects' nests). Belowground nesters are most common amongst wild bees, they make tunnels in the soil or use already existent empty underground nests. Aboveground nesters find cavities above the soil, commonly in dead wood, plant stems, rocks or abandoned nests created by other animals.

Declines in natural and semi-natural habitats means a loss of favorable nesting sites and food supply for the pollinators, who tend to remain in isolated fragments. The fragmentation of natural habitats becomes barriers to gene flow (Crenna et al., 2017). Wild bees are especially sensitive to changes in habitat since they depend on their nesting sites and the food resources near by the nest, most wild bees are not likely to roam further than 500 meters away from their nest (Choate et al., 2018). This makes them vulnerable to barriers such as roads and parking lots etc. in their foraging ranges from the nests. With an increasing urbanization comes a decrease in pollinator abundance and pollinating success, the urban barriers might be a main cause for that. There is still a rather big lack of knowledge about which factors that determine the abundance of bees and wasps in urban landscapes (Johansson et al., 2018).

Aim

The aim of this study is to provide knowledge about which factors that are important for the conservation of pollinators in urban landscapes by investigating their fundamental needs. Pollinators have different nesting habits and they rely on flowers for food. This study examines the availability of appropriate nesting sites and food resources in urban landscapes.

Previous studies

Johansson et al. (2018) made a study about accessible food resources for pollinators in urban landscapes. The researchers made inventories of bees and wasps at 23 locations within Sollentuna municipality, Sweden. Colorful pans filled with water, and a drop of detergent to reduce the tension of the water surface, was used as traps to collect bees and wasps. Three traps were positioned together. Two spatial scales were tested, 200 m and 400 m. The locations were examined to make an estimate of the available food sources and the attributes that have effect on the pollinators. These factors were later compared to the inventories of the bees and wasps to examine correlations between the species richness and abundance of pollinators and accessible food resources. The study confirms that bees and wasps are negatively affected by barriers in urban landscapes, such as roads and buildings (Johansson et al., 2018).

Bellamy et al. (2017) executed a study in Edinburgh, Scotland where the aim was to find a framework for targeting urban planning with regards for pollinators. By ensuring suitable environments for pollinators in urban areas, a win-win situation is likely to occur. The authors mean that not only will the pollinators provide ecosystem services, but the local people will also gain access to green areas and nature for recreation. The authors used habitat suitability models (HSM) with incorporated sensed vegetation data to be able to present how the urban landscapes affect the dispersal of species. This information can be used for planning of green infrastructure. The study also targeted citizens of the studied area to spread knowledge about pollinators to encourage interest in wildlife gardening and the well-being of pollinators (Bellamy et al., 2017).

Lowenstein et al. (2014) writes about the lack of knowledge regarding how the urbanization affect provisioning of ecosystem services and the patterns of biodiversity. The authors studied bee communities and the pollinating services of the bees in 25 areas across Chicago, USA. The study examined this ecological issue by investigating how the richness, abundance and composition of summer active bees are affected by surrounding land cover, socioeconomic aspects and local floral assets. Their results reveal that pollination services from bees can be sustained in dense urban neighborhoods if they maintain a diverse and abundant floral resource. The aim of the study is to achieve a greater understanding of how urban areas can contribute to pollination and the survival of pollinators by supplying floral resources in the areas (Lowenstein et al., 2014).

González et al. (2017) have made a study about habitat loss and edge effects in urban landscapes, where they examine how insect communities may be affected. In urbanized landscapes, fragmentation and reductions of natural habitats are frequently connected to declines in insect species richness and abundance. In addition to habitat loss, an increase in the proportion of edge habitat is frequently found in transformed landscapes. Edges are usually seen as abrupt limits between the remaining natural habitat and the "new" human-made areas. Edges generally have an increased light intensity, lower humidity, wind and thermal amplitude, compared with the interior of fragments. Such changes in microclimatic settings affect populations in numerous ways, including effects on behavior, abundance, geographic distribution, and dispersion. González et al. (2017) found that the abundance and species richness of insects were directly related to forest cover and predominantly higher at edges compared within the forest interior. A higher species richness was found at the edge rather than at the interior of the forest, this pattern is consistent with other studies. In contrast, total abundance did not differ between edge and interior (González et al., 2017).

Theories

Metapopulations are described as a group of discrete populations that are spatially separated, each occupying a patch of habitat with some sort of dispersal between them. The populations that habitat each patch change over time, some may go extinct and the patches will establish new populations, or they will be unoccupied for a period of time. These types of changes are called metapopulation dynamics. In metapopulation dynamics the connectivity and capacity of the habitat patches are essential. Metapopulation theory suggest that larger patches of habitat are more favorable and more likely to be able to provide for populations, while smaller patches are more vulnerable of local extinction. Habitat patches adjacent to other patches are considered better than more isolated patches because of a smaller possibility of immigration from other patches (Hanski et al., 1997). The environmental circumstances within the patches are also important factors that contribute to the perseverance of the populations (Parris, 2018).

Intermediate disturbance theory proposes that intermediate levels of disturbance is necessary for the abundance and species richness of organisms. The intermediate levels of disturbance, in persistence and intensity, favors the concurrence of a greater variance of species because the disturbance allows for the dominant species to be challenged at times, which creates opportunities for other species to colonize and compete (Lee et al. 2011, Catford et al., 2012). When there are high levels of disturbance only a few species can tolerate and survive, defeating the species that are not able to rapidly re-colonize. When the disturbance levels are low only the strongest species endure, due to competitive exclusion and dominance of some species. Both outcomes lead to low species diversity. Therefore, the intermediate level of disturbance is the optimal level where disturbance tolerant and competitive species can exist side by side and create a broad species richness (Kershaw & Mallik, 2013, Catford et al., 2012).

The theories applied to bees and wasps

According to Choate et al. (2018) and Plascencia & Philpott (2017) there are some important variables for pollinators nesting and food habits. Aboveground nesting pollinators nest in cavities in dead wood, but even underground nesters benefit from the woody vegetation and plant cover from the forest cover found where dead wood is established. Belowground nesters, who are the most common amongst wild bees, build their nests in the soil by digging tunnels. For the belowground nesters exposed sand is important, preferably in a sunny location. Pollinators are flower-visiting insects who depend on flowers for food. Edges provide suitable conditions for pollinating insects, where they can find both food resources and nesting sites in fragmented landscapes (González et al., 2017). Pollinators are affected negatively from the human maintenance of natural areas. Mowing of lawns, exotic ornamental flowers and fragmentation cause a decline in native flowering plants which cause a decline in their food resources and their nesting sites get disturbed (Choate et al., 2018), Plascencia & Philpott, 2017).

Most wild bee's live solitary in conjunction within their limited forage range. They usually do not roam further than 500 m from their nesting sites, making bees dependent on proximal forage availability near their nesting sites (Choate et al., 2018). Plascencia & Philpott (2017) found that at very local spatial scales, bee visitation rates to flowers can differ with floral resource patch size or with the occupation of other plant species in the same habitat patch. At larger spatial scales, visitation rates to flowers may be altered by floral connectivity in a landscape. Heterogeneous and patchy spatial resources over a landscape may allow foraging bees to shift to different floral resources and increase offspring production. Though, in some circumstances, floral diversity, rather than floral density drives bee foraging (Plascencia & Philpott, 2017).

Plascencia & Philpott (2017) found that spatial areas with high floral abundance and patchy flower resources had a negative effect on bee abundance and species richness. This has likely to do with the interaction with honeybees that compete with the wild bees.

Research questions

Which spatial factors of nesting sites and food availability is important for pollinators in urban landscapes?
Are local factors more or less important than landscape factors?

Methods

This quantitative study primarily builds on the previously mentioned study by Johansson et al. (2018). My study investigates the same 23 locations in Sollentuna municipality that also were studied by Johansson et al. (2018). I also have access to Johansson et al. (2018) collected field inventory of bees and wasps as data. The average minimum distance between two sites was ~760 m.

Johansson et al. (2018) performed three inventories during different time periods throughout the spring and summer period. The first inventory took place in the end of April, the second in the beginning of June and the third during the beginning of August 2015. The authors tested two different spatial scales within a buffer circle of 200 m and 400 m, respectively. They compared three different measures of accessible food habitats. First, they made a summation of all food habitats within the buffer circles. Secondly, they made a summation at buffer distance of 200 and 400 m, of the surrounding landscapes food habitat, weighted by the Euclidian distance, where the importance of the food habitats decreases with the increasing distance from the buffer zones. The third measure was friction based, where the landscape barriers, such as roads, buildings etc. are considered, measuring the permeability of movement of the bees and wasps in the landscape.

The study concluded that by only using the first and second measures of simple summations, both weighted and not, there is no significant correlation with species richness or abundance of bees and wasps. Using the third measure where the limitations of landscape friction is considered, the result prove a significant correlation for the species richness and abundance. The spatial scale of 200 m provided the best results in their study, proving that the bees and wasps are limited in their dispersion (Johansson et al., 2018), therefore this study will also use and test the same spatial scale of 200 m and food resources, that will represent the landscape factors.

My study will compare Johansson et al (2018) landscape factors to the local scale, of 20 m circles, collecting information about local factors that may affect pollinators. The buffer circles of 200 m are in this study considered as a landscape area while the 20 m buffer circle is viewed as a local area.

Five variables were chosen and used in this study to examine the local conditions; the availability of dead wood, exposed sand, flowering plant species richness, extended edge zone and the habitat-type of the location. Each variable was coded as a presence/absence variable. All locations were also scored for the number of present factors. The study was performed at the end of April 2019, due to a limited timeline only one inventory is used in this study.

The program *Collector for ArcGIS* was used to find the locations and to document the variables within the 20 m area of each location. Each location was given a spatial coordinate for use in the spatial analysis.

Method limitations

Due to a limited time period for this study, the field inventories were only made once, in the end of April 2019. For a better result and greater appreciation of the local variable *flowering plant species richness* on the locations, three different inventories during different months (April, June and August), would have been preferable, since this variable will differ during these months. Also, a new inventory of the bees and wasps of the locations would have been in place since the used inventory was collected during 2015. It would have been better for the study and it would also be interesting to compare the abundance and species richness of the pollinators from 2015 with a new inventory from 2019.

Habitat variables

Dead wood – Presence of dead wood.
Flowering plant species richness – If the location had flowering plants (flowering bushes are not included). This inventory was only performed at the end of April, when most flowering plants had not yet blossomed.
Habitat – Unmanaged and natural character or managed habitats.
Extended edge zone – An extended edge zone did only count if the edge had a sharp line going from a flat and somewhat bare area to an area with bushes and trees at different height levels.
Exposed sand – Occurrences of exposed sandy soil.

Case study area

Sollentuna municipality, just north of Stockholm, has a population of more than 72 000. This population is growing with almost 1000 per year, and 300-500 new houses and apartments are built yearly. Meaning that the municipality is becoming more urbanized (Sollentuna kommun, 2019).

The 23 study locations have very different characteristics altering from very urban, surrounded by concrete and traffic, to sites of natural character located in groves adjacent to a lake.

Statistical Data Analysis

The statistical software R was used to perform the statistical analyses. The package MASS made it possible to make generalized linear regression models using negative binomial error distribution (glm.nb) to handle overdispersed count data. These models analyzed pollinator abundance and species richness measured as counts as a function of landscape factors and local factors.

Species richness and abundance was tested with a glm.nb against each explanatory variable. The categorical variables *habitat* and *extended edge zone* (20 m), both showed positive relationships with species richness. Therefore, I also tested the relationship between habitat and extended edge zone, and the continuous variable *food availability* (200 m).

The index score of all the variables was tested against food availability at 200 m. Food availability was log-transformed to improve normality. This was also tested with a general linear model using negative binomial error distribution. The same analysis was also run for species richness and food availability pollinator abundance and food availability. I also analyzed the relationship between species richness and abundance with the index score using glm.nb.

Results

Statistical results

The result indicates that the pollinator species richness is positively affected by extended edge zones and unmanaged natural habitats (Table.1). There is a positive relationship between dead wood and species richness even though the result is not significant (Table.1). The abundance of the pollinators is not affected by the local variables (Table.2). Most important for both pollinator species richness and abundance are the landscape factor availability of food resources within 200 m. Food availability at a local scale has no significant effect on pollinator species richness or abundance.

Table 1. The effect of local factors on pollinator species richness. Tested with glm.nb.

Species richness	**Estimate**	**Std. Error**	**Z-value**	**P-value**
Dead wood	0.626	0.326	1.921	0.055
Flowering plant species richness	0.275	0.345	0.798	0.425
Exposed sand	0.598	0.395	1.511	0.131
Extended edge zone	0.761	0.327	2.325	**0.021**
Habitat	0.774	0.318	2.429	**0.015**

Table 2. The effect of local factors on pollinator abundance. Tested with glm.nb.

Abundance	**Estimate**	**Std. Error**	**Z-value**	**P-value**
Dead wood	0.394	0.462	0.852	0.394

Flowering plant species richness	0.578	0.459	1.258	0.208
Exposed sand	0.429	0.559	0.767	0.443
Extended edge zone	0.369	0.485	0.761	0.447
Habitat	0.625	0.464	1.346	0.178

The relationship between habitat and food availability is significant where the food availability increases with unmanaged habitat (Fig.1). There are more food resources at the locations with extended edge zones, even though the result is not significant (Fig.2).

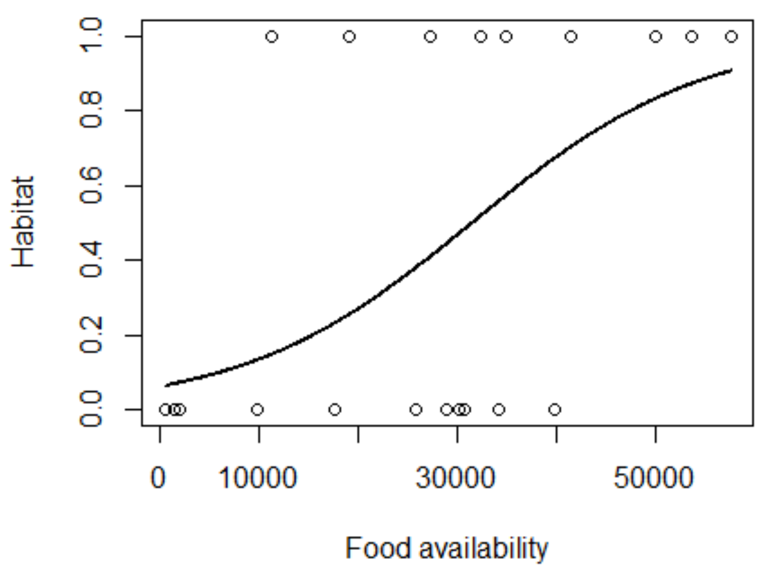

Fig.1 Logistic regression of habitat (20m) and food availability (200 m). The food availability is measured in m^2. A significant result (P-value= 0.0227) is shown where the food availability is higher at the unmanaged habitats.

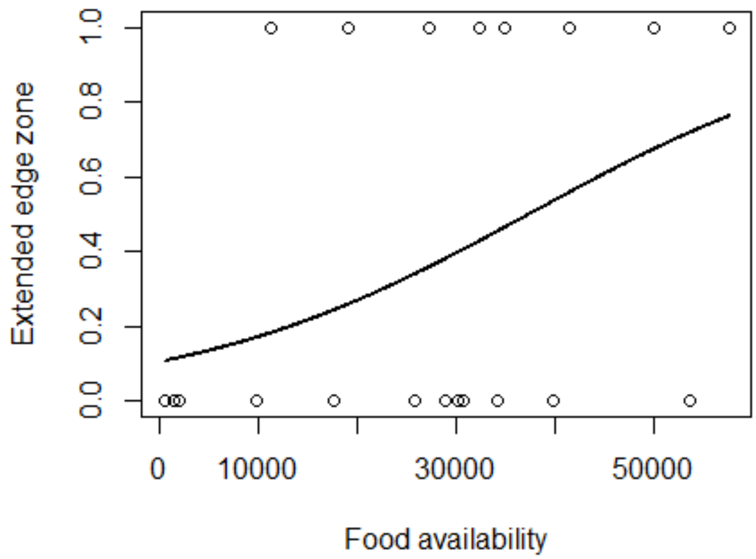

Fig. 2 Logistic regression of the relationship between the extended edge zone (20 m) and the food availability (200 m). The food availability is measured in m^2. The result is not significant (P-value= 0.0619), even though the figure presents a higher food availability at locations with an extended edge zone.

A negative binomial model on the log-transformed food availability analyzed together with the index on species richness and abundance exhibits that the food availability is significant for both species' richness and abundance, while the index is not significant (Table. 3, 4).

Table 3. Negative binomial model on the log-transformed food availability analyzed together with the index score on species richness. The log-transformed food availability is measured in m^2, species richness in amount of species of bees and wasps. The correlation between species richness and the log-transformed food availability is significant.

Species richness	**Estimate**	**Std. Error**	**Z-value**	**P-value**
Log-transformed food availability	0.246	0.102	2.410	**0.016**
+				
Index	0.139	0.091	1.529	0.126

Table 4. Negative binomial model of the relationship between abundance analyzed together with food availability (200 m) and index (points/20 m). The log-transformed food availability is measured in m^2, abundance in number of bees and wasps. The correlation between abundance and food availability is significant, the correlation between abundance and the index is not significant.

Abundance	Estimate	Std. Error	Z-value	P-value
Log-transformed food availability	0.424	0.141	3.012	**0.002**
+				
Index	0.082	0.133	0.618	0.537

When testing the index score and food availability separately towards the species richness and abundance the result for the index is different. The food availability has a significant effect on both species richness and abundance. The index score shows no significant relationship with pollinator species richness or abundance (Table. 5, 6).

The landscape factor of food availability is more important for the abundance of pollinators while both the local and landscape factor have a positive effect on the species richness. According to this study the result show that the landscape level is of most importance for pollinators in urban landscapes.

Table 5. Negative binomial model of the relationship between species richness and food availability (200 m) and index (points/20 m) tested separately. The log-transformed food availability is measured in m^2, species richness in amount of species of bees and wasps. The correlation between species richness and the log-transformed food availability is significant, the correlation between species richness and the index is also significant.

Species richness	Estimate	Std. Error	Z-value	P-value
Log-transformed food availability	0.323	0.103	3.142	**0.002**
Index	0.207	0.094	2.206	**0.027**

Table 6. Negative binomial model of the relationship between abundance and food availability (200 m) and index (points/20 m) tested separately. The log-transformed food availability is measured in m^2, abundance in number of bees and wasps. The correlation between abundance and food availability is significant, the correlation between abundance and the index is not significant.

Abundance	Estimate	Std. Error	Z-value	P-value
Log-transformed food availability	0.465	0.134	3.46	**0.001**
Index	0.178	0.137	1.297	0.195

Analysis

The result of this study shows that the landscape factor of available food resources within 200 m is favorable for pollinators in urban landscapes. This aligns with the metapopulation theory that suggest that larger habitats are more likely to provide better living conditions than smaller habitat areas. Larger habitat areas with a high connectivity of habitat patches are important drivers of metapopulation dynamics. However, environmental factors within each patch is also important for the persistence of populations and the likelihood of colonization, as determined by the ecological niche and resource claims of the species in question (Parris, 2018).

Bees and wasps are positively affected by a couple of environmental factors. Dead wood is important for nesting and shelter, and they depend on floral resources for food. Underground nesters thrive in exposed sand, especially in sunny locations. Edges provide good conditions for the pollinators. Bees and wasps are negatively affected by managed natural areas, the maintenance disturb the pollinators and limit the native floral resources (Choate et al., 2018), González et al., 2017, Plascencia & Philpott, 2017). These are the environmental factors that this study investigated on the local level (20 m). Parris (2018) claim that the environmental factors within the habitats are relevant to, the result of this study conclude that the variables had a positive effect on species richness but not on the abundance. The most important local factors were the extended edge zones and unmanaged habitats. Dead wood also had a positive effect on the species richness even though it was not significant. The food resources on a landscape level of 200 m was of greatest importance for both species' richness and abundance, not limiting the food resources to the local level of 20 m.

According to the intermediate disturbance theory the abundance and species richness of organisms gain from some disturbances. The disturbances need to be of a certain level, in between high and low, to be benefiting the organisms. Species richness contribute to an intermediate disturbance level, due to healthy competition between species (Kershaw & Mallik, 2013, Catford et al., 2012, Lee et al. 2011). Disturbances in urban landscapes are often to intense, such as traffic and frequent mowing and managing of the natural areas (Choate et al., 2018). These activities decrease the floral assets, removing dead wood, covering exposed sand etc. This research has not examined if the pollinators in this study gain from human-made disturbances and barriers caused by urbanization, or if there would be a higher abundance and species richness without the urbanization. Neither have this study examined the natural causes of disturbance on the pollinators.

Discussion

Urban landscapes are likely to be fragmented and contain barriers which limit the food proximity for the pollinators. The unmanaged natural habitats and the extended edge zones had a positive effect on the species richness of bees and wasps (Figure 1, 2), which can be connected to Choate et al. (2018), that writes about the natural or semi-natural landscapes that are urbanized and altered by intense managing and limiting of the natural vegetation and native floral assets. This has been shown to have a negative effect on the species richness and cause local declines in pollinating insects, which demonstrates the importance of unmanaged natural habitats and extended edge zones (Choate et al., 2018).

Dead wood also had a positive correlation on species richness on the local scale of 20 m. The landscape scale of 200 m would more likely contain bigger amounts of dead wood. The food availability on a landscape level can better provide for populations than on a local level, perhaps the local variables measured on the spatial scale of 20 m would have a greater effect on the landscape scale of 200 m. This was not tested, regardless, the results in this study establish that the landscape level is favorable for the species richness and abundance of pollinators.

Plascencia & Philpott (2017) found in their study that changes in bee species richness and bee abundance was largely driven by floral abundance. Even though floral abundance often is correlated with higher bee richness in urban landscapes, Plascencia & Philpott (2017) results indicate that bee species richness and abundance was lower in sites with more flowers and patchier flower resources.

Clustered floral resources may support many bees that forage both short and long distances but may be especially important for smaller bees that have limited foraging ranges. Also, different bees can react differently to floral patch size. Bee species richness and bee abundance responded to floral spatial distribution in different ways – whereas bee species richness responded positively to clustering, while bee abundance responded negatively to floral clustering (Plascencia & Philpott, 2017).

This study exhibits that pollinators species richness was positively correlated with extended edge zones and unmanaged natural habitats. Considering the results from Plascencia & Philpott (2017), one may speculate that these local variables offer clustered floral resources for the bees that contribute to the species richness. The pollinators abundance did not correlate with the local variables, only with the food availability at a landscape level of 200 m. The flower dispersal on the landscape level may be more scattered than on the local level. This is not a factor that was considered in this study but comparing the result to other studies can contribute to a deeper understanding to why species richness and abundance of pollinators react differently to different factors.

Johansson et al. (2018) found that the food availability at the spatial scale of 200 m was positively correlated to species richness and abundance of bees, more so than the spatial scale of 400 m. Indicating that the pollinators do not roam as far as 500 m from their nesting sites, at least not in urban landscapes. This could be an effect of low connectivity in urban landscapes, limiting the pollinators from roaming up to 500 m as they would in natural landscapes, making them even more exposed and sensitive to changes and barriers in the urban landscapes.

There has been a decline in pollinating insects worldwide where urbanization can be traced as one of the reasons, and therefore it is not likely that urbanization contribute to an intermediate disturbance that the pollinators would gain from. Urbanization rather cause a disturbance of a level too high, that is damaging for pollinators. Wild bees are limited to their nesting sites, since they usually do not roam further than 500 m from their nests, which makes them vulnerable to changes and barriers in the landscape (Lerman et al., 2018, Choate et al., 2018, Fitch et al., 2019).

There is no doubt that pollinators are important for all living beings and they contribute to our most important ecosystem services for our well-being. It is of great importance to make sure that pollinators have a place in urban landscapes where they are needed. The decline of pollinators, due to urbanization, amongst other reasons, emphasizes the urgency of understanding the fundamental needs of the pollinators for conservation and recovery efforts. Johansson et al. (2018) writes that there is yet little knowledge about the fundamental needs for pollinators in the ever-changing urban landscapes. Therefore, it is important that this subject gets the attention it needs for a better understanding of how to care for the pollinators that care for all other living beings on earth. Understanding the specific circumstances that drive bee population and diversity are important to increase pollination services.

Insights from this study can be applied to the conservation management of pollinators in planning green infrastructure in urban landscapes. Leaving natural habitats unmanaged and limiting the fragmentation of urban landscapes allowing for appropriate patch sizes with connectivity are examples of actions that can support pollinators species richness and abundance.

Conclusion

This study has come to the conclusion that the spatial factors of available food resources on a landscape level of 200 m are of most importance for bees and wasps.

Species richness of pollinators benefits from the local factors of extended edge zones, unmanaged habitats, and to some extent dead wood. At a landscape level the pollinators benefit from the factor of food availability.

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