Analysis of pollinator diversity under 3 urban grassland management strategies

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1 | Abstract

Pollinators are of great importance for the pollination of plants, over 85% of wild flowering plants depend on pollination by insects. 75% of the crops used for human consumption depend on pollination, making pollinators extremely important for the yield of vegetables and fruit. However, there is a worldwide decline in the abundance of pollinators, including a lot of endangered species. Urbanization causes tremendous effects on the vegetation composition of their original habitat. The comparison of different urban grassland management types could provide insight into the type of vegetation management yielding the highest pollinator diversity and abundance. Three different management strategies, sinus, sheep, and lawn were investigated. The number of bees, bumblebees, butterflies, and hoverflies was counted for the selected fields. Butterflies were identified at the species level to compare the species diversity between the management types. The highest number of pollinators was counted under sinus management. Sinus management showed the highest positive significant effect on the pollinator abundance for bees, bumblebees, butterflies, and hoverflies. Fields managed by sheep show the highest pollinator diversity regarding butterfly species. Even though sinus fields show a high pollinator abundance, there is a lot of variance between the sinus fields. There is a difference in the preference for flowering plants between pollinators. Further research on sinus management should focus on the vegetation composition and the preferred plants and flowers by pollinators to obtain more information. This ultimately increases pollinator abundance and biodiversity by including this knowledge in the way urban grasslands are managed.

2 | Introduction

Insects play an essential role in pollinating from one flower to another. When pollinators visit a flower to find nectar, they move along the reproductive part of the flower and bring pollen from one flower to another. A lot of plants depend on the carrying of pollen between plants by these insects (*The Importance of Pollinators* (n.d.)). Pollination is necessary for more than 75% of the food crops, mainly vegetables and fruit. Over 85% of the wild plants in nature need pollination from different insects. Therefore bees, butterflies, hoverflies, and other pollinating insects are essential for agricultural products, and necessary during the production of food for human consumption (Ministerie van Landbouw (2020)). These species help increase the yield of crops, which is even more important for a growing world population (*The Importance of Pollinators* (n.d.)). However, there is a worldwide decline in the number of these pollinating insects. It is estimated that out of the 360 different bee species in the Netherlands, over half of this amount is endangered and this applies to one-third of the hoverflies (Ministerie van Landbouw (2020)); (Meer (2019)).

An increasing world population causes a worldwide expansion of urbanization. It is estimated that by 2050 around the same amount of people that are currently living on the planet, will live in urban areas. The increase in urbanization has serious consequences for the environment of pollinating insects. Under high urbanization and disturbance, there is shown to be a decrease in pollinator diversity (Wenzel et al. (2019)). The habitats are replaced with abiotic elements, which include almost no flowers or living resources for pollinators. Most of the still available habitats are fragmented, affecting pollinator diversity negatively (Wenzel et al. (2019)). However, there also seems to be positive responses in pollinator diversity to moderate urbanization. During moderate urbanization, there is an increase in the heterogeneity of the environment.

The heterogeneity of an environment can be explained by the Intermediate Disturbance Hypothesis. The hypothesis explains the maximum species diversity when ecological and anthropogenic disturbances are not too low nor too high (*18.2: What Are the Effects of Disturbance?* 2022). Species tolerant to disturbances, competitively dominant species and species sensitive to disturbances are able to coexist when disturbances are intermediate and not too high or low (Yuan et al., 2016). Under high levels of disturbance, a low species richness is predicted, because most of the species cannot live under high disturbances. However under low disturbances, species are able to compete with each other, and competitive exclusion appears in these areas (Yuan et al., 2016). Pollinator abundance is negatively affected by low disturbance due to low vegetation diversity and the height of plants, which limits access to flowers (Dylewski et al., 2019).

The Netherlands is one of the countries where biodiversity loss is highest, in which urbanization increases each year (*Urbanization over the Past 500 Years* (n.d.)). This stresses the importance of management in the existing grasslands and preventing a further decrease in pollinator biodiversity. Changes related to the loss of quantity or quality are an important driver for pollinator diversity loss in urbanized areas (Aguilera et al. (2018)). The type of management plays an important role in the quality, quantity, and level of disturbances in these urbanized areas. Given that there is a close association between grasslands and butterfly biodiversity, almost no attention has been given to this topic. Therefore, it is important to gain more knowledge about management strategies in order to prevent pollinating diversity loss (Aguilera et al. (2018)).

Different management regimes of urban grasslands are performed in the Netherlands. In this study, research has been done on the effect of pollinator abundance and butterfly diversity on three different management strategies in which mowing is performed at the high, intermediate, and low-frequency disturbance. The different strategies are; Weekly mowing by a lawn mower, Mowing by sheep, and sinus management.

Weekly mowing by a lawn mower is seen as a high-frequency disturbance, where the lawn is kept around 5-8 cm. Humans like the idea of a grassland that looks tidy, however, pollinators are unable to find food (*Reducing Mowing for Pollinators – Brilliant for Bees, Harder for Humans!» All-Ireland Pollinator Plan* (2019)). It is important to have continuous flowers to provide food for pollinators. Frequent lawn mowing showed a decrease in the abundance of flowers used by bees (Lerman et al. (2018)).

Mowing by sheep is a low-frequency disturbance, where sheep have a preference for the most productive grasses. This gives more space for other plants such as flowers, nettle, and herbs. The stinging nettle is an important habitat for butterflies and other pollinators to lay their eggs and provide food (Donnelly, 2022). Sheep do not keep the lawn at an exact height, thereby causing fluctuation in the grassland. (*Maaien En Schapenbegrazing | Diensten BuitenRuimte | Circulus* (n.d.)). However, sheep also like to eat the flowers in grasslands, which reduces the flower resources for pollinating insects in low-diversity grasslands (Cutter et al. (2021). Thereby decreasing the pollinator diversity in these fields managed by this strategy.

Mowing by sinus management is a form of intermediate-frequency disturbance. This is performed in an organic pattern, where only a part of the vegetation is mown. These different patterns allow different heights of vegetation within the same grassland, outlining a natural pattern of vegetation growth, with different microclimates. There are colder and warmer areas in these fields but also space for flowering plants. Pollinating species and other animals can hide in these places and butterflies can lay their eggs (Waterstaat (2021)).

As described previously, pollinator species are important for plants and crops. During this study, the abundance of hoverflies, bees, bumblebees, and butterflies is investigated. Thereby also focusing on the species richness of the butterflies. This gives the following research question; Does the intensity of mowing affect pollinators in urban grasslands, and if so, what management of mowing yields the highest abundance and biodiversity? Therefore the hypothesis based on the intermediate disturbance theory is; Intermediate disturbances by either mowing at the low-frequency result in both early, intermediate, and late stages of succession, with their respective pioneer, intermediate, and climax species being present within urban grasslands at the same time. This could result in higher pollinator biodiversity and abundance in intermediate disturbed grasslands than in both rare and common disturbed urban grasslands.

3 | Materials and methods

3.1 | Field Characteristics

9 fields with a size of roughly 1300m^2 each have been selected at the Zernike campus to measure pollinator richness and abundance. The effect of 3 different mowing strategies on pollinators has been selected. These strategies are sinus mowing, the use of sheep, and weekly lawn mowing. The exact locations of the fields can be found in Figure 1. Sinus mowing occurs at a frequency of 3 times a year, during the spring, summer, and autumn. Depending on the vegetation height, sheep are led on the field for 2 weeks consecutively, for roughly 2 times per year. This season, the sheep were on the field in the spring prior to the experiment. The fields with the same mowing method should be as homogenous as possible. The first week of the project has been devoted to measuring the field characteristics of the allocated 9 fields. During this week, the following characteristics have been mapped: Vegetation height, flower coverage, and an estimation of the total number of plant species within each field. The vegetation height of the fields was measured at 10 random spots for every field, using a drop disk. These 10 data points then formed the average height of the field. To determine flower coverage, a frame quadrat has been thrown 10 times, landing at 10 random spots. Flower abundance was then measured with a 50 x 50 cm plot divided into 25 identical squares of 10 x 10 cm. The number of squares containing at least one flower of any plant species was noted. Each 10 x 10 cm square accounts for 4%, thereby the total flower coverage could be estimated. The average of the 10 percentages formed the total flower coverage of each field. To estimate the total number of plant species in each field, a plot was randomly chosen in the field. The plots started with a size of 0.25m^2, in which the plant species were identified. Next, the plot was enlarged to a size of 1m^2, and new plant species were identified and added to the already encountered plant species. Finally, the plot was enlarged to a size of 9m^2, and newly identified plant species were added.

3.2 | Pollinator counts

The total number of encountered pollinators was noted for all the fields on the same day. This included the abundance of bees, bumblebees, and hoverflies, combined with the butterfly species with their respective abundance. Butterflies were the only pollinators that could be determined at the species level in the field. Before each count, the date, temperature, time, cloud coverage, and average vegetation height of each field were recorded. Cloud coverage was rated on a scale from 0 to 5. Vegetation height was measured at 10 random spots in the field. Counting of the pollinators has been executed between 10.00 and 16.00 hours, at a minimum air temperature of 15℃, with preferably gentle (< 20 km h–1) or no winds and cloud cover <50%. In total, 2 counters spend 0.5 hours counting at the same field, walking separate routes. During the counting of the pollinators, the walking speed was low at a constant tempo. The same route through the field was followed for the different monitoring dates. Pollinators were recorded within a range of 2.5 meters beside and 5 meters in front and above the observer.

3.3 | Control group

Weekly mowing of the lawn is used as the control of the experiment. Before the introduction of alternative grassland management strategies such as sinus management and mowing with the use of sheep, weekly mowing was the primary form of grassland management at the Zernike campus.

3.5 | Data analysis

R version 4.1.2 was used to perform all statistical analyses. The homogeneity of the variance in vegetation height was tested using Bartlett's test. The vegetation height data has been log-transformed to yield homogeneity of the residuals and a normal distribution. We tested for the effect of management type, measuring day, and the interaction between these variables for effect on vegetation height, using an ANOVA test. The relationship between the encountered pollinators, and the measured independent variables was tested by using a multiple linear regression model. We tested for multicollinearity in the model and excluded unnecessary variables from the model to prevent correlation between the variables. Time, cloud coverage, temperature, and management have been incorporated into the statistical analysis. Our linear regression model plots the data of the encountered pollinator species over an x-axis containing the management types lawn, grazing, and sinus, with an x-value of 1, 2, and 3, respectively. We used the Shannon-Wiener Index to measure the biodiversity of the fields and calculated the average degree of biodiversity for each grassland management strategy. We calculated the diversity of each field using the following formula of the Shannon-Wiener index: $H =- \Sigma Pi(lnPi)$. The degree of biodiversity is based on the data of the encountered butterfly species and the abundance of each species.

3.4 | Validity

High-quality sources have been consulted during the literature research of the project. Data on pollinator abundance and diversity has been collected using reliable and commonly used counting methods obtained from "De Vlinderstichting" (De Vlinderstichting, 2018). Data of the butterfly diversity is used for calculating the pollinator diversity. Butterflies are ideal as they are both easy to observe in the field, and they are indicators, both for their rapid and sensitive responses to subtle habitat or climatic changes and as representatives for the diversity and responses of pollinators (UKBMS, 2023). On each measuring day, data collection was performed at random times for each of the fields, in order to reduce the parabolic effect time has on pollinator activity, and therefore on their abundance. For the analysis, a number of parameters were taken into account that could have influenced the pollinator counts. These parameters were cloud coverage, date, temperature, time, and vegetation height, which all have been incorporated into the statistical models to validate the outcome of the model.

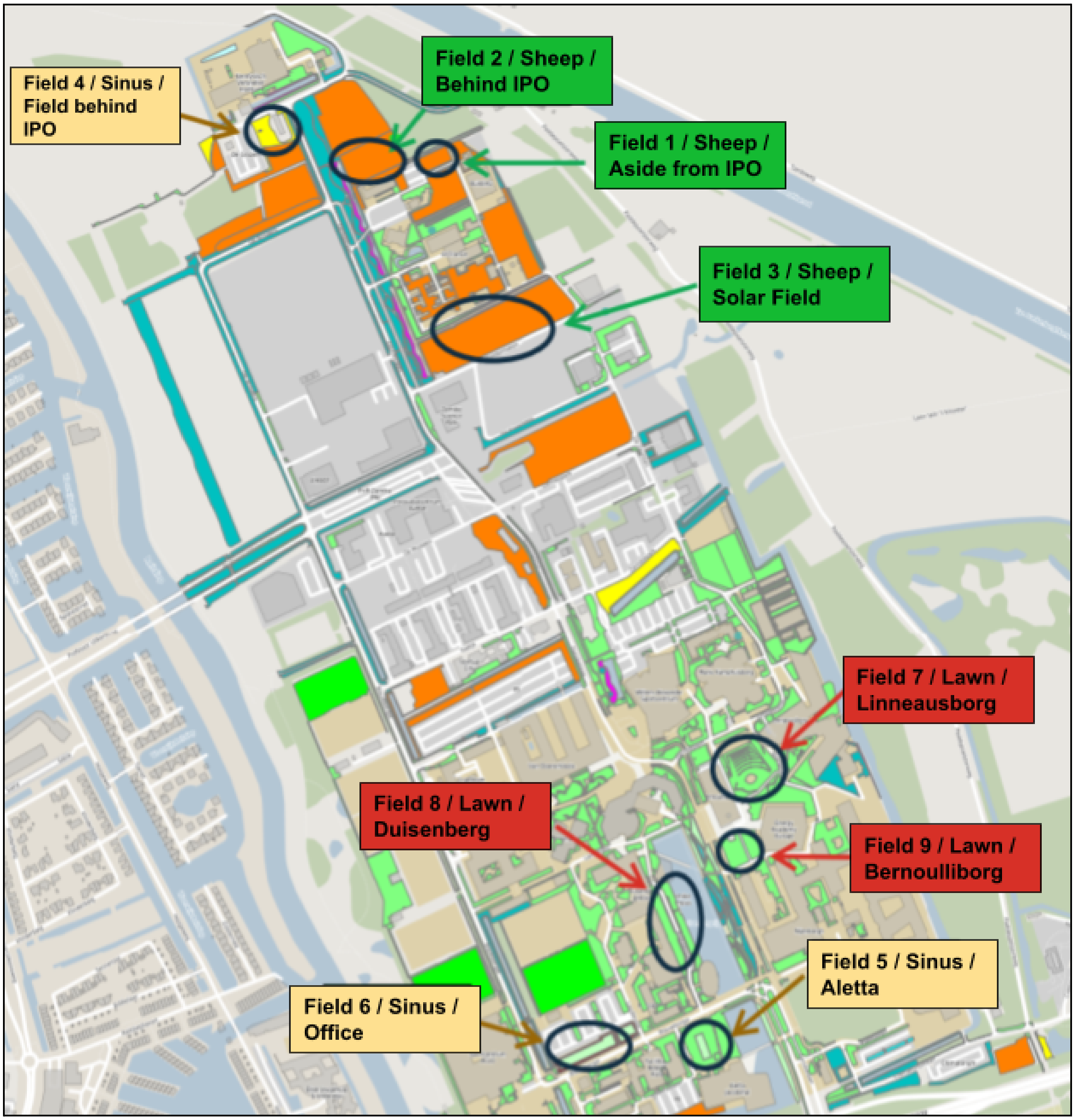

Figure 1: *Allocation of the 9 fields indicated by the grassland management strategy. In green textboxes, fields grazed by sheep. In yellow textboxes, use of sinus management. In red textboxes, lawns with weekly mowing.*

4 | Results

4.1 | Highest total pollinator abundance under sinus management

In total, 1378 pollinators have been encountered during 5 days of measuring. In Table 1, the total abundance of bees, hoverflies, and bumblebees is listed combined with the total diversity of butterfly species with their respective abundance, per management type. The highest abundance of pollinators was found in fields with sinus management (827 pollinators), followed by sheep grazing (488 pollinators), and the lowest pollinator abundance has been found on the lawns (63 pollinators).

Total counts

	Butterfly		Bee	Hoverfly	Bumblebee
Sheep	Species	Count	Count	Count	Count
	Aglais io	19	132	138	57
	Aglais urticae	13			
	Anthocharis cardamines	28			
	Araschnia levana	7			
	Autographa gamma	4			
	Gonepteryx rhamni	5			
	Lycaena phlaeas	4			
	Pararge aegeria	4			
	Pieris napi	17			
	Pieris rapae	54			
	Spilosoma lubricipeda	1			
	Vanessa atalanta	5			
	Total	**161**	**132**	**138**	**57**
Sinus	Species	Count	Count	Count	Count
	Aglais urticae	4	363	204	110
	Algais io	6			
	Anthocharis cardamines	14			
	Autographa gamma	8			
	Gonepteryx rhamni	3			
	Lycaena phlaeas	8			
	Macroglossum stellatarum	2			
	Pararge aegeria	3			
	Pieris napi	57			
	Pieris rapae	40			
	Vanessa atalanta	5			
	Total	**150**	**363**	**204**	**110**
Lawn	Species	Count	Count	Count	Count
	Lycaena phlaeas	2	25	27	9
	Total	**2**	**25**	**27**	**9**

Table 1: *All encountered pollinators per management strategy.*

4.2 | Variance between pollinator species in their effect on management strategies

Management type has a significant (*P<0.001*) positive effect on hoverfly abundance (*Figure 2A*). The slope of the effect of management has a value of 5.901. The temperature has a negative effect (*P=0.163*) on hoverfly abundance. Management type is the best explanatory variable of the model for hoverfly abundance. Sinus management has the highest positive effect on hoverfly abundance, followed by grazing management.

Management type is the only variable that has a significant (*P<0.001*) positive effect on bee abundance (*Figure 2B*). The slope of the effect of management has a value of 12.169. Management is the only explanatory variable of the model that has a significant effect on bee abundance. Sinus management has the highest positive effect on bee abundance, followed by grazing management.

Management type has a significant (*P<0.001*) positive effect on bumblebee abundance (*Figure 2C*). The slope of the effect of management has a value of 3.404. Time has a positive effect (*P=0.075*) on bumblebee abundance. Management type is the best explanatory variable of the model for bumblebee abundance. Sinus management has the highest positive effect on bumblebee abundance, followed by grazing management.

Management type has a significant (*P<0.001*) positive effect on butterfly abundance (*Figure 2D*). The slope of the effect of management has a value of 3.885. The temperature has a significant positive (*P=0.041*) effect on butterfly abundance. This effect is weaker than the effect of management type. Management and temperature are the best explanatory variables for butterfly abundance. Sinus management has the highest positive effect on butterfly abundance, followed by grazing management.

To conclude, management type has significant positive effects on the abundance of all pollinator species. The explanatory variables differ between species, which indicates different responses to management type and field conditions for each pollinator species. The effect of management type has the strongest influence on bees (12.169), followed by hoverfly (5.901), butterfly (3.885), and the lowest influence on bumblebee (3.404) abundance.

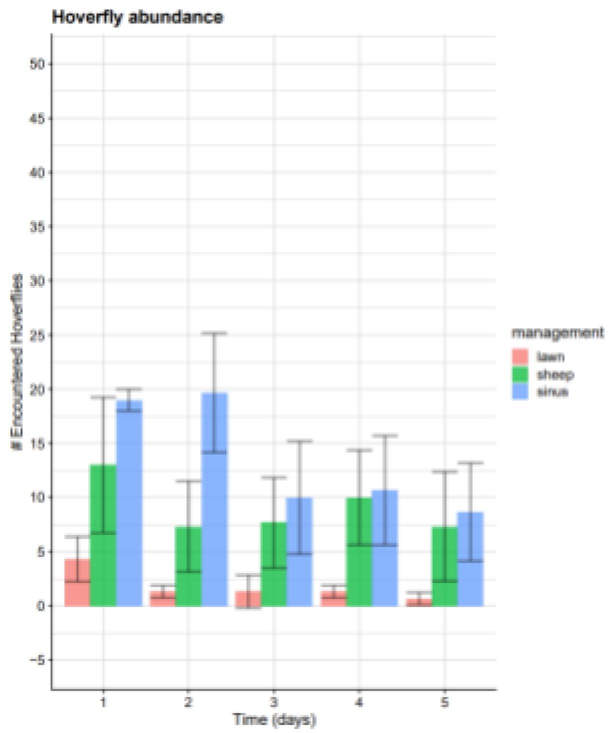

Figure 2A: Hoverfly abundance under the 3 management strategies

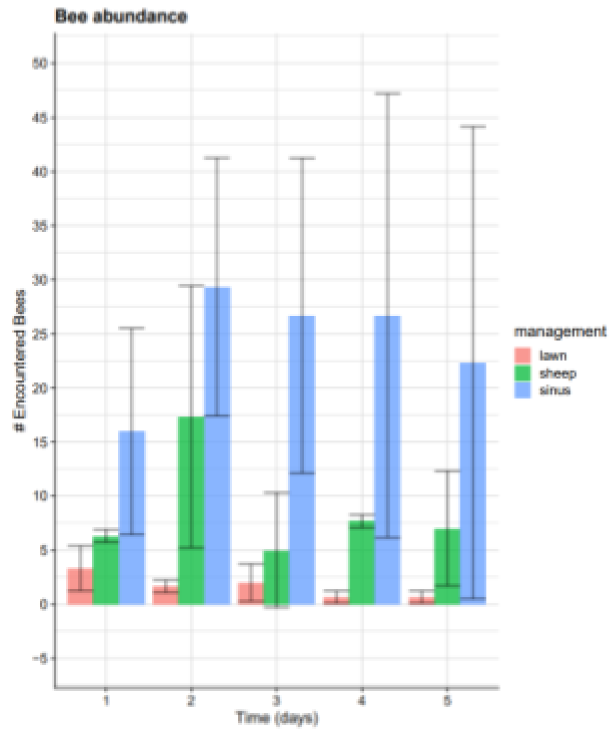

Figure 2B: Bee abundance under the 3 management strategies

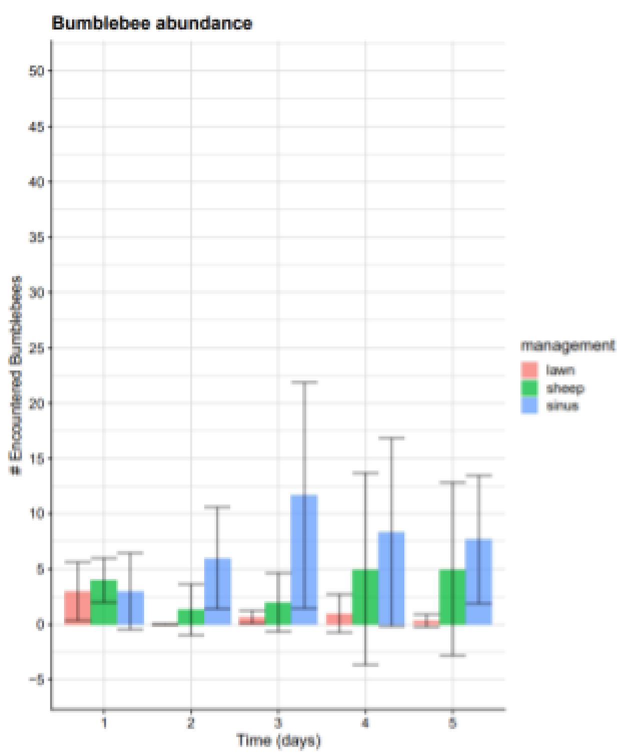

Figure 2C: Bumblebee abundance under the 3 management strategies

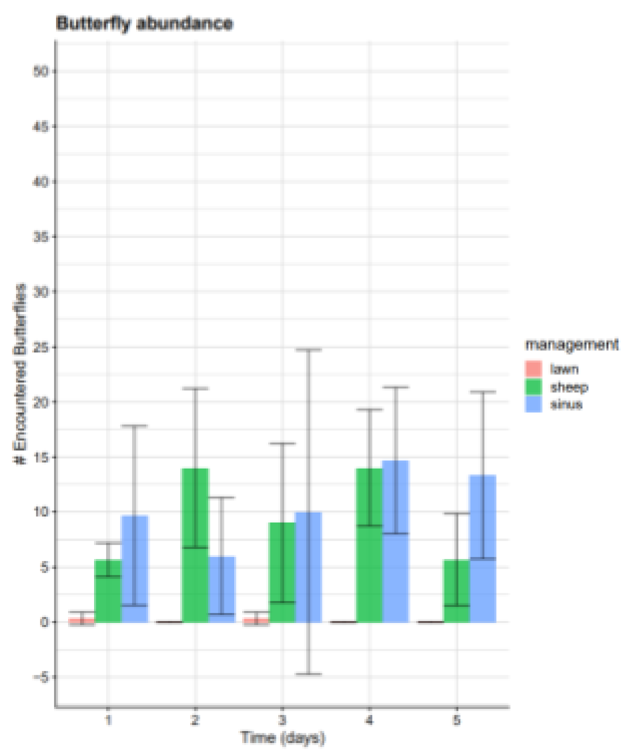

Figure 2D: Butterfly abundance under the 3 management strategies

4.3 | Management, day, and their interaction have a significant effect on vegetation height

Management (*P=2.2e-16*), day (*P=2.2e-16*), and the management:day interaction (*P=4.021e-09)* all have a significant influence on the vegetation height for each field. In sinus management, there was a higher variance in the vegetation height within the fields. Sinus and sheep management increased in vegetation height over time, while lawns kept a vegetation height of roughly 5cm tall (*Figure 3*).

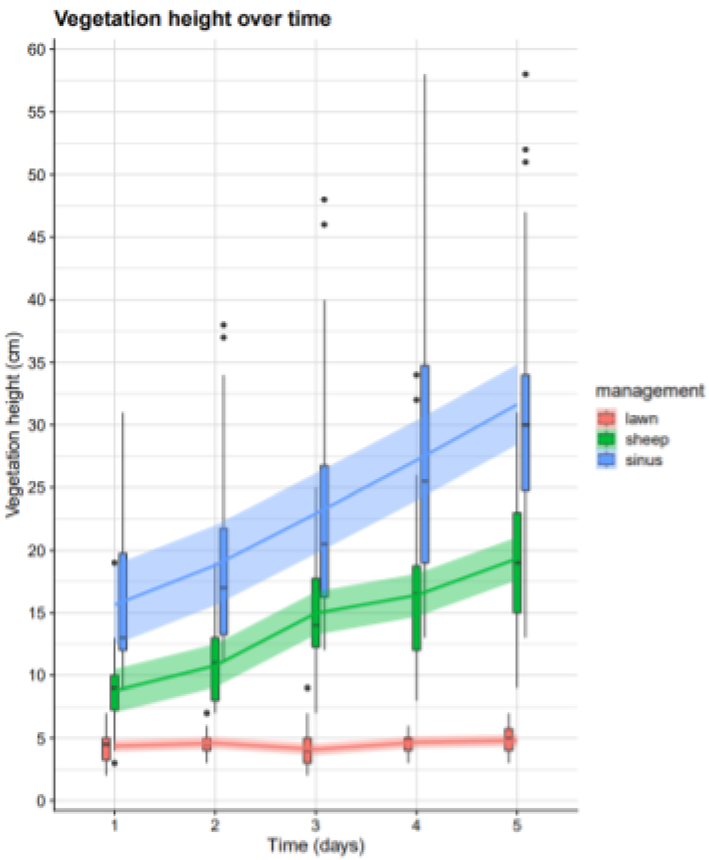

Figure 3: Vegetation height over time for each management type

4.4 | Highest biodiversity under sheep management

For calculating the Shannon-Wiener Index, data of the total number of encountered butterfly species with their respective abundance under the different management strategies was used. This resulted in the highest Shannon-Wiener Index for grazing by sheep (*2.0223*), followed by Sinus management (*1.8070*). Lawn management (*0.000*) has the lowest Shannon-Wiener Index, with only one butterfly species (*L. phlaeas*) encountered (*Table 1*). Based on the observed data, grazing by sheep yields the highest butterfly biodiversity, followed by sinus management and weekly lawn mowing yields the lowest biodiversity.

5 | Discussion

To conclude, the research question; “Does the intensity of mowing affect pollinators in urban grasslands, and if so, what management type yields the highest abundance and biodiversity?” is considered answered. The results show different effects of management type on pollinators in urban grasslands. The intermediate-frequency disturbance by sinus management shows the highest significant positive effect on the abundance of bees, bumblebees, hoverflies, and butterflies, compared to sheep and lawn management. The low-frequency disturbance by sheep management results in the highest Shannon-Wiener index, indicating the highest butterfly biodiversity of the management strategies in this study. The high-frequency disturbance by weekly mowing of the lawn results in the lowest pollinator abundance as well as diversity. The hypothesis is partly accepted; under intermediate disturbances of sinus management, there is a higher pollinator abundance. However, low-frequency disturbances by sheep seem to yield the highest pollinator diversity, when taking the butterfly species richness into account.

The height of the vegetation seems to have a parabolic effect on the influence of pollinator abundance. This result could be due to the absence of pollinators in the sheep and sinus fields or either they were not visible due to the height of the vegetation. The vegetation height seemed too low under lawn management and flowering plants did not get the chance to flower before they were mown. The lawns were weekly mowned, which contributes to a 2.5 times lower number of flowering plants, compared to mowing once a week (Lerman et al., 2018). Under sheep and sinus management it was observed that due to differences in growth speed within the vegetation, some of the flowering plants were outcompeted by the faster increase in height of other plant species, also described in the paper of Dylewski et al. from 2019. This results in lower plant diversity and results in a negative effect on pollinator abundance (Dylewski et al., 2019).

Through time there were also a lot of changes visible within the fields. Not only did the vegetation grow in height over time, but there were also noticeable differences in the timing of the flowering stage between different plant species. This affected the pollinators observed within the fields and the abundance of specific species. For example, bumblebees were observed to be present at a specific plant; *Symphytum officinale,* however, no statistical data was collected to prove this. During the flowering stage of this plant, a lot of bumblebees were observed on or near this flower. This corresponds to the paper of (Baracchi, 2019) where it is stated that pollinators can adapt to certain flowers based on their shape, size and color. These pollinators show preference for the learned flower even though other flowers might be equally rewarding (Baracchi, 2019). Therefore, plant species might also show an effect on the abundance of a specific pollinator group or species. Plant species could be an explanation for the higher number of counts for one pollinator group in a specific field, due to the presence of a preferred flowering plant species. This could also help explain the variances within the management type, due to differences in the presence of flowering plant species.

The Shannon-Wiener index showed the highest butterfly diversity under the management of sheep. Nettle (*Urtica dioica*) was present on these fields and not eaten by the sheep as other plants and grasses were. As described, the nettle provides an important habitat for butterflies as they provide places to lay their eggs and food for these pollinators (Donnelly, 2022). In our research, the Shannon-Wiener index was completely determined by the diversity of butterflies. Butterflies are a good indicator for the diversity of other pollinators (UKBMS, 2023). The presence of nettle in sheep-managed fields could explain part of the highest butterfly diversity under sheep management compared to sinus, and lawn management. However no scientific literature was found in which sinus and sheep management were compared in their pollinator diversity.

In this study three management types were compared with each other, however, sinus management showed the highest significant positive effect on the abundance of all encountered pollinator groups. Even though sheep management showed the highest butterfly diversity, this is only based on one group of pollinators. It would be interesting to compare different sinus fields with one another. The sinus fields showed a lot of variation within the height, but also the number of pollinators counted per group. Future research should not only focus on the vegetation height and the number of accounted pollinator species but also gather information regarding plant species composition and the abundance of flowers and flowering plants throughout the whole study. For future research, it would be best to not only look at butterfly diversity, even though they are a good indicator for other pollinators (UKBMS, 2023). It would be good to notate the diversity of other pollinators, to get more reliable data. Specific pollinator groups showed a preference for certain flowering species. For further protection of these pollinators, these preferences should be notated and taken into account by managing the sinus fields.

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