SOLAR PARK BIODIVERSITY: POLLINATOR ABUNDANCE IN DIFFERENT LOCATIONS WITH SEED MIXTURES

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AERES
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Biodiversity
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Voorwoord

Voor u ligt het afstudeerwerkstuk van Ilah van der Haas uit 4TBb, student op de Aeres Hogeschool Almere. Ik zou graag alle medewerkers van Naturalis willen bedanken voor de kans en de verantwoordelijkheid om me in te zetten voor een groot onderzoeksinstituut en te werken met bestuivers. Ik dank Koos Biesmeijer en Lisette van Kolfschoten voor hun kennis en vertrouwen. Ook wil ik mijn supervisor Roy Veldhuizen bedanken voor het geduld en het vertrouwen in mij als persoon.

Samenvatting

Steden groeien steeds sneller en zorgen in veel gevallen voor een gefragmenteerd landschap, waar de biodiversiteit onder lijdt. Er zijn verschillende dieren die zich aan kunnen passen aan de verstedelijking, zoals insecten. Wereldwijd gaat het erg slecht met de insecten en verschillende studies tonen daling aan. Insecten zijn onmisbaar vanwege hun belangrijke rollen in ecosystemen, zoals het bestuiven van natuurlijke maar ook gekweekte gewassen. Veel bijen zijn hier verantwoordelijk voor. Door de verandering van het landschap gaat het slechter met bijen, maar er zijn plekken die voordelen kunnen bieden. Een goed voorbeeld hiervan zijn zonneparken. Wereldwijd groeit de markt in de bouw van zonneparken en veelal zijn deze grootschalig en grondgebonden. Een voorbeeld hiervan is Shell Moerdijk in Noord-Brabant. Om de biodiversiteit te verbeteren in het park zijn zaadmengsels met bloemdragende planten uitgezaaid. Deze studie heeft hierna gekeken welke bijen er leven en of er verschil is tussen verschillende locaties waar zij voorkomen. Het bleek dat er een locatie was waar de hoeveelheid bijen groter was dan de rest van de locaties, maar dit lag niet aan de zaadmengsels. Er is meer tijd nodig om de zaadmengsels te laten ontwikkelen. In de toekomst moeten meer studies uitwijzen of deze mengsels effect hebben op het voorkomen en de hoeveelheid van de bijensoorten in het zonnepark.

Abstract

Urban areas are growing faster and in many cases create a fragmented landscape, threatening biodiversity. There are numerous organisms that can adapt to urbanization, such as insects. Multiple studies show a worldwide decline in their numbers. Insects are indispensable because of their important ecosystem services, such as pollinating natural but also cultivated crops. Many bee species fulfill this role. Bees are declining due to the change of land use, but there are urban places that potentially benefit them, providing foraging and nesting sites. One of these examples are solar parks. The worldwide market for the construction of solar parks is growing and these are often large-scale and ground-mounted. An example of this is Shell Moerdijk in Noord-Brabant. To improve biodiversity in the park, seed mixtures with flowering plants have been sown in selected areas. This study focused on which bees can be found and if there is a difference in locations where they occur. It was found that there was one location where the amount of bees was greater than the rest of the locations, but the seed mixtures were not likely to be a factor in this. More time is needed for the seed mixtures to develop. In the future, more studies should show if there is any effect of the mixtures on the abundance of the bee species in the solar park.

Content

H1: Introduction

Urban areas are growing twice as fast on average compared to their human population densities, creating fragmented habitats and threatening biodiversity (Seto, Guneralp, & Hutyra, 2012). One of the groups affected are pollinating insects; almost 40% of invertebrate pollinators are or were at risk of extinction, of which some might already be extinct by now (IPBES, 2016). Providing a vital ecosystem service like pollination, their existence is essential and indispensable (Hallmann et al., 2017).

In the last couple of decades, more attention has been drawn to the importance of invertebrates and their abundance. Multiple recent studies show a rapid decline in invertebrate species globally (Goulson, Nicholls, Botías, & Rotheray, 2015; Hall & Steiner, 2019; Hallmann et al., 2017; Potts et al., 2010; Sánchez-Bayo & Wyckhuys, 2019). The probable main drivers behind these declines were shown to be habitat loss, pollution, biological factors (like pathogens and introduced species) and climate change, all deriving from human activity as main source (Hall & Steiner, 2019; Mupepele et al., 2019; Sánchez-Bayo & Wyckhuys, 2019; Wagner, 2019). With invertebrates being responsible for numerous ecosystem services, preserving their abundance and diversity should be a top conservation priority (Hallmann et al., 2017).

One of these important ecosystem services is pollination. Although abiotic factors play a role, many different animal species provide this service. The biggest group is dominated by pollinating insects, consisting of roughly 280000 species (Nabhan & Buchmann, 1997). They are responsible for pollination of nearly 90% of flowering plants worldwide (Hall & Steiner, 2019; Ollerton, Winfree, & Tarrant, 2011). Among this group of insect pollinators are hoverflies and bees. Bees are widely used in agriculture for pollinating edible crops and for the production of honey, which are important human food sources. Only a few species are managed, like *Apis melifera* (honey bee), some bumble bees and a few other bee species. It is a largely unknown fact that the majority of pollinator species are wild, and more than 20000 of these species are bees (IPBES, 2016).

Bees can be classified as either eusocial or solitary. Most bees build their own nests, as while some solely depend on hosts to rear their young. Nest-building bees are mostly ground nesting and collect nectar and pollen from plants; nectar is mostly used as a fuel for bee-activity and pollen are gathered as protein source for larvae. Polylectic bees forage on a wide variety of plant families, whereas oligolectic bees are highly specialized, visiting only one species or a closely related plant group (Crane, 1990; Denisow, 2011; Westrich, 1996). Bees have a close relationship with hoverflies, as some species are parasites of their nests or larvae and could serve as indicators. These insects mostly forage on flowers for their own consumption and are also important for pollinating, since they do not have a nest and can travel long distances (Reemer et al., 2009).

Due to their species richness and variety of habitat preferences, hoverflies and bees might find good conditions for nesting and foraging sites in semi-natural and rural habitats. Many examples include railway banks, field margins, farmsteads or even urban gardens (Denisow & Wrzesień, 2015; Westrich, 1996). A similar pollinator-friendly environment could be provided by ground mounted solar parks. Due to their open, often undisturbed sparsely vegetated sandy soil, they could serve as potential habitat for many ground nesting bees (Westrich, 1996).

With the energy transition on the rise, solar power is getting more attention. In 2018 alone, the installed Dutch solar PV capacity grew with 46%, which is twice as fast compared to the growth of the market worldwide. With the prices of solar panels in Europe lowering every year, it is expected that this trend will continue (Zee et al., 2019). Even though the use of roofs for installing solar panels could be very space efficient, most of these instalments are ground mounted large-scale solar farms. These farms are big; some take up dozens of hectares of land (Montag, Parker, & Clarkson, 2016). In the Netherlands there is a debate about the use of installing these farms, due to the country's scare open space. Others argue about the negative impact that the solar farms might have on the scenic beauty of the landscape (Zee et al., 2019). However, the reduction in the intensity of agricultural activities in these farms could create a great botanical diversity. This could ultimately positively benefit other plant-dependent taxonomic groups, like pollinators. A study done in the United Kingdom in 2015 found that butterflies and bumblebees were in greater abundance on solar farms than on selected control plots outside of the solar farms, especially where botanical diversity was also high (Montag et al., 2016).

An example of these solar parks is Shell Moerdijk. With 76000 solar panels covering 39 hectares of land, it is one of the biggest solar parks of The Netherlands. The park was officially opened on the 14th of March 2019 (Shell, 2019). With lots of flowering plant species and suitable nesting sites already present in the area, there is a lot of potential for wild bees and hoverflies (Figure 1 and 2). For example, there is potential habitat for *Bombus veteranus*, which is one of the rarest bumblebees to still occur in The Netherlands (Peeters et al., 2012). This species has been seen numerous times in the area surrounding the solar park, such as nature reserve the Biesbosch (Appendix 3). In between the years 2000 and 2017, at least 30 species of bees were observed in the area, with the potential for around 154 bee species (Nederland Zoemt, 2017). At least 2 of these species are marked as "Sensitive" on the Dutch Red List of Bees (Reemer, 2018). These observations were done before the solar park was installed. It is unclear how many bee and hoverfly species are still present and whether new species have settled in the area.

Figure 1: Sandy soil under solar panels in March

Figure 2: Undergrowth with flowering plants in June

Shell wanted to contribute to the biodiversity in solar park Shell Moerdijk. Multiple studies have shown that sowing different flowering plant species in solar parks will enhance biodiversity (Montag et al., 2016). Therefore, different seed mixtures with different kinds of flowering plants were created and sown in assigned plots in March 2019. Selected control plots which were not sown were raked only (Haas, 2019).

In the present research project, the viability of the Moerdijk solar park for enhancing and preserving pollinating species will be studied. The aim was to determine if the abundance of bee and hoverfly species found in the park is a result of the conditions of each individual location. To test if they have any effect on the pollinators in the area, it is important to know which flowers are visited by pollinators, and if these were in the mixture. It is also important to know where in the park the pollinators are found. A long-term monitoring of the background bees and hoverflies on different locations in the solar park has to be done to determine which species are present and on which plants they are foraging. By using pan taps, colored buckets placed on the ground to lure and capture pollinators, it can also be determined which color they are attracted to. This could be an estimation which flower color and thus which plants these pollinators prefer. It is also a very efficient method for collecting and identifying species in a certain location (Vrdoljak & Samways, 2012). The outcome of this study can be used to create and improve mixtures of plants for solar parks for other organizations, for enhancing biodiversity and to provide insights in the relationships of plants and pollinators. Future repeating studies must be undertaken to monitor the plants and bees in the park, to provide evidence of the effect of these seed mixtures.

This study will focus on the bee and hoverfly diversity and abundance in the ground mounted solar park of Shell, Moerdijk. Therefore, the following research question is proposed:

- Which bee and hoverfly species can be found in the solar park of Shell, located in Moerdijk and does the location where they are found in the park have an effect on their abundance?

To support these questions, a few additional questions are proposed:

- What species of bees and hoverflies can be found in solar park Shell Moerdijk?
- Which location shows the highest bee and hoverfly diversity?
- Which location shows the highest abundance of bee and hoverfly species?
- Which plants do the bees and hoverflies forage on inside the solar park and which species is most visited?
- Which flower color is most attractive to bees and hoverflies present in the solar park?

The flowering plants already present in solar park Shell Moerdijk were not documented before, so it is unsure what plants will be visited. Overall, plants in the families *Boraginaceae* and *Lamiaceae* have the best pollination potential, while plants in families *Fabaceae*, *Asterceae* and *Apiaceae* have an intermediate potential (Ion, Odoux, & Vaissière, 2019). Multiple bee species tend to depend on plants of the *Fabaceae* family, for example species in the genera *Trifolium* and *Lotus* (Peeters et al., 2012). The location with mixture Green Manure contains plants from those genera, so these plants are expected to be visited the most if they emerge and flower (Appendix 1 and 4). Locations with bare sand and less undergrowth are not expected to have a lot of foraging visitors, but bees might be seen searching for nesting sites. Pan taps placed in these areas stand out since there are very few flowers available and might still catch some bees. It is expected that the location with the thickest vegetation will have the highest abundance. The control plot might vary greatly with the mixture plots in visiting pollinator species, depending on the melliferous weeds that might already grow in the area. It is expected that the control plot will not have more visiting pollinator species than the plots with seed mixtures, rather slightly less. These expectations completely depend on the growth of the plant seed mixtures and there is a big chance that the seeds do not germinate at all. The soil can be too dry, the present weeds can outcompete the seeds for space, the weather can be unsuitable for a long period of time and the seeds can also be eaten by animals. In terms of flower visits, hoverflies have been found in great abundance on the blue colored *Centaurea* *cyanus* and on the orange/red *Papaver rhoeas*, two flowers present in the seed mixtures. They also tend to forage on yellow colored flowers (Hoyle et al., 2018). Thus, it is expected that they will be found most in blue and yellow pan traps. Since bumblebees are large and are very sensitive to subtle differences of colors, it is likely that there will be less of them caught in the evenly colored pan traps than bees and hoverflies (Lunau, 2016). Bees are most attracted to the colors white, yellow, blue and violet, so it is hard to determine which pan trap color will attract the most bees. Thus it is expected that there might be an even distribution of preferred pan trap colors (Pereira, da Silva, Goldenberg, Melo, & Varassin, 2011). Expected bee species that have been seen in the area surrounding the solar park are listed in Appendix 3. Expected bee species that have been seen interacting with plants from the mixtures are listed in Appendix 4. There could be at least 30 species of bees in the solar park, with *Bombus veteranus* not being likely to occur (Nederland Zoemt, 2017).

H2: Materials & Methods

2.1 Study site

The study site concerned the Shell solar park next to the Shell Moerdijk chemical complex, located in Moerdijk, province Noord-Brabant, the Netherlands. This park contained rows of solar panels covering 39 hectares. For this study, the area was subdivided into 7 replica sections A to G (Figure 3). Section H has not been used for this study. In each of the sections A to G, 6 square plots of 20 by 20 meters were assigned, of which 5 were used for sowing of different seed mixtures and 1 control in a random order (7x6=42 plots in total, covering 16,800 m2 of study area). Inside all sections, different soil types and present vegetation are described (Table 1).

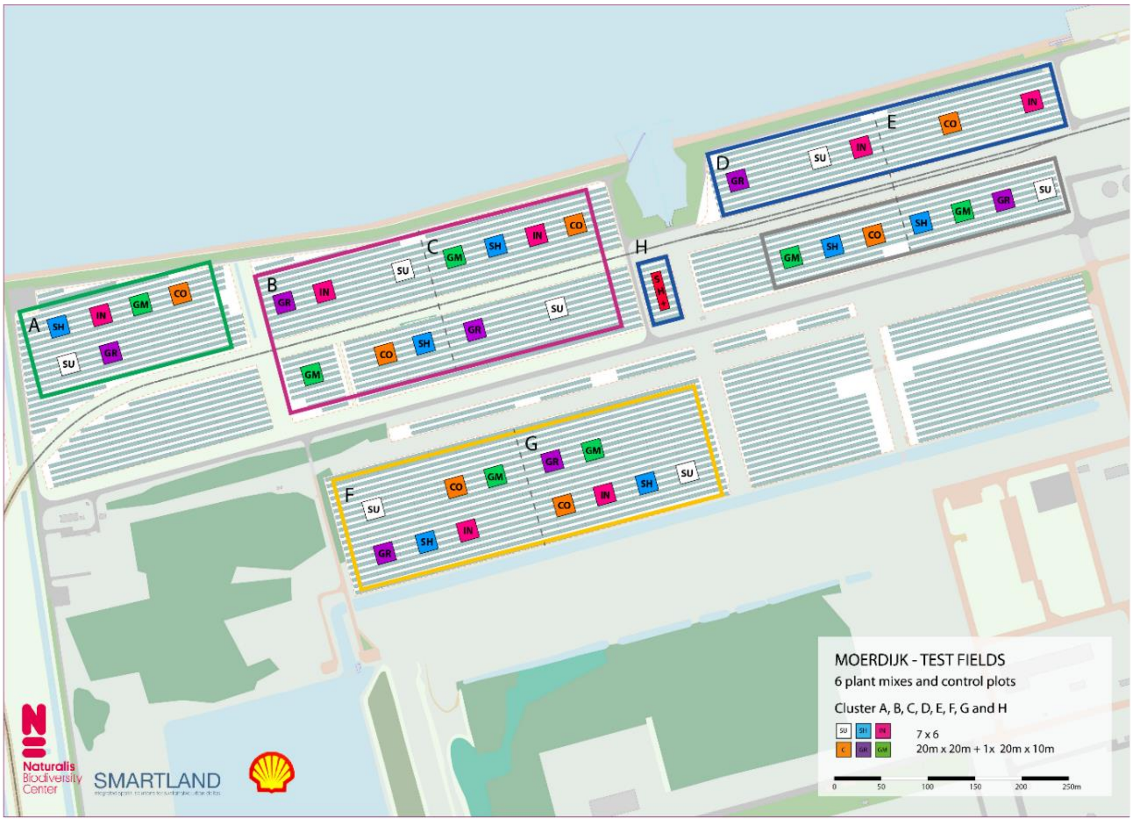

Figure 3: Map of Shell Moerdijk solar park

Table 1: Soil types in the solar park sections

Sections	Rectangle color	Soil type	Vegetation
A	Green	Wet organic/sandy soil	Thick: grass and herbs
B + C	Pink	Moist to dry sandy soil	Intermediate: grass, herbs and small trees
D top + E top + H	Blue	Moist dense clayish soil	Open: grass, moss and herbs
D bottom + E bottom	Gray	Gravel and dry sandy soil	Bare: grass and herbs
F + G	Yellow	Dry sandy soil	Open: grass and herbs

2.2 Shell safety precautions

Because of the solar park being located next to the oil refinery of Shell, strict safety precautions were made before anyone entered the study area. The main rules are listed below.

2.2.1 Before entering the area

All people involved needed to bring a passport, ID-card or driver's license for identification at the reception desk. Researchers requested a red Shell pass for being able to check in and out of the Shell area daily. To require this pass, it was necessary to attend a four hour safety briefing, watch a 15 minute safety video and pass the safety test that is taken right after watching. Red pass holders were able to bring volunteers who could acquire visitor passes, after identification and passing the safety test. Visitor passes allowed the volunteers to check in and out of the Shell area on the day of issue.

2.2.2 Safety briefing

Before entering the study site, all people involved would first be escorted to the shack owned by Brass Fijnaart (gardening and landscaping company working for Shell) for a safety briefing. Volunteers were handed over a map of the area and the field activities were explained in detail. The researchers provided safety equipment for everyone involved. This included a safety reflective vest, safety glasses, a helmet, shoes with steel toecaps and working gloves.

2.2.3 Inside the park

Inside the solar park everyone needed to wear long sleeves, a safety reflective vest, safety glasses, a helmet and shoes with steel toe caps at all times. Work gloves were provided but not obligatory. Use of mobile phones and taking pictures was prohibited anywhere near the chemical complex, but in the solar park. Pictures taken in the solar park were not allowed to be posted anywhere on social media.

2.2.4 Transport

Transport in the area was mostly done on bikes owned by Shell. Keys for bikes were obtained at the reception desk, by showing a red pass or visitor pass. Heavy or large items were brought to the field by car with the help of Brass Fijnaart. Red pass holders were allowed to register one car on their pass so they could enter the area by car.

2.3 Plots with seed mixtures

To test the growth of different plants for pollinators in the solar park, different seed mixtures were created and distributed between March 20 and March 25 2019 (Appendix 1 and 2). These mixtures were created with the help of the database of Dr. Arie Koster, an expert on Dutch wild bees and native plants who created a database of 1500 native plants, which indicates the plant attractiveness level to pollinators. The websites www.drachtplanten.nl and www.wildebijen.nl were used for looking up interactions between plants and bees. Results were compared with current wild bee observations in the surrounding area on www.waarnemingen.nl and a wild bee-plant interaction database of EIS, the European Invertebrate Survey in the Netherlands.

2.3.1 Mixtures

The seed mixtures created in March 2019 were: Diverse Grasses (GR=purple), Green Manure (GM=green), Eco Sun (SU=white), Eco Shade (SH=blue) and Industrial (IN=pink) (Figure 3). Each mixture contained seeds of 6 different flowering melliferous plant species, except for Diverse Grasses, which contained seeds of 6 different grass species (Appendix 1 and 2). Diverse Grasses was created with the idea that grassland without flowering plants is not attractive for pollinators. Green Manure was created with species that enrich the soil and therefore make it more suitable as arable land after the solar panels are removed. Eco Sun and Eco Shade are created with native plant species which grow around the area of Moerdijk, which prefer sunlight or shade, are attractive to bees and grow well on sandy soil. Industrial reflects a standard mix with species known to be attractive to pollinators, similar to the commercial Tübinger mix (Hofman, 2019).

2.4 Periodical visits

5 plots with all different plant mixtures will be visited twice roughly every 2 weeks from April 23 until July 10, when it was not raining within 24 hours and when the weather is good for monitoring (Pollard & Yates, 1993) (Figure 4). These visits were done to monitor and collect the background bees and hoverflies in the solar park area.

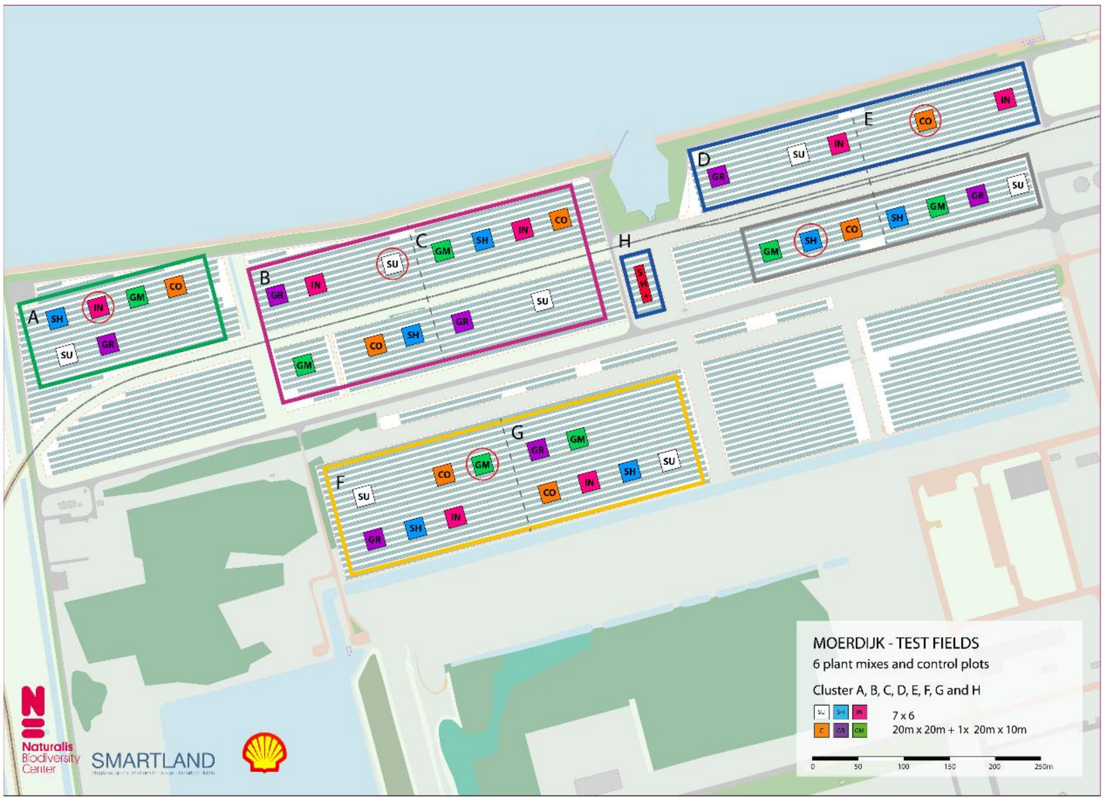

Figure 4: Locations of monitoring and pan trap placements (encircled)

2.4.1 Pan traps

During the visits pan traps were used for collecting pollinators (Vrdoljak & Samways, 2012). These traps were blue, yellow and white colored small buckets placed on the ground and contained a 2-finger tall layer of water with a drop of neutral soap. Bees and hoverflies would mistake them for flowers, fly in and drown due to the disappeared surface tension of the water, created by the soap (Figure 5). Using every color twice, 6 traps were placed on sunny soil, 6 on half-shady soil and 6 in the shade underneath the solar panels in every plot (Figure 6). In total 18 pan traps were placed per plot 5 times resulting in 90 pan traps per visit.

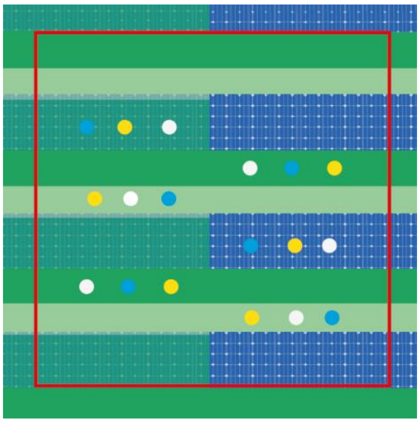

Figure 5: Pan trap with insects

Figure 6: Placement of pan traps in plot

The pan traps were collected the next day, roughly within 24 hours. Bees and hoverflies were picked out by hand and placed in a plastic collecting tube. On the tubes the date, time, pan trap color and number, section, mixture, treatment, weather and temperature was written. The tubes were brought to the shack of Brass Fijnaart and there they were filled up halfway with 70% alcohol and shaken well to clean the insects. They were filtered out the tubes and blow dried with a tea strainer, pinned inside an insect collector box with insect pins and taken to Naturalis in Leiden for further identification.

2.4.2 Bee monitoring

On both visiting days, a 15 minute monitoring was done in each plot conform conditions of the British Butterfly Monitoring Scheme (Pollard & Yates, 1993). Below 13 °C, transects were not walked. Between 13 and 17 °C, there should be at least 60% sun and above 17 °C transects were walked in any weather condition as long as there was no rainfall. In each plot 3 transects of 20m were walked for 5 minutes. During the monitoring, a butterfly net was used. Within 5 meters of eyesight and within the boundaries of the plot, bee or hoverfly species and visited flowering or non-flowering plant were noted, together with the section, mixture, date, time, weather and temperature. If the species could not be identified, if possible, the bee or hoverfly was caught and put in a plastic collecting tube with a cotton ball drenched in ethyl acetate. If there was no ethyl acetate available, collected insects were put in the freezer overnight and treated with the cotton ball of ethyl acetate the next day. All bees and hoverflies were pinned in the same box as the individuals caught with pan traps.

2.5 Identification

The insects were identified in a process room at Naturalis in Leiden using a Zeiss zoom light microscope and with the help of the following books: "Natuur van Nederland 11: De Nederlandse Bijen" (Peeters et al., 2012), "Veldgids Bijen voor Nederland en Vlaanderen" (Falk, 2017) and "Zweefvliegen van Nederland en België" (Schulten, 2018) (Figure 7). Identified bee and hoverfly species were noted in a database in Excel, together with genus, sex, date, section, mixture, treatment, color, pan trap number, location (coordinates), weather and temperature.

2.6 Species data

A list of all the found pollinators is made and compared with the expected bees in the surrounding area and the mixtures. It is also documented which species are found with pan traps, monitoring or both to see if there are any differences.

Figure 7: Process room for identification

2.7 Statistical analysis

For testing the plausibility of this study, a few statistical tests were performed to ensure significant outcomes.

2.7.1 Locations: monitoring and pan traps

For testing the difference in abundance between the 5 locations with monitoring and pan traps, a chi-square test was performed in RStudio. Beforehand H0 was expected to be an equally common distribution across the 5 different locations. H1 was expected to show a significantly not common distribution. This was done for total number of pollinators and species abundance per location. Only significant outcomes were used for display in a boxplot graph. The rest of the data was put in Appendix 5.

2.7.2 Pan trap color

For testing the difference between the 3 colors of pan traps per location, a chi-square test was performed in RStudio. Beforehand H0 was expected to be an equally common distribution across the 3 different pan trap colors per location. H1 was expected to show a significantly not common distribution. This was done for total number of pollinators and for categories bumblebee, other bee and hoverfly. Only significant outcomes were used for display in a boxplot graph. The rest of the data was put in Appendix 5.

2.7.3 Flower color

For testing the difference between the 3 colors of flowers visited per location, a chi-square test was performed in RStudio. Beforehand H0 was expected to be an equally common distribution across the 3 different pan trap colors per location. H1 was expected to show a significantly not common distribution. This was done for total number of pollinators and for categories bumblebee, other bee and hoverfly. Only significant outcomes were used for display in a boxplot graph. The rest of the data was put in Appendix 5.

2.8 Plant data

To calculate which plant species were preferred and if these were from the mixture, a few calculations were done in Excel.

2.7.1 Plant preference

It was calculated in Excel which plant species was visited most per location by counting all the observations on flowers. Results are shown in a table.

2.7.2 Plants from the mixture

It was calculated in Excel which plant species from the mixtures were visited by which pollinator per location. Results are shown in a table.

H3: Results

3.1 Species data

In this section the results of all species are shown.

3.1.1 Overview species

In the graph below all species and their abundance inside the solar park are shown (Figure 8).

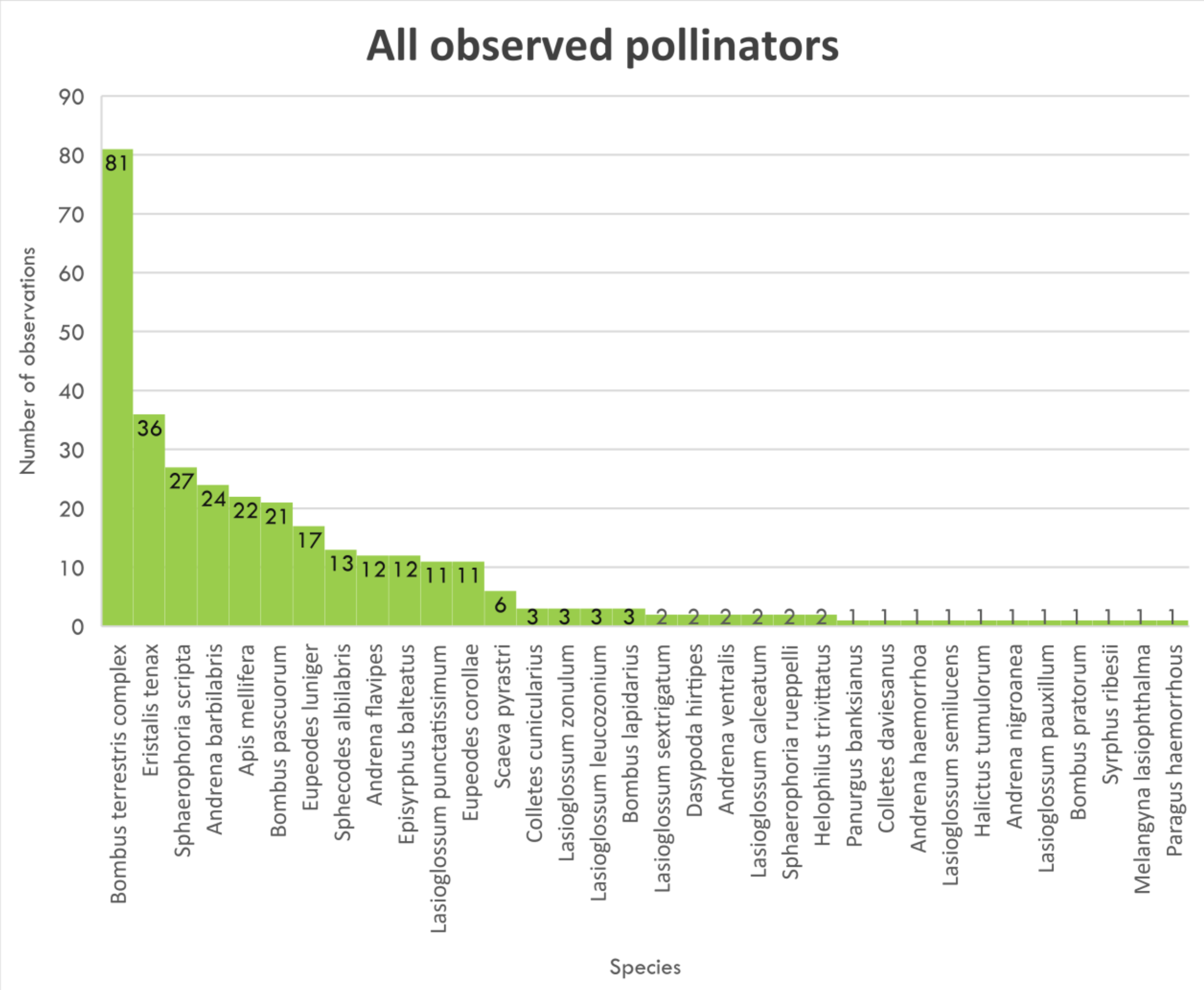

Figure 8: All observed pollinators in solar park Shell Moerdijk

In total 4 bumblebee, 19 other bee and 11 hoverfly species were found with a total number of 35 species and a total of 477 observations. The complete list can be found in Appendix 5.

3.1.2 Expected and observed pollinators

In the table below it is compared which species were expected and found or not expected and found (Table 2). In total 2 bumblebee and 9 other bee species that were expected were also found in the solar park (marked in green in Appendix 3). In total 10 other bee species who were not expected were found in the solar park. In total 4 bumblebee and 26 other bee species who were expected were not found (marked in black in Appendix 3).

Table 2: Expected and found pollinators

Expected and found	Dutch	Not expected and found	Dutch
Sphecodes albilabris	Grote bloedbij	*Andrena barbilabris*	Witbaardzandbij
Andrena flavipes	Grasbij	*Apis mellifera*	Honingbij
Colletes cunicularius	Grote zijdebij	*Lasioglossum punctatissimum*	Fijngestippelde groefbij
Lasioglossum sextrigatum	Gewone franjegroefbij	*Lasioglossum zonulum*	Glanzende bandgroefbij
Dasypoda hirtipes	Pluimvoetbij	*Panurgus banksianus*	Grote roetbij
Andrena ventralis	Roodbuikje	*Colletes daviesanus*	Wormkruidbij
Lasioglossum calceatum	Gewone geurgroefbij	*Lasioglossum semilucens*	Halfglanzende groefbij
Andrena haemorrhoa	Roodgatje	*Halictus tumulorum*	Parkbronsgroefbij
Lasioglossum leucozonium	Matte bandgroefbij	*Andrena nigroanea*	Zwartbronzen zandbij
Bombus pascuorum	Akkerhommel	*Lasioglossum pauxillum*	Kleigroefbij
Bombus lapidarius	Steenhommel		

3.2 Pan traps and pan trap color

In the boxplots below the significant data of the pan traps and pan trap color are shown. Other data is listed in Appendix 5.

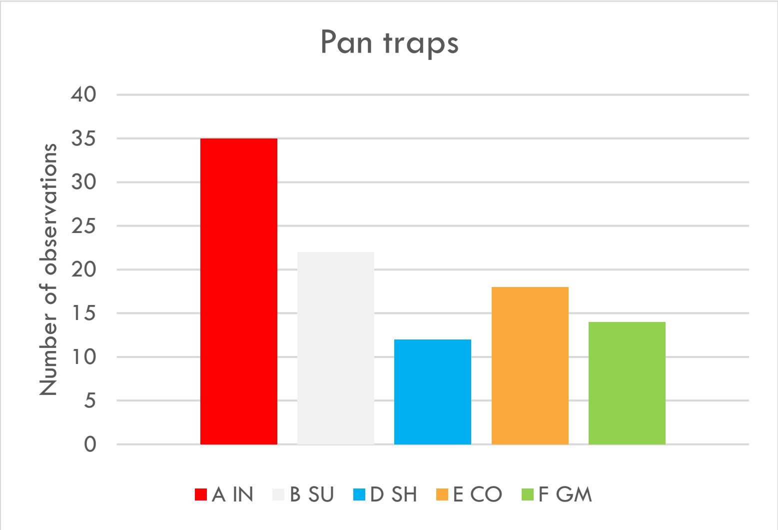

Figure 9: Pan trap observations per location

In the figure above the abundance of pollinators caught with pan traps is shown per location (Figure 9). The chi-square analysis revealed a value of p=0.00244 which shows the distribution among the locations is significantly not common. The highest abundance of individual pollinators can be found in location A IN. The lowest abundance shows to be location D SH. The abundance of species per location showed no significant difference.

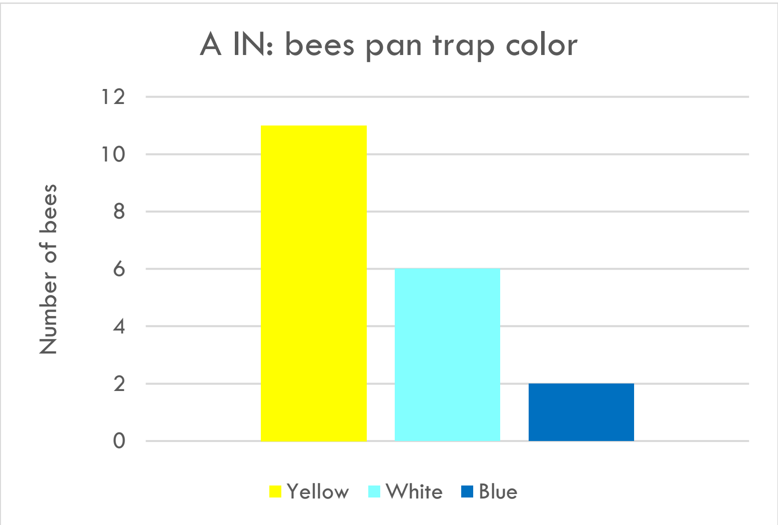

Figure 10: Pan trap color preference of bees in location A IN

In the figure above the abundance of bees caught per pan trap color is shown for location A IN (Figure 10). The chi-square analysis revealed a value of p=0.0403 which shows the distribution among the colors is significantly not common. This shows that bees in location A IN are most attracted to the yellow colored and least attracted to the blue colored pan traps. The abundance of other species per color showed no significant difference.

3.3 Monitoring

In the boxplots below the significant data of monitoring is shown. Other data is listed in Appendix 5.

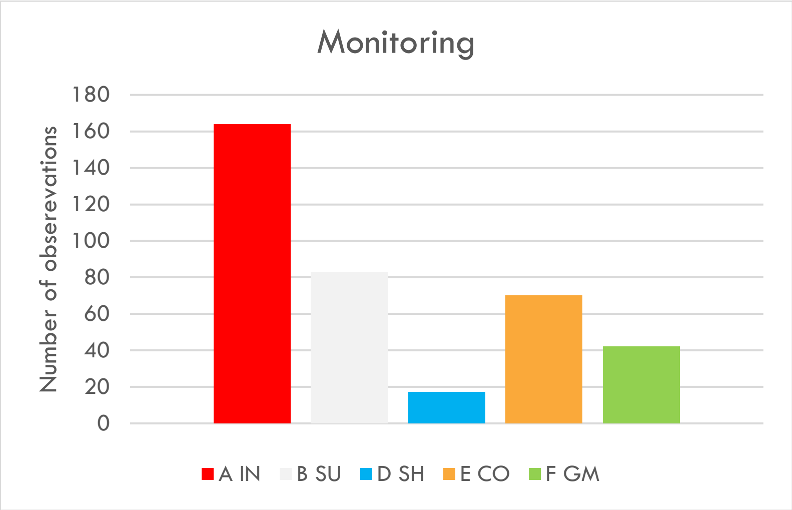

Figure 11: Monitoring observations per location

In the figure above the abundance of pollinators observed with monitoring is shown per location (Figure 11). The chi-square analysis revealed a value of p=8.63e-35 which shows the distribution among the locations is significantly not common. The highest abundance of individual pollinators can be found in location A IN. The lowest abundance shows to be location D SH. The abundance of species per location showed no significant difference. The data is listed in Appendix 5.

3.4 Pan taps + monitoring

In the boxplots below the results of monitoring and pan traps are combined.

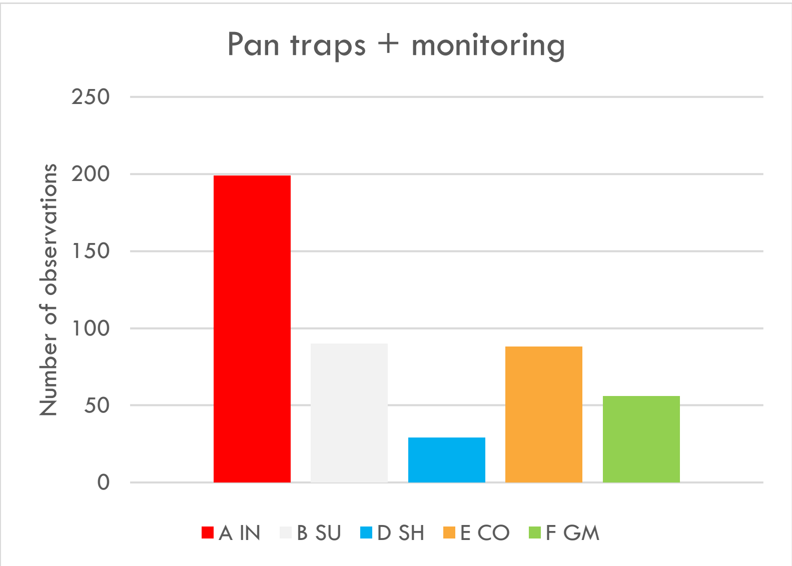

Figure 12: All observations per location

In the figure above all observations are shown per location (Figure 11). The chi-square analysis revealed a value of p=4.34e-38 which shows the distribution among the locations is significantly not common. The highest abundance of individual pollinators can be found in location A IN. The lowest abundance shows to be location D SH. The abundance of species per location showed no significant difference. The data is listed in Appendix 5.

3.5 Flower colors

In the boxplots below all significant flower color data is shown (Figure 13-17). Other data is listed in Appendix 5.

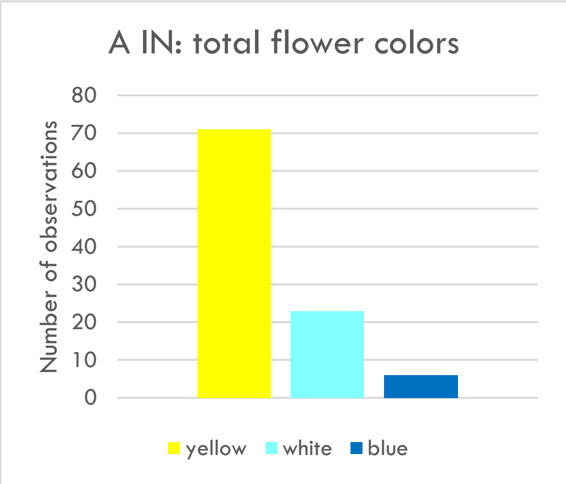

Figure 13: A IN total flower color counts (p=1.57e-15)

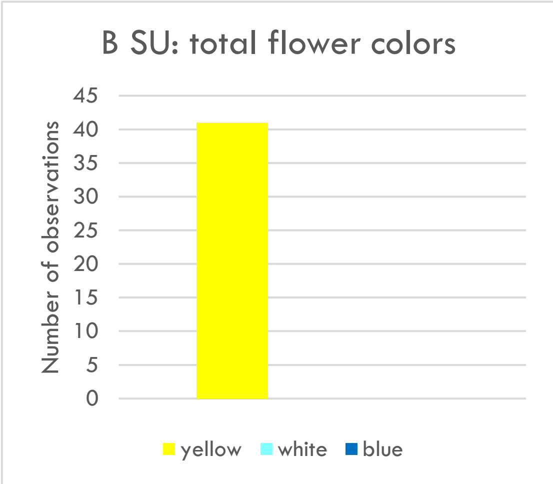

Figure 14: B SU total flower color counts (p=1.56e-18)

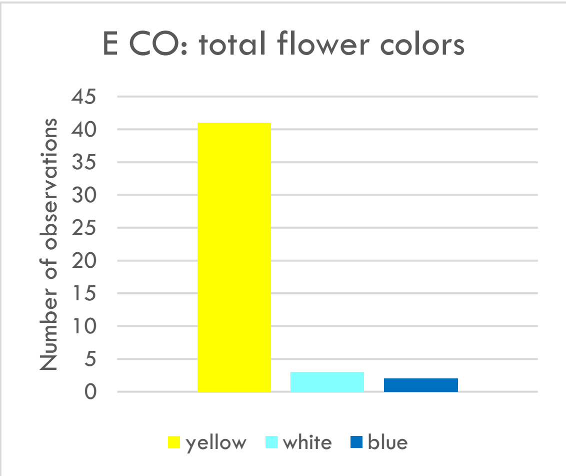

Figure 15: E CO total flower color counts (p=9.97e-15)

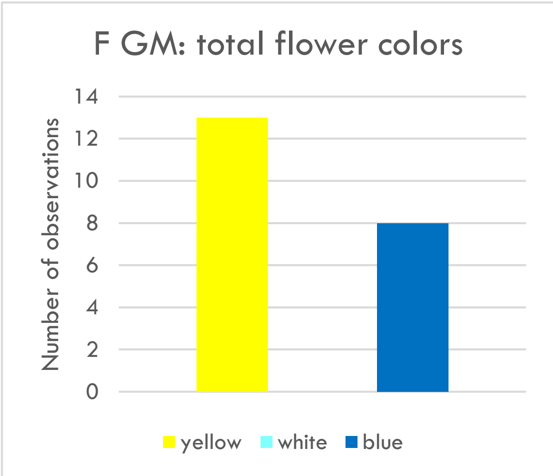

Figure 16: F GM total flower color counts (p=0.00215)

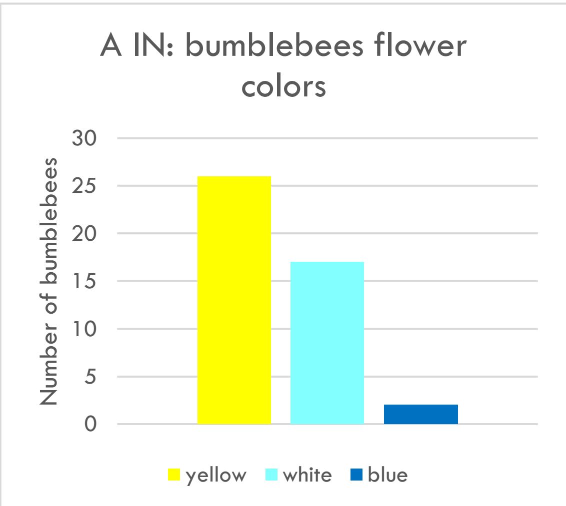

Figure 17: A IN bumblebee flower color count (p=5.55e-05)

In the figures above it is shown that in 4 locations the preferred flower color is yellow. Location D SH showed no significant difference. Blue is preferred least in A IN and E CO. White is preferred least in F GM. There were no white and blue observations in B SU. Bumblebee species showed the only species with a significant result in A IN only; preferring yellow flowers most.

3.6 Plant species

Most visited plant species are listed in the table below (Table 3). This table shows the plant species most visited by the pollinators during the monitoring per location. None of these species were plants from the mixtures.

Table 3: Most visited plant species

Location	Plant most visited	Visit rate percentage
A IN	Brassica sp.	47%
B SU	Brassica sp.	53,70%
D SH	Senecio inaequidens	75%
E CO	Jacobea vulgaris	29,20%
F GM	Senecio inaequidens	42,90%

The table below shows monitoring data on flowers of the plant species used in the seed mixtures (Table 4). In total 4 out of 376 monitoring observations were seen on seed mixture plants in 2 locations. Only 1 plant species per mixture was observed. There were no expected hoverflies documented beforehand, but *Apis mellifera* was not expected to be foraging on *Phacelia tanacetifolia.*

Table 4: Seed mixture plant observations

Location	Frequency	Plant species	Bee/hoverfly species
A IN	1	Centaurea cyanus	Syrphidae sp.
F GM	1	Phacelia tanacetifolia	Apis mellifera
F GM	1	Phacelia tanacetifolia	Scaeva pyrastri
F GM	1	Phacelia tanacetifolia	Bombus pascuorum

H4: Discussion

In this chapter different parts of the study are discussed and evaluated.

4.1 What species of bees and hoverflies can be found in the solar park?

In total 4 bumblebee, 19 other bee and 11 hoverfly species were found with a total number of 35 species and a total of 477 observations. In total 2 bumblebee and 9 other bee species that were expected were also found in the solar park. In total 10 other bee species who were not expected were found in the solar park. In total 4 bumblebee and 26 other bee species who were expected were not found. An explanation for this could be that the surrounding area consist of very different habitats which are not very likely to have similar bee species inhabiting them. De Biesbosch for example contains mostly forest with different plant species that cannot be found in the solar park.

4.2 Which location shows the highest bee and hoverfly diversity?

Location A IN had the highest species diversity with pan taps, monitoring and both of the methods combined, but none of these results showed a significant difference. The combination looked promising but the p value of p=0.0617 just exceeds the significance level of alpha = 0.05. This could have been prevented. There were 121 hoverflies, 4 bees, 6 bumblebees and another 15 undefined pollinators left unidentified, which is almost 30% of all observed identified species. If one extra species was found in A IN for example, the p value would go below the alpha and show a significant difference. The main problem is the skill of the observers; they were untrained in identifying bee and hoverfly species in the field. If there was a little more preparation beforehand the results would have been more significantly interesting.

4.3 Which location shows the highest abundance of bee and hoverfly species?

Location A IN shows the highest abundance in all species with pan traps, monitoring and both methods combined. It is very unlikely that the sowing of seed mixtures could be a factor in enhancing the abundance of visiting pollinators at this time. The best explanation for the attractiveness of the location is the difference in soil and vegetation (Table 1). A IN shows to have wet sandy soil with organic material and the vegetation is very thick. Most likely the plant biodiversity is highest in this location, but this was not studied. There were flowers seen during the monitoring that grew only in this location, like *Symphytum officinale*. This could make this location more attractive for foraging than other locations. Therefore, the expectation that the location with thickest vegetation had the highest abundance was right. The control plot did not show slighty less species than the other locations. This can be explained by location D SH; the conditions of this locations were not very good for foraging and nesting, due to asphalt and gravel in the area (Table 1). The locations varied concerning the soil types and vegetation.

4.4 Which plants do the bees and hoverflies forage on inside the solar park and which species is most visited?

Senecio inaequidens, *Jacobea vulgaris* and species of the *Brassica* family were visited most by the pollinators. It is most likely that these were also in highest abundance inside the park, but this was not studied. All these plants happen to have yellow flowers. Due to the untrained observers it is likely that some plant species could be mistaken for other species, especially species in the *Asteracea* group. There were only 4 documented observations on plants from the mixtures in all locations. The expectation of *Fabaceae* species of Green Manure being visited most proved to be wrong. This is due to the fact that the seed mixtures did not germinate fast enough to make any difference on the foraging behavior of the pollinators in the park. This could be explained by the present vegetation growing faster than the seedlings were able to catch up on. If the soil would have been treated differently before sowing, the seeds might have had a better chance of developing. The rows of the solar park do not allow heavy machines to go through them. Since it is nearly impossible to do this without being able to use heavy machinery and very few people, this could not be avoided. The fact that *Phacelia tanacetifolia* and *Centaurea cyanus* were able to germinate and flower proves that these plants grow well inside a solar park which has sandy soil. There were no expected hoverflies on mixture plants documented beforehand, but *Apis mellifera* was not expected to be foraging on *Phacelia tanacetifolia*. Since this species is very common and generalistic, it most likely was forgotten to be documented.

4.5 Which flower color is most attractive to bees and hoverflies present in the solar park?

The overall color preference of the pollinators shows to be yellow, but this is probably highly biased. Since the vast majority of the plants already present in the area had yellow flowers, the pollinators did not have much else to choose from. The pan trap results show no significant difference in color, so the estimation that the preference of the colors would be evenly distributed is highly probable.

4.6 Difference in pan trap and monitoring

More than half of the found hoverfly species are only found with monitoring and a little less than half of the bee species are only found in pan traps. *Lasioglossum* bee species tend to be small and most of them are brown or black colored. This makes them less visible in the field and they could be mistaken for ants or flies. Why the hoverflies are less seen in the pan traps is harder to explain. Most hoverfly species do not have a nest so they do not have to gather food for larvae. They might be more active with defending their territory than searching for food. They are very agile fliers and most of them are small and less heavy than bees, so they might be able to escape the pan traps better than bees. The estimation that bumblebees would be found least in pan traps is true. There have been 81 observations of *Bombus terrestris complex* without finding them more in pan traps compared to *Andrena barbilabris*, for example. The estimation that hoverflies are found more in blue and yellow pan traps looks like it is true, but it is not significant. More data is needed to provide evidence for this claim.

H5: Conclusion

In total 4 bumblebee, 19 other bee and 11 hoverfly species were found in solar park Shell Moerdijk with a total number of 35 species and a total of 477 observations. Location A IN shows the highest abundance in all species with pan traps, monitoring and both methods combined. There is no significant difference in the locations for species diversity. This is very likely the cause of unskilled observers.

It is very unlikely that the sowing of seed mixtures could have been a factor in enhancing the abundance of visiting pollinators in this study. Soil type and vegetation are very likely to be a factor in their preference of location A IN. The vegetation was very thick due to the wet sandy soil with organic material. If the seed mixtures continue to flourish over time, the floral composition of the park will change and could result in attracting more pollinator species to the park. The mixtures need more time to develop since the germinating time of the seeds varies and some species that have not been seen flowering will start to flower in the coming years. Future studies have to be executed in the park to test if the mixtures will have any effect on the pollinator abundance and diversity.

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Appendix 1: Table seed mixtures

Mixtures							
Name mixture	Company	Species (Dutch)	Species (scientific)	Sowing density (kg/ha)	Distribution in mixture	kg used	Price in euro's (inc. 9% BTW)
Diverse Grasses							
Bermo 3	Hofman AP	Roodzwenkgras	*Festuca rubra*	75	46,93% (15,64% p. s.)	12,6	100,4
		Hardzwenkgras	*Festuca cinerea*				
		Gewoon struisgras	*Agrostis cappilaris*				
-	Hofman AP	Fijnbladig schapengras	*Festuca filiformis*	40	7,45%	2	42,2
-	Hofman AP	Kamgras	*Cynosurus cristatus*	35	8,38%	2,25	29,92
-	Ten Have Seeds	Engels raaigras	*Lolium perenne*	25 – 40	37,24%	10 (15 kg bag)	53,14
					100%	**26,85**	172,52
Green Manure	Hofman AP	Witte klaver	*Trifolium repens*	15	5,96%	0,7	
		Rode klaver	*Trifolium pratense*	25	9,88%	1,16	
		Seradelle	*Ornithopus sativus*	25	9,88%	1,16	
		Gele lupine	*Lupinus luteus*	100	59,63%	7	
		Phacelia	*Phacelia tanacetifolia*	42,86	4,77%	0,56	
		Gewone rolklaver	*Lotus corniculatus*	25	9,88%	1,16	
					100%	**11,74**	120
Eco Sun	De Bolderik	Gewoon duizendblad	*Achillea millefolium*	18,21	27,63%	0,851	
		Grasklokje	*Campanula rotundifolia*	2,39	3,63%	0,112	
		Beemdkroon	*Knautia arvensis*	10,71	16,23%	0,5	
		Wilde marjolein	*Origanum vulgare*	5,93	8,98%	0,277	
		Wilde reseda	*Reseda lutea*	22,79	34,54%	1,063	
		Grote tijm	*Thymus pulegioides*	5,93	8,98%	0,277	
					100%	**3,08**	1248,63

Eco Shade	De Bolderik	Veldhondstong	*Cynoglossum officinale*	31,54	47,76%	1,471	
		Geel nagelkruid	*Geum urbanum*	12,25	18,65%	0,571	
		Gewone brunel	*Prunella vulgaris*	8,64	13,13%	0,404	
		Dagkoekoeksbloem	*Silene dioica*	8,79	13,30%	0,41	
		Bosandoorn	*Stachys sylvatica*	4,11	6,22%	0,192	
		Lange ereprijs	*Veronica longifolia*	0,68	1,04%	0,032	
					100%	**3,08**	682,51
Industrial	De Bolderik	Groot akkerscherm	*Ammi majus*	5,71	4,81%	0,269	
		Bernagie	*Borago officinalis*	54,86	45,72%	2,56	
		Akkergoudsbloem	*Calendula arvensis*	18,46	15,40%	0,862	
		Echte karwij	*Carum carvi*	13,86	11,55%	0,647	
		Korenbloem	*Centaurea cyanus*	21,93	18,29%	1,024	
		Grote klaproos	*Papaver rhoeas*	5,07	4,23%	0,237	
					100%	**5,6**	441,29
Eco Shade Plus	De Bolderik	Borstelkrans	*Clinopodium vulgare*	1,5	1,22%	0,0027	
		Veldhondstong	*Cynoglossum officinale*	55,36	42,07%	0,0926	
		Geel nagelkruid	*Geum urbanum*	16,07	12,20%	0,0264	
		Stijf havikskruid	*Hieracium laevigatum*	2	1,52%	0,0033	
		Schermhavikskruid	*Hieracium umbellatum*	1,79	1,37%	0,003	
		Muskuskaasjeskruid	*Malva moschata*	9,5	7,01%	0,0154	
		Gewone brunel	*Prunella vulgaris*	14	10,43%	0,023	
		Dagkoekoeksbloem	*Silene dioica*	17	12,80%	0,028	
		Bosandoorn	*Stachys sylvatica*	7	5,12%	0,0113	
		Valse salie	*Teucrium scorodonia*	6	4,48%	0,0099	
		Lange ereprijs	*Veronica longifolia*	1,5	1,22%	0,0027	
		Mannetjesereprijs	*Veronica officinalis*	0,5	0,55%	0,0012	
					100%	**0,22**	86,75
							2751,7

Appendix 2: Proposal plant species

Advice by Klaas Jan Wardernaar in Dutch (Landscape Architect at Smartland) 10-2-2019:

Groepje laagblijvende soorten van schaduw tot halfschaduw:

Hondsdraf	*Glechoma hederacea*
Kruipend zenegroen	*Ajuga reptans*
Gewone brunel	*Prunella vulgaris*
Klimopereprijs	*Veronica hederifolia*
Mannetjesereprijs	*Veronica officinalis*
Gewone ereprijs	*Veronica chemaedris*
Maagdenpalm	*Vinca minor*
Gele dovenetel	*Lamiastrum geleobdolon*

Groepje iets hogere soorten van halfschaduw:

Geel nagelkruid	*Geum urbanum*
Rankende helmbloem	*Ceratocapnos claviculata*
Stinkende gouwe	*Chelidonium majus*
Veldhondstong	*Cynoglossum officinale*
Robertskruid	*Geranium robertianum*
Valse salie	*Teucrium scorodonia*
Springzaad	*Impatiens parviflora*

Groepje hogere soorten van halfschaduw:

Gewone Hennepnetel	*Galeopsis tetrahit*
Dagkoekoeksbloem	*Silene dioica*
Bosandoorn	*Stachis sylvatica*

Groepje meer 'solitaire soorten' van schralere bossen(randen):

Bergbasterdwederik	*Epilobium montanum*
Schermhavikskruid	*Hieracium umbellatum*
Stijf havikskruid	*Hieracium laevigatum*
Boshavikskruid	*Hieracium sabaudum*
Duinsalomonszegel	*Polygonatum odoratum*
Gewone salomonszegel	*Polygonatum multiflorum*

Extra planten toegevoegd:

Lange ereprijs	*Veronica longifolia*
Muskuskaasjeskruid	*Malva moschata*
Borstelkrans	*Clinopodium vulgare*

Appendix 3: Expected bees surrounding area

Documented bee sightings retrieved from www.waarnemingen.nl (Dutch):

Bijen in de omgeving: Biesbosch

Akkerhommel
zandhommel EB (verifieerd, meerdere keren in 2018 en 2017)
gewone koekoekshommel TNB
zuidelijke zijdebij TNB
tronkenbij TNB
bremzandbij KW
slanke kegelbij KW
steenhommel TNB
roodrandzandbij BE (verifieerd, meerdere keren in 2018)
grasbij TNB
gewone geurgroefbij TNB
pluimvoetbij TNB
kattenstaartdikpoot TNB
gewone slobkousbij TNB
tuinhommel
boomhommel
weidehommel
pluimvoetbij TNB
veldhommel
geelstaartklaverzandbij KW
langtongige buikverzamerlaarbijen Megachilidae indet.
Poldermaskerbij
Sphecodes
Knautiabij BE BEEMDKROON
Roodgatje TNB
bruine rouwbij KW verifieerd
donkere klaverzandbij KW verifieerd
gewone dwergzandbij TNB
grijze zandbij TNB
gewone wespbij TNB
vosje TNB
grote zijdebij TNB
rosse metselbij TNB
zwart-rosse zandbij TNB
grijze rimpelrug TNB
matte bandgroefbij TNB

Bijen in de omgeving: Appelzak

Tweekleurige zandbij TNB

Bijen in de omgeving: Industriegebied

Gewone wespbij TNB
Goudpootzandbij TNB
Grasbij TNB
Bleekvlekwespbij TNB

Roodzwarte dubbeltand TNB
Geelschouderwespbij TNB
Lichte wilgenzandbij TNB
Viltvlekzandbij TNB
Vroege zandbij TNB
Grijze zandbij TNB
Roodbuikje TNB
Gewone franjegroefbij TNB

Bijen in de omgeving: Lokkersgors

Weidehommel TNB
Fluitenkruidbij TNB
Roodbruine groefbij TNB

Appendix 4: Expected bees mixture interaction

The lists below were assembled using the wild bee-plant interaction database of EIS, the European Invertebrate Survey in the Netherlands.

Green Manure

Witte klaver	Rode klaver	geslacht lupine	Phacelia	Gewone rolklaver	Serradelle
Andrena bicolor	Andrena flavipes	Andrena ovatula	Apis mellifera	Andrena chrysosceles	
Andrena dorsata	Andrena labialis	Anthophora retusa	Bombus bohemicus	Andrena dorsata	
Andrena flavipes	Andrena labiata	Eucera longicornis	Bombus hortorum	Andrena labialis	
Andrena fulvida	Andrena ovatula	Megachile alpicola	Bombus hypnorum	Andrena ovatula	
Andrena labialis	Andrena wilkella	Megachile centuncularis	Bombus lapidarius	Andrena similis	
Andrena ovatula	Anthophora quadrimaculata	Megachile circumcincta	Bombus pascuorum	Andrena wilkella	
Andrena schencki	Bombus barbutellus	Megachile willughbiella	Bombus sylvestris	Anthidiellum strigatum	
Andrena wilkella	Bombus bohemicus		Bombus terrestris	Anthidium byssinum	
Anthidiellum strigatum	Bombus campestris		Hylaeus communis	Anthidium manicatum	
Apis mellifera	Bombus cryptarum		Hylaeus hyalinatus	Anthidium oblongatum	
Bombus bohemicus	Bombus hortorum		Hylaeus pictipes	Anthidium punctatum	
Bombus campestris	Bombus hypnorum			Anthophora quadrimaculata	
Bombus hortorum	Bombus jonellus			Anthophora retusa	
Bombus humilis	Bombus lapidarius			Bombus bohemicus	
Bombus hypnorum	Bombus lucorum			Bombus hortorum	
Bombus jonellus	Bombus muscorum			Bombus jonellus	
Bombus lapidarius	Bombus pascuorum			Bombus lapidarius	
Bombus lucorum	Bombus pratorum			Bombus lucorum	
Bombus muscorum	Bombus ruderarius			Bombus muscorum	
Bombus norvegicus	Bombus rupestris			Bombus pascuorum	
Bombus pascuorum	Bombus soroeensis			Bombus pratorum	
Bombus pratorum	Bombus sylvestris			Bombus ruderarius	
Bombus ruderarius	Bombus terrestris			Bombus soroeensis	
Bombus rupestris	Bombus vestalis			Bombus terrestris	
Bombus sylvestris	**Bombus veteranus**			Chalicodoma ericetorum	
Bombus terrestris	Epeolus cruciger			Coelioxys aurolimbata	
Bombus vestalis	Eucera longicornis			Coelioxys conica	
Bombus veteranus	Halictus tumulorum			Coelioxys elongata	
Coelioxys conica	Lasioglossum lativentre			Coelioxys inermis	
Coelioxys elongata	Lasioglossum xanthopus			Coelioxys mandibularis	
Coelioxys inermis	Megachile centuncularis			Colletes daviesanus	
Colletes fodiens	Megachile circumcincta			Colletes marginatus	
Colletes impunctatus	Melitta leporina			Dasypoda hirtipes	
Colletes marginatus	Osmia aurulenta			Eucera longicornis	
Halictus confusus	Osmia bicornis			Eucera nigrescens	
Halictus rubicundus	Osmia caerulescens			Halictus confusus	
Halictus tumulorum				Halictus tumulorum	
Hoplitis claviventris				Hoplitis claviventris	
Hoplitis leucomelana				Hoplitis leucomelana	
Hylaeus confusus				Hoplitis ravouxi	
Lasioglossum albipes				Hoplitis tridentata	
Lasioglossum calceatum				Hylaeus communis	
Lasioglossum leucozonium				Lasioglossum albipes	
Lasioglossum punctatissimum				Lasioglossum leucozonium	
Lasioglossum sexnotatum				Lasioglossum lineare	
Lasioglossum sexstrigatum				Lasioglossum pauxillum	
Lasioglossum zonulum				Lasioglossum punctatissimum	
Megachile circumcincta				Lasioglossum sexstrigatum	
Megachile lapponica				Megachile alpicola	
Megachile leachella				Megachile analis	
Melitta leporina				Megachile centuncularis	
Osmia aurulenta				Megachile circumcincta	
Osmia caerulescens				Megachile lapponica	
Osmia niveata				Megachile leachella	
Osmia uncinata				Megachile maritima	
Panurgus calcaratus				Megachile pilidens	
Sphecodes monilicornis				Megachile versicolor	
				Megachile willughbiella	
				Melitta leporina	
				Nomada fucata	
				Nomada striata	
				Osmia aurulenta	
				Osmia caerulescens	
				Osmia leaiana	
				Osmia maritima	
				Osmia niveata	
				Osmia parietina	
				Osmia xanthomelana	
				Stelis signata	

Eco Sun

Wilde marjolein	Gewoon duizendblad	Grasklokje	Beemdkroon	Wilde reseda	Grote tijm	
Andrena minutuloides	Andrena coitana	Andrena bicolor	**Andrena hattorfiana**	Andrena barbilabris	Lasioglossum leucopus	
Anthidiellum strigatum	Andrena denticulata	Andrena coitana	Anthidium manicatum	Andrena bicolor	Lasioglossum morio	
Bombus bohemicus	Andrena nigriceps	Andrena curvungula	Anthophora retusa	Andrena carantonica	Megachile leachella	
Bombus campestris	Andrena nitidiuscula	Bombus lapidarius	Bombus hypnorum	Andrena combinata	Megachile willughbiella	
Bombus lapidarius	Andrena flavipes	Bombus lucorum	Bombus lapidarius	Andrena dorsata	Osmia aurulenta	
Bombus lucorum	Ceratina cyanea	Bombus muscorum	Bombus pascuorum	Andrena flavipes		
Bombus pascuorum	Chelostoma rapunculi	Bombus pratorum	Bombus pratorum	Andrena haemorrhoa		
Colletes fodiens	Colletes daviesanus	Bombus soroeensis	Bombus soroeensis	Andrena minutuloides		
Heriades truncorum	Colletes fodiens	Bombus terrestris	Chalicodoma ericetorum	Andrena nigroaenea		
Hylaeus hyalinatus	Colletes hederae	Chelostoma campanularum	Coelioxys aurolimbata	Andrena ovatula		
Hylaeus pictipes	Epeolus cruciger	Chelostoma distinctum	Dufourea dentiventris	Andrena pilipes		
Lasioglossum morio	Epeolus variegatus	Chelostoma rapunculi	Epeoloides coecutiens	Andrena semilaevis		
Lasioglossum sexnotatum	Halictus tumulorum	Dasypoda hirtipes	Halictus tumulorum	Andrena synadelpha		
Lasioglossum sexstrigatum	Heriades truncorum	Dufourea dentiventris	Lasioglossum leucozonium	Andrena tibialis		
Nomada flavopicta	Hylaeus communis	Epeolus variegatus	Megachile ligniseca	Andrena wilkella		
Nomada marshamella	Hylaeus cornutus	Halictus confusus	Nomada armata	Anthidium punctatum		
	Hylaeus hyalinatus	Halictus maculatus	Nomada flavopicta	Anthophora quadrimaculata		
	Hylaeus pictipes	Halictus tumulorum	Osmia bicornis	Bombus lapidarius		
	Hylaeus annularis	Heriades truncorum	Osmia caerulescens	Bombus lucorum		
	Lasioglossum minutissimum	Hylaeus communis	Osmia niveata	Bombus ruderarius		
	Lasioglossum sexstrigatum	Hylaeus confusus	Stelis punctulatissima	Bombus terrestris		
	Lasioglossum calceatum	Hylaeus incongruus	Thyreus orbatus	Chelostoma rapunculi		
	Megachile centuncularis	Hylaeus signatus		Coelioxys inermis		
	Megachile willughbiella	Lasioglossum albipes		Colletes fodiens		
	Nomada fuscicornis	Lasioglossum fratellum		Colletes impunctatus		
	Sphecodes ephippius	Lasioglossum laticeps		Colletes marginatus		
	Sphecodes monilicornis	Lasioglossum leucopus		Epeolus variegatus		
	Sphecodes gibbus	Lasioglossum leucozonium		Halictus tumulorum		
	Sphecodes longulus	Lasioglossum morio		Hylaeus annularis		
	Sphecodes geoffrellus	Lasioglossum punctatissimum		Hylaeus brevicornis		
	Sphecodes rufiventris	Lasioglossum sexstrigatum		Hylaeus communis		
	Stelis breviuscula	Lasioglossum villosulum		Hylaeus confusus		
		Megachile analis		Hylaeus cornutus		
		Megachile circumcincta		Hylaeus dilatatus		
		Megachile willughbiella		Hylaeus hyalinatus		
		Melitta haemorrhoidalis		Hylaeus incongruus		
		Melitta leporine		Hylaeus pictipes		
				Hylaeus punctulatissimus		
				Hylaeus signatus	<- sterk specialistisch	
				Lasioglossum leucopus		
				Megachile circumcincta		
				Megachile leachella		
				Nomada baccata		
				Nomada obtusifrons		
				Sphecodes monilicornis		

Eco Shade

Gewone brunel	Dagkoekoeksbloem	Lange ereprijs	Veldhondstong	Bosandoorn	nagelkruid
Anthidium manicatum	Anthophora plumipes	Hylaeus communis	Andrena ruficrus	Anthidium manicatum	Andrena chrysosceles
Bombus lapidarius	Bombus hortorum	Hylaeus confusus	Andrena vaga	Anthophora furcata	Andrena niveata
Bombus pascuorum	Bombus hypnorum	Hylaeus hyalinatus	Anthophora plumipes	Anthophora quadrimaculata	Hylaeus hyalinatus
Osmia caerulescens	Bombus pascuorum		Bombus campestris	Apis mellifera	Hylaeus incongruus
	Bombus pratorum		Bombus jonellus	Bombus hortorum	Hylaeus pictipes
	Bombus terrestris		Bombus pascuorum	Bombus hypnorum	Lasioglossum minutissimum
	Lasioglossum sexstrigatum		Bombus pratorum	Bombus lucorum	Megachile centuncularis
				Bombus muscorum	
				Bombus pascuorum	
				Bombus pratorum	
				Bombus terrestris	
				Megachile ligniseca	
				Osmia caerulescens	

Industrial

Bernagie	Korenbloem	grote klaproos	geslacht goudsbloem	Geslacht karwij	groot akkersche
Apis mellifera	Andrena labialis	Bombus lapidarius	Anthidium manicatum	Osmia leaiana	
Bombus hortorum	Apis mellifera	Bombus terrestris	Bombus pascuorum		
Bombus hypnorum	Bombus hypnorum	Hoplitis papaveris	Chelostoma campanularum		
Bombus lapidarius	Bombus lapidarius	Megachile centuncularis	Dasypoda hirtipes		
Bombus pascuorum	Bombus pascuorum	Megachile circumcincta	Heriades truncorum		
	Bombus terrestris	Osmia bicornis	Hylaeus hyalinatus		
	Chelostoma rapunculi		Lasioglossum calceatum		
	Halictus scabiosae		Megachile alpicola		
	Hoplitis papaveris		Megachile centuncularis		
	Megachile centuncularis		Megachile leachella		
	Megachile versicolor		Osmia caerulescens		
			Osmia leaiana		
			Panurgus calcaratus		
			Stelis ornatula		

Appendix 5: Bee data

Monitoring	Total	A IN	B SU	D SH	E CO	F GM	p value chi2
Total species:	25	16	14	4	10	12	p=0.109
Total bee species:	11	5	5	1	5	4	NA
Total bumblebee species:	3	2	2	0	1	2	NA
Total hoverfly species:	11	9	7	3	4	6	p=0.415
Total number:	376	164	83	17	70	42	p=8.63e-35

Pan traps	Total	A IN	B SU	D SH	E CO	F GM	p value chi2
Total species:	22	15	5	5	8	9	p=0.0916
Total bee species:	13	8	4	3	6	5	p=0.584
Total bumblebee species:	4	4	0	2	2	2	NA
Total hoverfly species:	5	3	1	0	0	2	NA
Total number:	101	35	22	12	18	14	P=0.00244

Both	Total	A IN	B SU	D SH	E CO	F GM	p value chi2
Total species:	35	25	17	8	15	17	p=0.0617
Total bee species:	19	12	8	3	9	9	NA
Total bumblebee species:	4	3	2	2	2	2	NA
Total hoverfly species:	11	11	7	3	4	6	NA
Total number:	477	199	90	29	88	56	p=4.34e-38

Pan trap colors total	yellow	white	blue	p value chi2
A IN	14	11	11	p=0.779
B SU	12	5	5	p=0.108
D SH	6	2	5	NA
E CO	8	4	6	p=0.513
F GM	7	6	5	p=0.846

Pan trap colors bumblebees	yellow	white	blue	p value chi2
A IN	1	2	7	NA
B SU	0	0	0	NA
D SH	1	0	2	NA
E CO	1	0	2	NA
F GM	0	2	1	NA

Pan trap colors bees	yellow	white	blue	p value chi2
A IN	11	6	2	p=0.0403
B SU	3	0	1	NA
D SH	4	2	3	NA

E CO	7	4	4	NA
F GM	3	3	2	NA

Pan trap colors hoverflies	yellow	white	blue	p value chi2
A IN	2	2	1	NA
B SU	0	0	0	NA
D SH	0	0	0	NA
E CO	0	0	0	NA
F GM	1	0	2	NA

Flower colors total	yellow	white	blue	p value chi2
A IN	71	23	6	p=1.57e-15
B SU	41	0	0	p=1.56e-18
D SH	9	0	0	NA
E CO	41	3	2	p=9.97e-15
F GM	13	0	8	p=0.00215

Flower colors bumblebees	yellow	white	blue	p value chi2
A IN	26	17	2	p=5.55e-05
B SU	11	0	0	NA
D SH	0	0	0	NA
E CO	7	0	1	NA
F GM	1	0	2	NA

Flower colors bees	yellow	white	blue	p value chi2
A IN	5	0	2	NA
B SU	5	0	0	NA
D SH	0	0	0	NA
E CO	5	0	1	NA
F GM	3	0	4	NA

Flower colors Hoverflies	yellow	white	blue	p value chi2
A IN	40	6	2	p=1.46e-12
B SU	25	0	0	NA
D SH	9	0	0	NA
E CO	29	3	0	NA
F GM	9	0	2	NA

Species	Dutch	Frequency	Pan/Mon
Bombus terrestris complex	Aardhommel	81	Pan + Mon
Bombus pascuorum	Akkerhommel	21	Pan + Mon
Bombus lapidarius	Steenhommel	3	Pan + Mon
Bombus pratorum	Weidehommel	1	Pan

Species	Dutch	Frequency	Pan/Mon
Andrena barbilabris	Witbaardzandbij	24	Pan + Mon
Apis mellifera	Honingbij	22	Pan + Mon
Sphecodes albilabris	Grote bloedbij	13	Mon
Andrena flavipes	Grasbij	12	Pan + Mon
Lasioglossum punctatissimum	Fijngestippelde groefbij	11	Pan
Colletes cunicularius	Grote zijdebij	3	Mon
Lasioglossum zonulum	Glanzende bandgroefbij	3	Pan
Lasioglossum sextrigatum	Gewone franjegroefbij	2	Pan + Mon
Dasypoda hirtipes	Pluimvoetbij	2	Mon
Andrena ventralis	Roodbuikje	2	Pan
Lasioglossum calceatum	Gewone geurgroefbij	2	Pan
Panurgus banksianus	Grote roetbij	1	Mon
Colletes daviesanus	Wormkruidbij	1	Mon
Andrena haemorrhoa	Roodgatje	1	Mon
Lasioglossum leucozonium	Matte bandgroefbij	3	Pan + Mon
Lasioglossum semilucens	Halfglanzende groefbij	1	Pan
Halictus tumulorum	Parkbronsgroefbij	1	Pan
Andrena nigroanea	Zwartbronzen zandbij	1	Pan
Lasioglossum pauxillum	Kleigroefbij	1	Pan

Species	Dutch	Frequency	Pan/Mon
Eristalis tenax	Blinde bij	36	Pan + Mon
Sphaerophoria scripta	Grote langlijf	27	Pan + Mon
Eupeodes luniger	Grote kommazweefvlieg	17	Pan + Mon
Episyrphus balteatus	Snorzweefvlieg	12	Mon
Eupeodes corollae	Terrasjeskommezweefvlieg	11	Pan + Mon
Scaeva pyrastri	Witte halvemaanzweefvlieg	6	Mon
Sphaerophoria rueppelli	Kleine langlijf	2	Mon
Helophilus trivittatus	Citroenpendelvlieg	2	Mon
Syrphus ribesii	Bessenbandzweefvlieg	1	Mon
Melangyna lasiophthalma	Wilgenelfje	1	Mon
Paragus haemorrhous	Gewoon krieltje	1	Mon