PLANNING FOR POLLINATION

- creating cohabitation through social-ecological urbanism

Amanda T. Häll

Masters thesis preparation course 2, ARK641
Architecture and planning beyond sustainability, MPDSD

Chalmers 2022/2023
Examiner: Lars Marcus
Supervisor: Meta Berghauser Pont

Planning for pollination
- creating cohabitation through social-ecological urbanism

AMANDA T HÄLL

Contact: amanda.hall@live.se

Final Seminar:
Examiner: Lars Marcus
Supervisor: Meta Berghauser Pont

Direction of Social ecological urbanism

Keywords: biodiversity, resilience, social-ecological systems, pollination, ecology, landscape architecture, urban habitat

Master's Thesis at Chalmers Architecture
Master Programme Architecture and Planning Beyond Sustainability
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: +46(0)31-772 1000

Frontpage illustration by author

ABSTRACT

It is estimated that 657 billion US dollars worth of annual global food production relies on the contribution of pollinators. That does not consider other crucial ecosystem services that pollinators provide, such as maintaining balanced ecosystems. Still, the decline of pollinating insects is showing in alarming numbers around the world. Industrialization of agriculture, use of pesticides and fragmentation of habitats has led to species declining to the brink of extinction. Many wild bees have adapted to the urban landscape as an alternative habitat due to high urban biodiversity and the loss of their original habitats. The urbanization of cities and exploitation of nature is increasing intensively and rapidly, threatening the biodiversity that is crucial for species survival. The urban landscape has a high potential to further support biodiversity if properly planned and designed. There is however not many studies showcasing how this can be done. This thesis dives into the complex world of urban ecology and urban habitats. The focus is on two species of wild bees (Andrena marginata and Osmia bicornis) which represent different levels of sensitivities and can indicate the level of biodiversity. The report is divided into two parts; Identifying the needs and challenges in the current urban landscape for wild bees to spread and thrive; and based on that development, a plan and design proposal for Gothenburg to support a social ecological system through promoting urban habitats for the chosen species.

The research identified two aspects that are equally important for increasing the quality of urban habitats: connectivity and resources – feeding and foraging within a reachable distance and spreading between habitats. The proposal suggests the usage of three scales of design: city-, neighborhood and street-scale, reflecting the dependency of the individual habitat, its surrounding context as well as its entire urban habitat network.

TABLE OF CONTENT

ACKNOWLEDGMENTS

I would like to especially acknowledge the people who have supported throughout this thesis.

To Meta Berghauser Pont, Oskar Kindvall, Louise Didriksson and Lars Marcus, thank you for your time, knowledge and guidance throughout this work. It has been an honor to learn from you. Thank you for giving me the space to write about a passion of mine.

To my colleagues at White for giving me support and a professional perspective.

I would like to thank my family for listening to my ongoing share about the subject and their loving support. To my partner, Kreshnik for the incredible support given through food, music and endless discussions.

Lastly, a tribute to my closest non-human who has kept my keyboard warm. If the reader notices a spelling error, it was definitely the cat.

STUDENT BACKGROUND

B-Sc. in Landscape Architecture
Swedish University of Agricultural Sciences, Alnarp 2018-2021

Internship
White Architects, Göteborg 2022 - ongoing

Master studies
Architecture and planning beyond sustainability, MPDSD
Chalmers University of Technology, Göteborg 2021 - 2023

ARK650 Sustainable development and the design professions
ARK324 HT21 Design and planning for social inclusion
ARK177 Design system
ARK142 Social-ecological urbanism
ARK610 History, theory and method 5
ARK636 Masters thesis preparation course 1
ARK641 Masters thesis preparation course 2

DICTIONARY

Ecosystem:	a geographic area where plants, animals and other organisms co-exist and form a system of life.
Habitat:	an area where an organism makes its home.
Biotope:	an area where the characteristics, environment and species make up the type of biotope, for example: a grassland, forest or ocean.
Biodiversity:	the variation of plant and animal species, often within a certain area.
Resilience:	the capacity to withstand changes, for example floodings or heat waves.
Green infrastructure:	a network of green environments that are strategically planned to serve ecological, social and economical functions.
Pollinator:	an animal or insects that carries pollen from the same flower or from one to another, fertilizing them to produce fruits or nuts.
Nectar:	a sweet secretion produced by flowers to attract pollinators from which they reveice energy.
Redlisted species:	a list of endangered and extinct species.
Ecocide:	direct or indirect human-made destruction of natural environments.
Mowing:	cutting of grass, either by a machine or schythe.
Decidious:	trees that loose their leaves in autumn
Coniferous:	trees with cones that mostly stay green throughout the year
Cohabitation:	organisms that live together within a habitat, supporting each other's existence.
Urban sprawl:	the phenomenon of rapid urban expansion, often characterized by low density residential housing.

Figure 1
"Nödräddad urskog" by Mattias Bäcklin (n.d.)

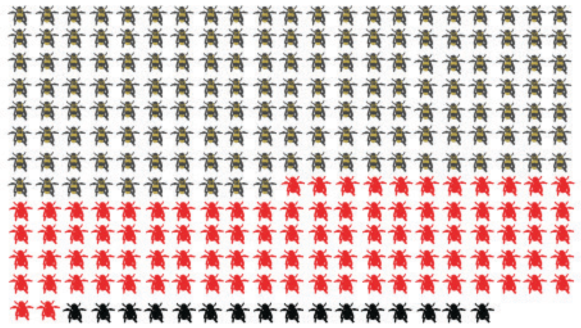
"This is not just about bumblebees, but about creating a future environment for our children to enjoy, where there are still flowers, bees, butterflies and birds, and healthy crops to eat."
Dave Goulson (2013)

CHAPTER 1: INTRODUCTION

BACKGROUND

Alarming numbers

We are facing a sixth mass extinction, nature is declining at unprecedented rates in human history (IPBES, 2019). The decline of insects, especially pollinators, is a mayor factor of the decline of biodiversity. 97 of Sweden's 270 wild bees are endangered and 16 of these are believed to be extinct (Naturskyddsföreningen, 2021). Industrialization of agriculture, use of pesticides, fragmentation and decreasing habitats are the main reasons for the declining numbers of pollinating insects (Borgström et al., 2018).



Out of 270 wild bees, 97 of these are endangered and 16 are believed to be extinct. Illustration by author.

Cities are expanding and densifying, often to the expense of nature. Today, more than half of the world's population, 3.5 billion people, live in cities and the amount is estimated to double by the year of 2050 (Secretariat of the Convention on Biological Diversity, 2012). Urbanization in the form of urban sprawl causes habitat destruction and fragmentation (TNC, 2018). Often, cities expand more rapidly in size than in population which results in a change of land use (from natural to urban) that causes biodiversity loss (Berghauser Pont et al. 2021). Another reason for species decline is the decrease of grazing lands and meadows that used to be common landscapes in previous centuries (Jordbruksverket, 2018)

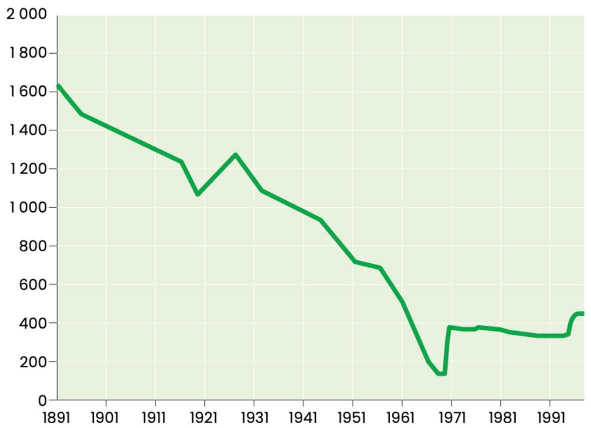


Figure 2
Natural habitats for many pollinators such as grazing and meadow lands have decreased significantly since the 1800s (Jordbruksverket, 2018)

Humans have often chosen to build their cities settlements in biologically rich environments (Güneralp et al., 2020). In regards to the level of biological richness of cities is not entirely agreed amongst scientists. Some claim that biodiversity in cities is high (Persson, 2021) while others state that the biological richness is poorer in terms of biodiversity (Goddard et al., 2009).

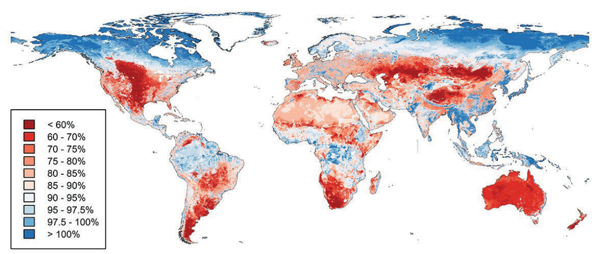


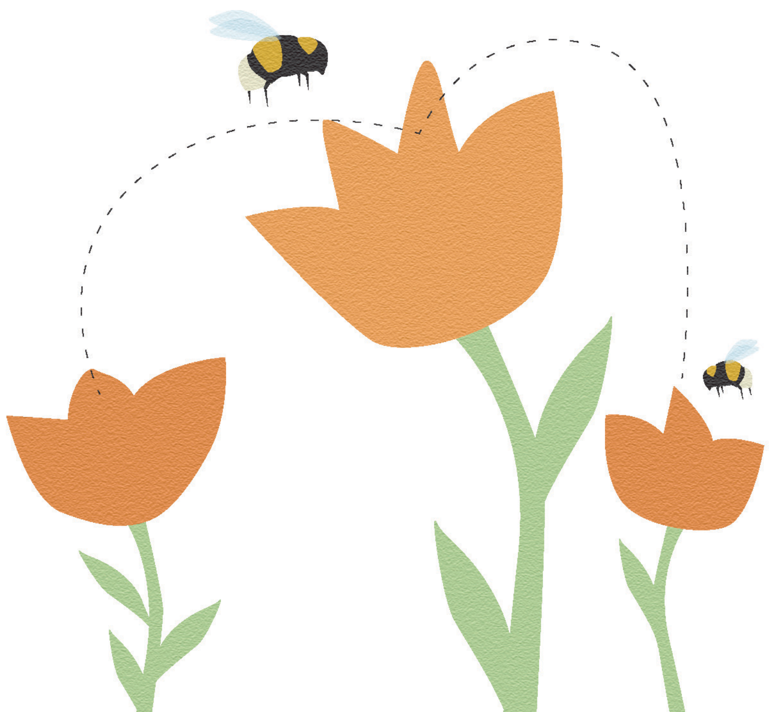
Figure 3
The global loss of biodiversity (Newbold et al., 2020)

Pollination and our dependence on it

Pollinators are essential for food production and maintaining balanced ecosystems. They are ecological keystones as they pollinate 78-94 % of all wild plants (Ollerton, Winfree, Tarrant, 2011). In addition, a third of our food is produced due to pollination (Peters, 2012). The diversity of pollinators builds the foundation for functional ecosystems (Soliveres et al., 2016) as well as improving the resilience in social-ecological systems (Jansson and Polasky, 2010). A global economic value of animal pollination was estimated up to 657 billion US$ annually (Porto et al., 2020). Furthermore, a summary of research regarding pollination and food production presented by the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) showed that the decrease of pollination insects will lead to long term severe outcomes for the world's food production (Borgström et al., 2018). Evidently, the importance of protecting pollinators is crucial.

Pollination is a biological process when pollen is transferred from a plant's reproductive organs which leads to fertilization. Most of the plants are dependent on pollination to an extent and in Sweden this is mainly carried out by insects (Borgström et al., 2018). Wild bees are considered the most efficient and important pollinators, in Sweden there are around 300 wild bees in Sweden, 40 of these are bumble bees (Naturvårdsverket, n.d.a).

A third of our food is produced through pollination



Pollination can occur within same flower, an entire plant or from one plant to another

Pollination, biodiversity and resilience

Biodiversity is key for ecosystem stability and resilience. Landscapes with high biodiversity is more stable than others with lower biodiversity and carries a higher resilience (Fransson, Andersson, Kruuse, Poppius, Nordius Stålhamre, Malmberg, John Block, 2017). This means that the environment is more resilient towards changes, for example floodings, droughts, heat waves or invasive species. In other words, in a landscape with high diversity of species, one sudden change could affect one or a few groups of species but the entire ecosystem would still survive. In contrast, a decline in diversity will have large consequences for an ecosystem. For example, the effect of declining insects has led to a decrease in populations of birds since insects are the primary food source for many birds (Goulson, 2021). In pollination, diversity is crucial because different pollinators visit different flowering plants during different parts of the season; a lower diversity of pollinators would decrease the efficiency and resilience that pollination brings. Further, a diversity of pollinators are necessary to reach the need of pollination in agriculture and nature (Borgström et al., 2018). A high diversity of species have significant positive effects on both ecosystems and human life (Hooper et al., 2012). The diversity of pollinators is directly dependent on the diversity of plants (Fransson, et al., 2017). To preserve and protect as many species as possible is also crucial (ibid). In addition, both climate and soil also affects the level of biodiversity (Fransson et al., 2017). What is required to achieve high biodiversity will be discussed further in the chapter.

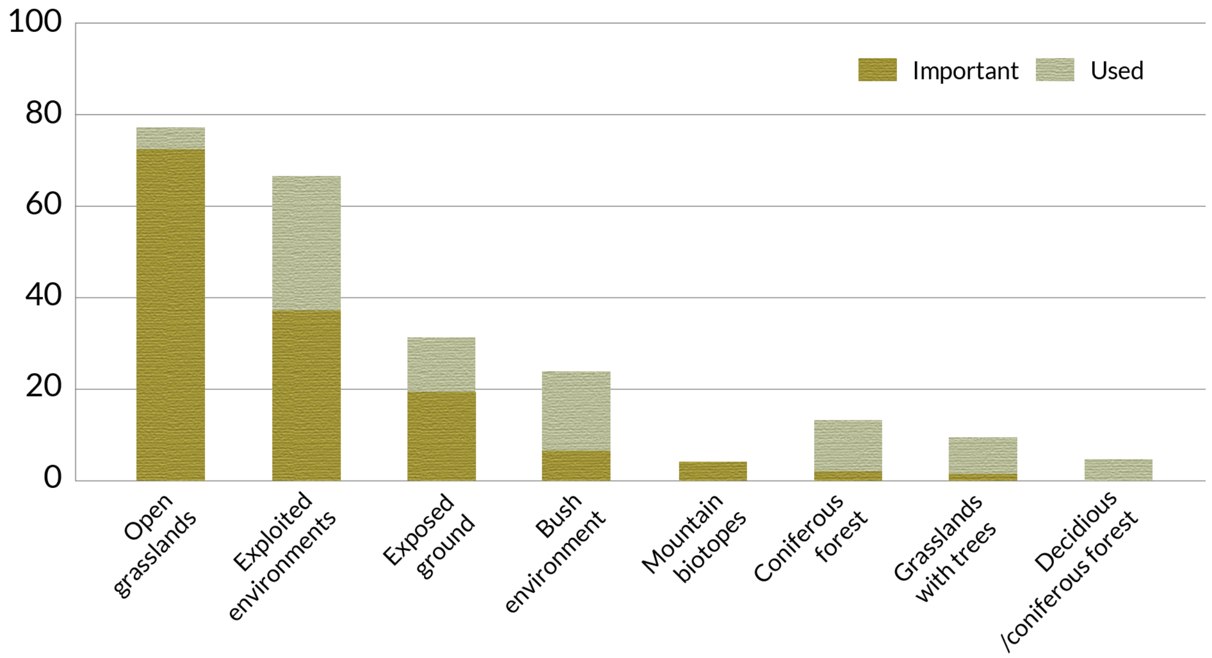
Ecosystem services

Green infrastructure has many important functions in the urban landscape, it provides us with ecosystem services (ESS) such as cleaning the air, increasing wellbeing, regulating and temperature. Pollination is an essential ESS that also supports other ESS. As discussed above, the quality and quantity of ESS becomes more stable if the green structure that provides these services are more diverse (Fransson et al., 2017).

Why pollinators in the city

Due to the loss of natural habitats and a monocultural rural landscape, the city has become an alternative host of habitats for wild bees (see e.g. Saure, 1996; Tommasi et al., 2004; Andersson et al., 2007; Matteson et al., 2008; Zetterberg, 2011). Cities have a great potential to support and sustain pollination when planned and designed properly (e.g. Andersson et al., 2007; Jansson and Polasky, 2010). A study made in the UK showed how bumble bees (Bombus terrestris) thrived more in cities than on agricultural land (Samuelson, Gill, Brown, Leadbeater, 2018). Important to note is that not all wild bees can adapt to live in the urban environment, some thrive better than others, researcher Anna S. Persson points out in an interview (Persson, 2020, 3 June). Nevertheless, this is why cities have shown to play an important function as an alternative habitat by providing biotopes for certain species. In addition, supporting urban habitats for pedagogical purposes is also essential as increasing contact between humans and nature also raises knowledge, awareness and ultimately the will to care for nature (von Post et al., 2022). There is a common agreement among researchers that the future role of the city as an urban habitat will become even more important in order to support pollinating species and increase biodiversity (Borgström et al 2018) and strengthening the relation between humans and nature.

Figure 4
Open grasslands and exploited environments have shown to be important biotopes for redlisted bees. The graph is translated from swedish (Borgström et al., 2018).



Governmental and private reactions

A reaction to the decline of insects is the increased attention and awareness to the role of urban habitats to sustain pollinators and protect biodiversity. Both private initiatives and governmental organizations around the world are highlighting the importance of supporting pollinators and protecting biodiversity. On an international level, Agenda 2030 includes goals that focus on resilience, protection and promotion of ecosystems and halting biodiversity loss. Secondly there is the UN's Convention on Biodiversity (CBD). Recently, the European Commission revised their initiative to address pollinator decline (European Commission, 2023). On a national level there is Miljöbalken (1998:808), a law abiding document that considers protection of natural areas with high ecological value. These documents also consider urban green areas. Secondly, Sweden has 16 climate goals where many of them relate to protection and restoration of ecosystems, biodiversity and nature (Ekologigruppen, 2022). Until the end of 2022, municipalities and organizations could receive financial support from the government to invest in projects to support pollination, LONA (Lokala naturvårdssatsningar) (Naturvårdsverket, 2023a). Three municipalities in Sweden, Södertälje, Österåker and Vaxholm, have developed a pollination plan to tackle the issues of declining species and to protect biodiversity. The goal of a pollination plan is to create an action-plan that focuses on protecting, enhancing and developing pollination (Ekologigruppen, 2022; Naturvårdsverket, 2023b). These primarily focus on ecological aspects of the landscape and point out important habitats and connections on regional scale. The pollination plans include analysis of spreading of species as well as specific strategies and measures to protect, enhance and support pollination (Arnström, 2023).

Figure 5
Sustainable development goal number 15; life on land. (SDG, n.d.).

Figure 6
Two of Sweden's 16 national environmental goals, "a rich flora and fauna" and "well built environments". Naturvårdsverket (n.d.b).

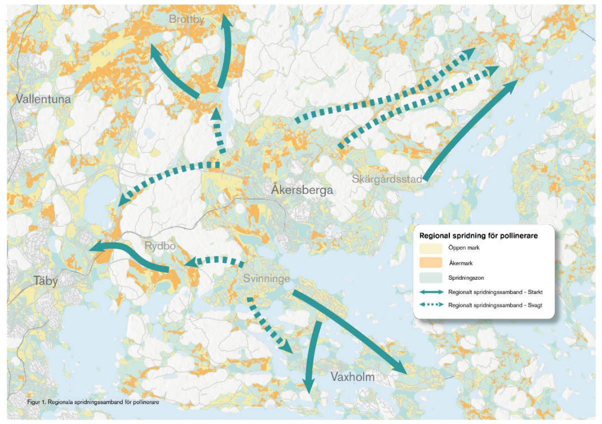


Figure 7
A plan showing pollination on a regional level as a part of Österåker's pollination plan (Ekologigruppen, 2022)

The pollination plans mentioned have been great sources of inspiration in this paper but the social ecological approach suggests merging the ecological system with the social system, which is my attempt in this thesis.

Extinction vortex

The effects of climate change and declining nature are unpredictable and scientists are fearing that the circumstances might be far worse than what has already been predicted. So what would happen if we continued with "business as usual"?

We do not know how far over the edge of ecocide we have gotten. For example, in southwest China, Bengal and Brasil farmworkers have to hand pollinate their crops due to fast declining populations of pollinators (Goulson, 2021). If crop yields have decreased, one can assume that wildflowers are also likely to have declined. If wildflowers would decline further, this would result in less food for other pollinators. Some scientists believe that this could lead to an "extinction vortex" leading to far more species with a higher resilience becoming endangered (ibid.).

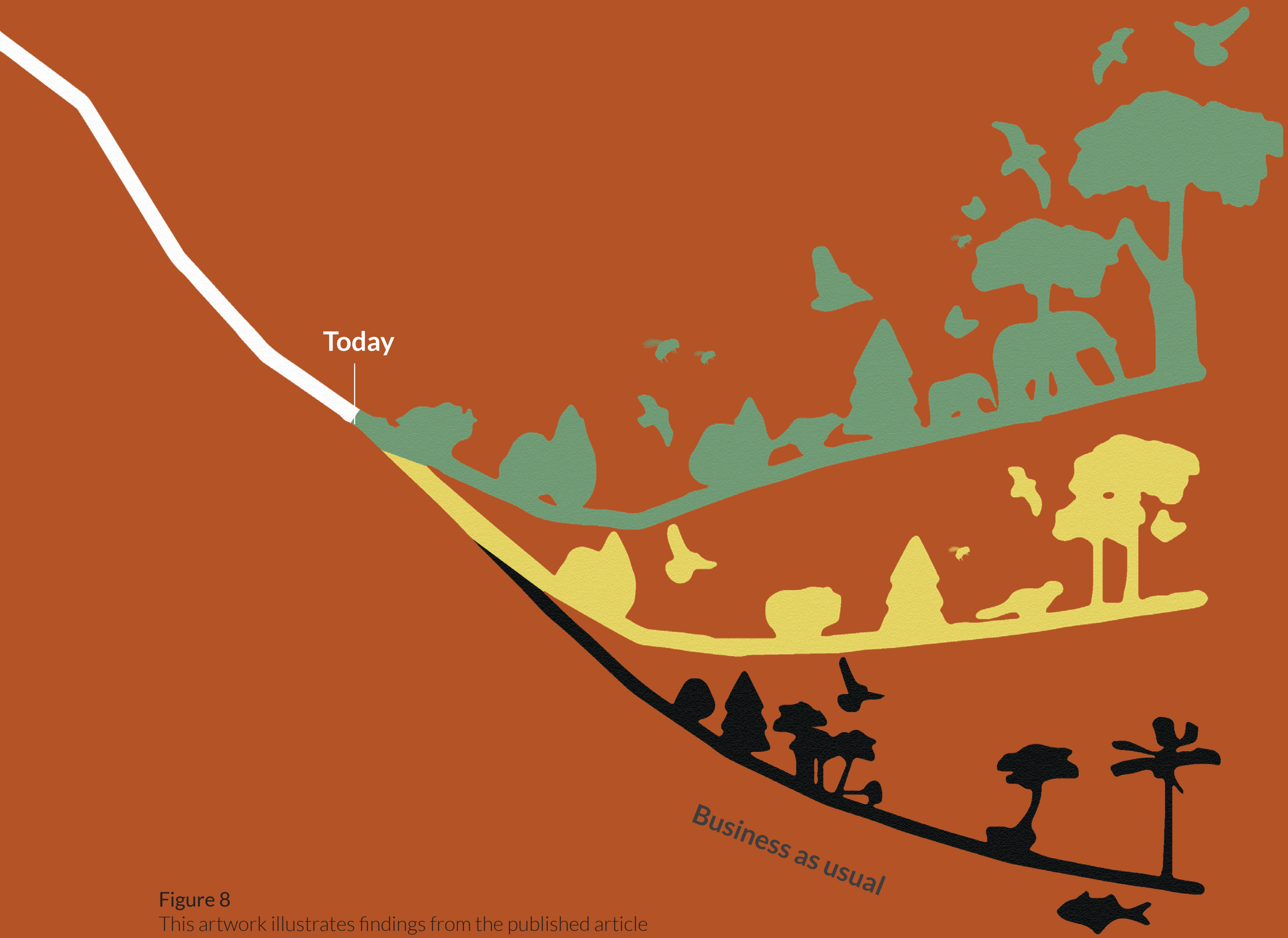


Figure 8
This artwork illustrates findings from the published article "Beinding the curve of terrestrial biodiversity needs an integrated strategy" but does not indent to accurately represents its results (Leclère et al., 2020).

"If all mankind were to disappear, the world would regenerate back to the rich state of equilibrium that existed ten thousand years ago. If insects were to vanish, the environment would collapse into chaos."
Edward O. Wilson

SCOPE

The knowledge gap

Ecosystem services are used to argue for protecting valuable urban green structures but often the underlying services as biodiversity is forgotten in those conversations (von Post et al., 2022). Valuable urban nature is being lost when there is a lack of biological knowledge in the interest of urban planning and design (ibid). Biodiversity is often mentioned in urban planning but the purpose and the depth of it is rarely explained in detail. The lack of clarity makes it harder to propose efficient measures to support biodiversity (Persson and Smith 2014).

Aim

The aim of this thesis is to explore the city as a network of urban habitats for wild bees and to find synergies between these and social spaces. I want to gain knowledge on how planning for pollination not only improves the city from the pollination perspective but also increases human well-being.

Purpose

The purpose of this thesis is to find ways to contribute to turning the trend of declining species. This will highlight the opportunities with urban planning, adding the ecological network as a critical layer to the current urban morphology. The purpose is also to challenge the idea that the city is entirely for humans and explore the concept that through ecologically and socially sensitive implementations, create symbiosis between humans and non-human species. Thus, promoting social ecological urbanism.

Research questions:

» **What are the requirements to support pollination in cities and what potential do cities currently have?**

» **How can urban planning and design at different scales enable for pollinating insects to spread and thrive?**

» **How can these urban habitats for pollinators cohabit with people and social spaces in cities?**

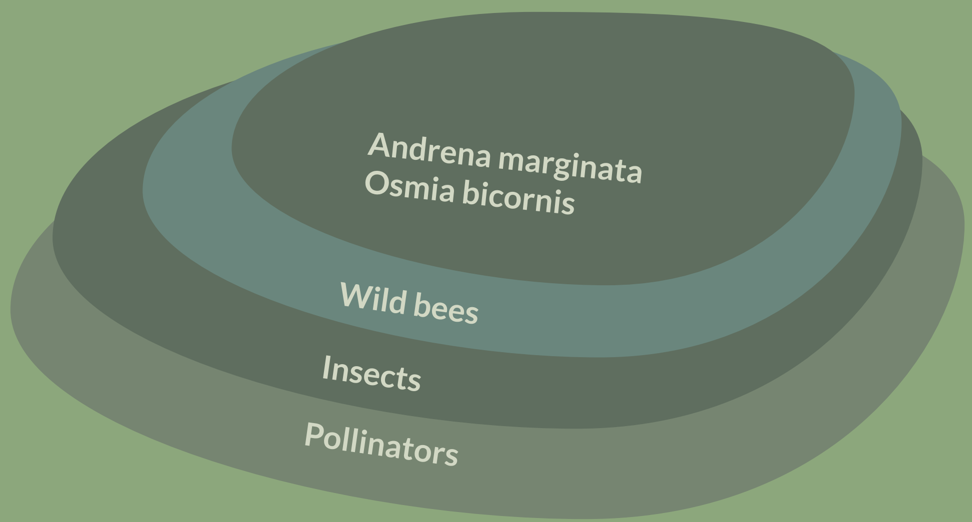
DELIMITATIONS

In Sweden, pollination is mainly carried out by insects and wild bees are considered an important group of pollinators. Amongst wild bees, there are generalists and specialists. In this thesis I focus on two species, one specialist and one generalist. The site is the entire city of Gothenburg as well as a focus area within the city.

Discourses
Social ecological urbanism
Urban ecology
Green infrastructure
Urban habitats
Urban planning and design
Urbanization

This thesis is about...
Wild bees
Pollinators
Biodiversity
Gothenburg
Habitat network
Ecological resources
Green connections

This thesis is not about...
Urban farming
Rooftop gardens
Rural planning
Other ecosystem services
Stormwater planning
Light pollution



THESIS OUTLINE

This first chapter introduces the theme of the thesis of which the rest of the project is based on.

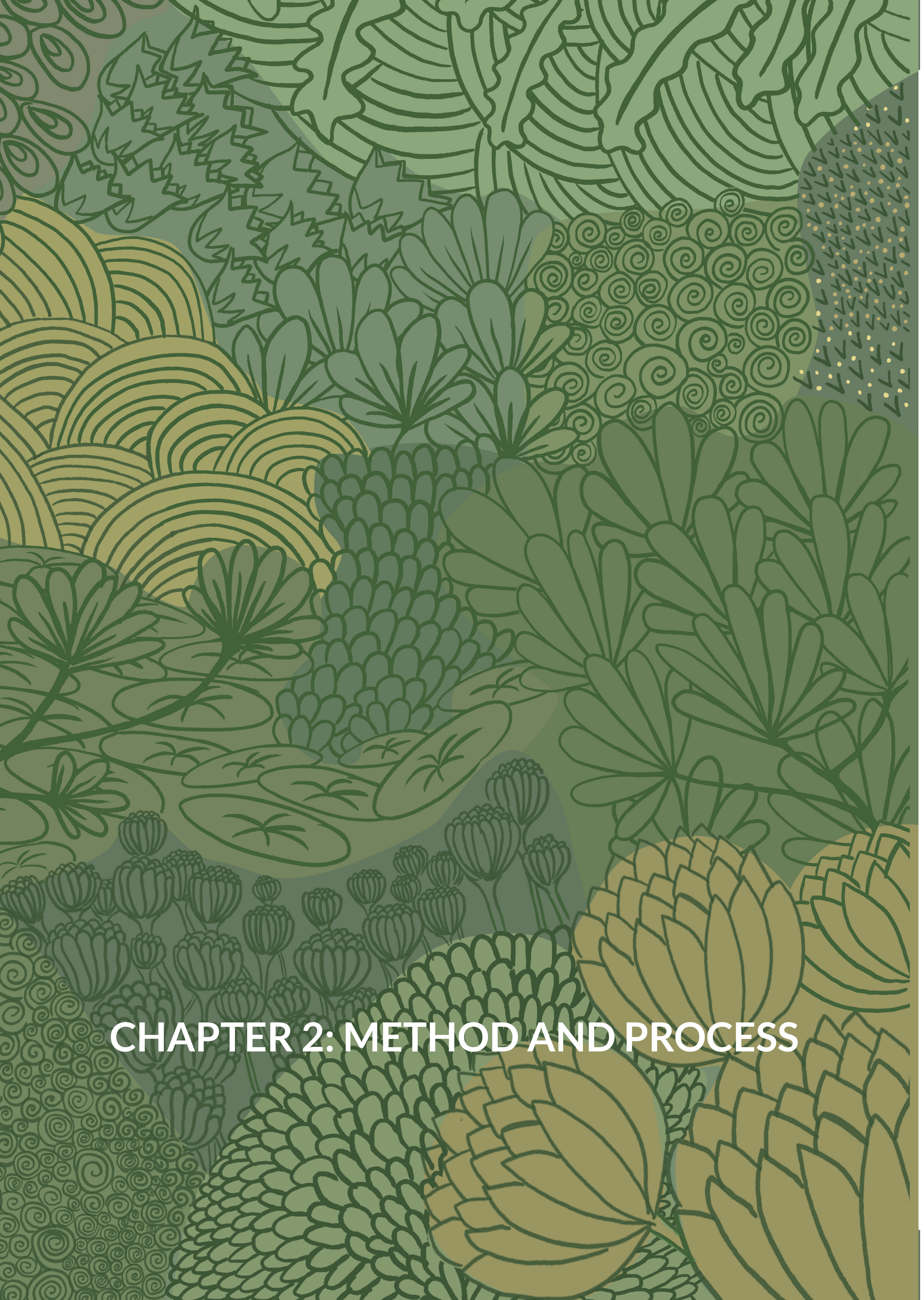
Chapter 2 introduces the framework of the thesis and an overview of the methods and the process

Chapter 3 presents the results from the literature review and interviews and regards the research of the thesis.

Chapter 4 presents two design and plan guidelines based on the research from previous chapter.

Chapter 5 presents the the landscape analysis made in GIS. This analysis is based on the research from the chapter 3. This chapter also include a pollination plan and design proposal in three different scales: city-, neighborhood- and streetscale. The streetscale design proposal is presented in two different scenarios.

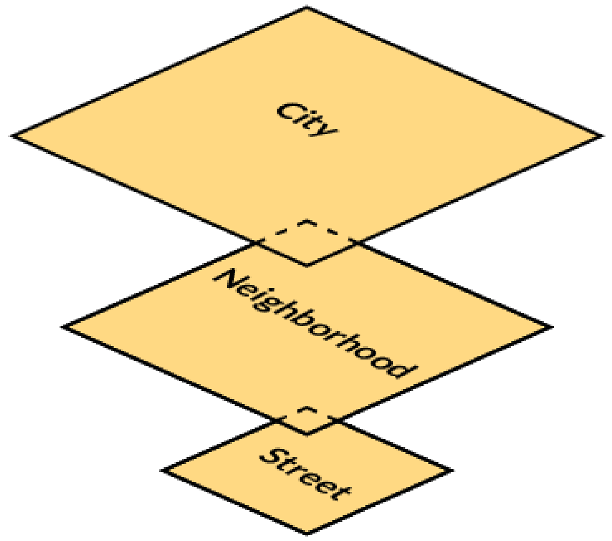
Chapter 6 summarizes the thesis with a reflection and discussion of the method, process and result.



CHAPTER 2: METHOD AND PROCESS

This project has been conducted through research, landscape analysis and design. The scope of the thesis concerns a multiscalar perspective that includes three scales: city, neighborhood and street. This is for reviewing an individual site and the larger network that it's a part of. This is important because in supporting pollination, the quality of an individual habitat is highly dependent on its connectivity to the surrounding habitat network.

I have used a social ecological approach, regarding the city as a social and ecological system where nature and society are intertwined rather than two separate entities. The design part is to an extent based on theoretical research and I have made space for speculation on possible outcomes and results of the proposals. The social ecological approach also invited a multispecies perspective which I have used through the entire thesis.



The thesis regards a multi-scalar perspective in order to capture an individual habitat, the surrounding context and the entire network. In order to support pollination on a local scale, we must also look at connections within the entire habitat network at city-scale. To secure spreading between habitats, connections between these need to be enhanced or developed.

OVERVIEW OF METHODS AND PROCESS

Below are the steps of the thesis presented...

1. Literature review

The literature review included gathering of scientific studies, papers and articles regarding urban habitats, pollination planning, urban ecology and ecology of pollinators and wild bees. This part also included reviewing earlier master theses on related themes. In parallel with the research, there was a listing of the relevant data needed for the GIS analysis.

2. Interviews

The interviews were conducted over the phone with people within the professional field of landscape architecture, ecology, biology and urban planning;

- Martin Allik, landscape architect at Mareld
- Karin Ahrné, environmental analysist specialist at SLU
- Jesper Arnström, environmental expert and green planner at Ekologigruppen
- Niklas Johansson, environmental analysist specialist at SLU
- Åsa Gren, lecturer and researcher Department of Building Engineering, Energy Systems and Sustainability Science at University of Gävle

This part also considers conversations with landscape architects at White architects. In both the literature review and the interviews, it became evident that choosing 2-3 species to focus on was helpful in order to analyze the city from an ecological perspective. The species I chose represents different sensitivities and needs.

3. GIS mapping and data analysis

The analysis was made through QGIS. I used two plug-in tools; one to create a habitat network analysis and the second, Place Syntax Tool (PST) (Spatial Morphology Group [SMoG]), to analyze human movement and centrality through the street network. The first one uses land cover data to represent different biotopes, secondly these biotopes are differentiated by parameters, describing them as a nesting (reproduction) or foraging (quality) site. The land cover types are also weighed in for spreading, by giving different levels as barriers (friction). For example, a highly trafficked road weighs as a high barrier while an allotment garden weighs as a low barrier. Another parameter is flying distance, the value is based on foraging ranges found in the research. Some examples of the biotopes in the land cover data are pine forest, open land with vegetation, exploited land etc. There are two different versions of the parameters (yellow and red in the table) that are given to the land cover data, this is because they represent two different species of wild bees that have different needs as well as sensitivities.

Classification of the layers, sources in [x]:
- Motorized and non-motorized network [SmoG]
- Buildings, streets and properties [Lantmäteriet]
- Land use [Lantmäteriet]
- Land cover data (biotopes) [Calluna AB]
- Reported species findings [Artportalen]
- Trees of particular value [Länsstyrelsen Västra Götaland]

GIS - geographic information system, a computer system that analyzes and displays geographically referenced information. It can display data by different values.

	Guldsandbi			Rödmurarbi		
BiotopeName	Quality	Reproduction	Friction	Quality	Reproduction	Friction
1.1.1. Tallskog/Pine forest	0	0	70	0	0	70
1.1.2. Granskog/Spruce forest	0	0	100	0	0	100
1.1.4. Lövblandad barrskog/Mixed forest	0	0	7	0	0	7
1.1.8. Temporärt ej skog (inkl hyggen)/Temporarily non forest	5	0	1	5	1	1
6.2. Hav/ Marine water surfaces	0	0	1000	0	0	1000
4.2. Övrig öppen mark med vegetation/Vegetated other open land	9	0	1	10	0	1
5.3. Exploaterad mark, väg /Roads	0	0	100	0	0	100
301 Koloniområde	10	0	1	10	0	1
302. Skyddsvärda träd (>20 cm diameter)	9	0	1	10	1	1
305. Sandig öppen mark	10	1	1	8	0	1

This is a simplified and shortened version of the lift of weights used in the analysis

4. Proposal of design guidelines

The design guidelines are based on the research from step 1 and 2. My own reflections, observations and conclusions contributed to the making of these guidelines. They are presented as diagrams and graphs.

5. Exemplifying design guidelines on three scales: city, neighbourhood and street

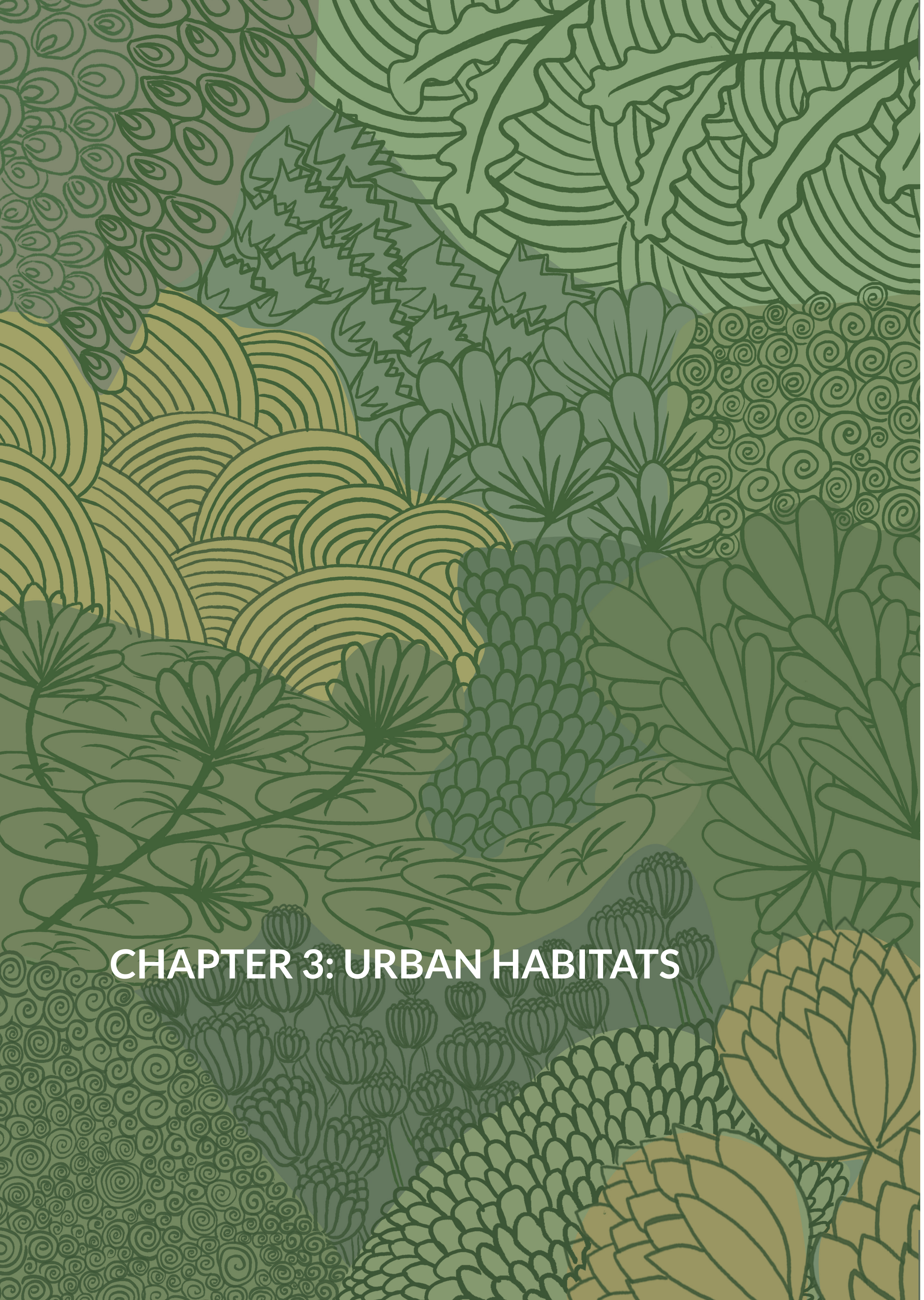
The design guidelines are exemplified in Gothenburg on three different scales: city, neighborhood and street. Each scale represents different types of implementations.

The city-scale plan presents the context of a larger scale landscape that consists of a network of habitats. This plan is based on the landscape analysis from step 4 and shows hotspots and connections. Implementations at this scale consist of locating areas to increase connectivity or quality.

The neighborhood-scale plan presents a focus area within the city where connectivity is especially important. This plan presents more detailed implementations divided between different properties and functions; habitat or connector.

The street-scale spatial design presents an additional focus area within the previous one. At this scale, the design and implementations are even more detailed and divided between two scenarios. The reason is to explore the different levels of social-ecological enmeshment.

The project area includes the urban parts of Gothenburg

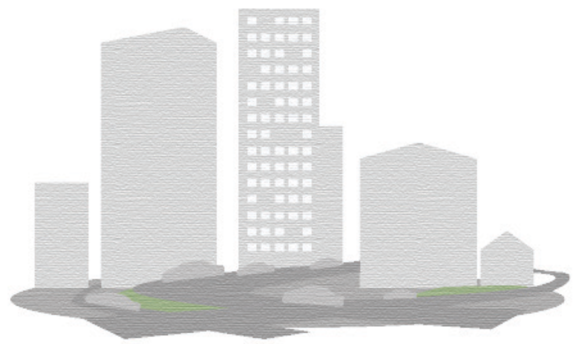


CHAPTER 3: URBAN HABITATS

THE CITY AS A HABITAT

Urban ecology and the city's potential

The urban environment can often be described as harsh, dry and hot. The high amount of hard surfaces such as facades and pavement leads to making cities hotter and drier than their surrounding landscapes (Mimet et al., 2009). Cities are often home to many non-native species (Persson, 2021) and the unique urban landscape includes a variety of different types of habitats (Müller, Werner and Kelcey, 2010). The types of species in an urban environment depend on the biodiversity of the surrounding landscape, the form of the city and the species unique characteristics (Aronson et al. (2016).

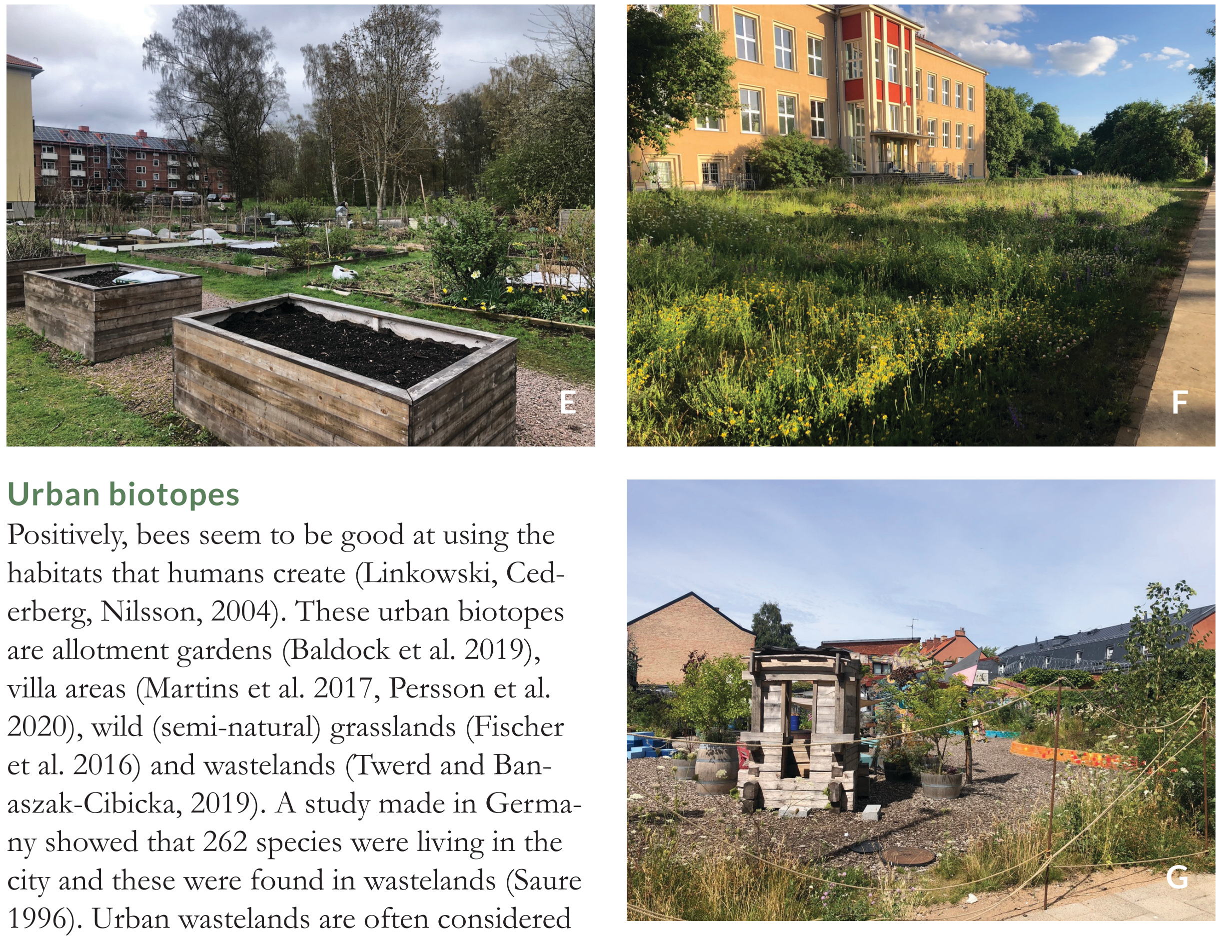


The urban environment is generally covered with hard and grey surfaces, contributing to a harsh, dry and hot environment.

There is a high potential for cities to sustain pollinating insects if well planned and designed. To protect and develop biodiversity, a network of urban habitats that are ecologically functional are needed. Green infrastructure could be developed to a greater extent and with relevant qualities to secure survival of pollinators (von Post et al., 2022). The green areas of the city need to be planned and maintained based on a larger perspective that considers the entire urban landscape and its rural surroundings (Ekologigruppen, 2019). In that way even smaller areas can be functional, as a part of a larger network of green infrastructure (ibid.). A study showed how groups of well placed small habitat patches can be sufficient to inhabit birds in an urban landscape (Andersson and Bodin, 2009). The urban form and configuration of green structures have a high potential to manage pollinator diversity (Berghauser Pont, Ahrné, Gren, Kaczorowska, Marcus, 2017). Urban habitats may not replace semi-natural habitats in the rural landscape but it may contribute to conservation of pollination (Baldock et al., 2019).

Developing and protecting green infrastructure is essential in order for different organisms to adapt to the exploitation of land and for discovering how different species respond to human interaction and the alterations we do to the landscape (Dearborn and Kark 2010). If interventions and changes to urban environments are not well planned or built, to support biodiversity, there is a great risk that the inhabited species might disappear (Hahs et al. 2009).

Green patches in the urban landscape. A) An overgrown garden in Saumur, France. B) Gothenburg. C) Two layered vegetation on a central street in Kiel, Germany. D) Dead wood in an urban forest in Gothenburg.
All photos by author



Potential urban biodiversity hotspots E) An allotment garden in Gothenburg. F) An overgrown grassland in Leipzig, Germany. G) A wasteland turned into an allotment garden and playground, Malmö. All photos by author

Urban biotopes

Positively, bees seem to be good at using the habitats that humans create (Linkowski, Cederberg, Nilsson, 2004). These urban biotopes are allotment gardens (Baldock et al. 2019), villa areas (Martins et al. 2017, Persson et al. 2020), wild (semi-natural) grasslands (Fischer et al. 2016) and wastelands (Twerd and Banaszak-Cibicka, 2019). A study made in Germany showed that 262 species were living in the city and these were found in wastelands (Saure 1996). Urban wastelands are often considered the neglected and abandoned part of the city, such as the side of the road, railway or near abandoned infrastructure (Twerd and Banaszak-Cibicka, 2019). These types of urban landscapes are often sun-exposed, have low nutrient soil and a low coverage of vegetation, creating an ideal environment for many pollinators. These human-made biotopes often offer a diverse alternative to the wild bees original habitat (Saure 1996). It can then be expected that wild bees would respond well to suitable restorational measures (Linkowski, Cederberg, Nilsson, 2004).

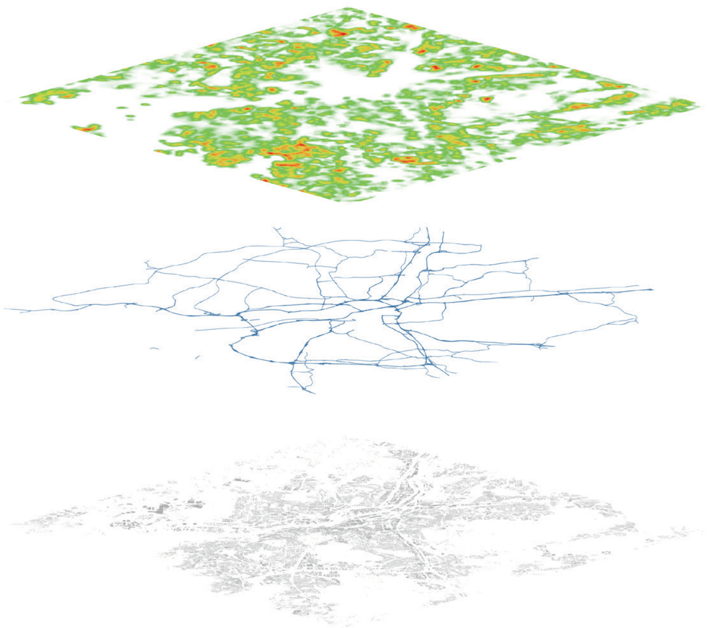
Different intensities of urbanism affects the biodiversity, a more dense urban landscape has different qualities and levels of barriers than the sub-urban or the industrial landscape. There is a significantly higher richness and abundance of wild bees in the wastelands located in the suburbs compared to the urban areas (Twerd and Banaszak-Cibicka, 2019).

Biotopes and habitats
A biotope is an area where the environment and the species determine what type of biotope it is, for example a forest, grassland or ocean. A habitat is an environment where the characteristics and landscape fits the requirements of a certain species (Ekologigruppen, 2019).

SOCIAL ECOLOGICAL URBANISM

Social ecological urbanism offers a broader perspective of urban sustainability by addressing cities as social-ecological systems. This approach is an understanding of the intertwined relation between nature and humans, highlighting the interconnectedness and interdependence between these (Biggs et al., 2021). The core of the vision is to integrate ecosystems in the practice of urban design just like social systems always have been (Barthel et al., 2013). The separation of nature and human, which has been a foundational Western thought since the Age of Enlightenment (Davidson-Hunt and Berkes 2003), is still present in today's urban design that is dominated by human infrastructure that disregards other species. Note that this approach of an interconnectedness between human and nature is not "a new concept" but can be found in traditional ecological knowledge that still today is practiced amongst Indigenous cultures (Kennedy, 2022).

Multispecies urbanism is another approach that rethinks the idea of human-center urban planning: "Multispecies urbanism acknowledges urban nature as a critical stakeholder, advocating for nature-based and ecological approaches to urban planning, governance, and resource management" (Kennedy, 2022). This approach describes the city as ecological formations where people are not only shaped by infrastructure but by soils, water and vegetation (Barua and Sinha, 2020). Cities aren't just hard surfaced landscapes but living systems and we, as planners, should treat them as such (Romice et al., 2020). There is a potential to plan better by planning less, if we plan for resilience and use the simple framework of diversity (ibid.).



The core of this thesis is to approach the habitat network as a critical layer of the urban morphology.

FUNCTIONAL SOCIAL ECOLOGICAL LANDSCAPES

The urban form, distribution and content highly affects the social ecological system. There is an ongoing debate whether what type of urban form, high or low density, is ideal for preserving and promoting biodiversity. Higher density of people have shown to have a negative impact on biodiversity and the population of pollinators (Persson, Ekroos, Olsson, Smith 2020). As mentioned earlier, a large part of the human population lives in cities that are located on biodiversity hotspots (CBD, 2012) and these cities are also home to many threatened and declining species (Persson, 2021b). As cities grow, many of these species risk being subject to 'extinction debt', further decreasing urban biodiversity. Although, densification itself may not be a direct threat of biodiversity as it leads to remaining natural areas in vicinity to cities (Berghauser Pont et al. 2021).

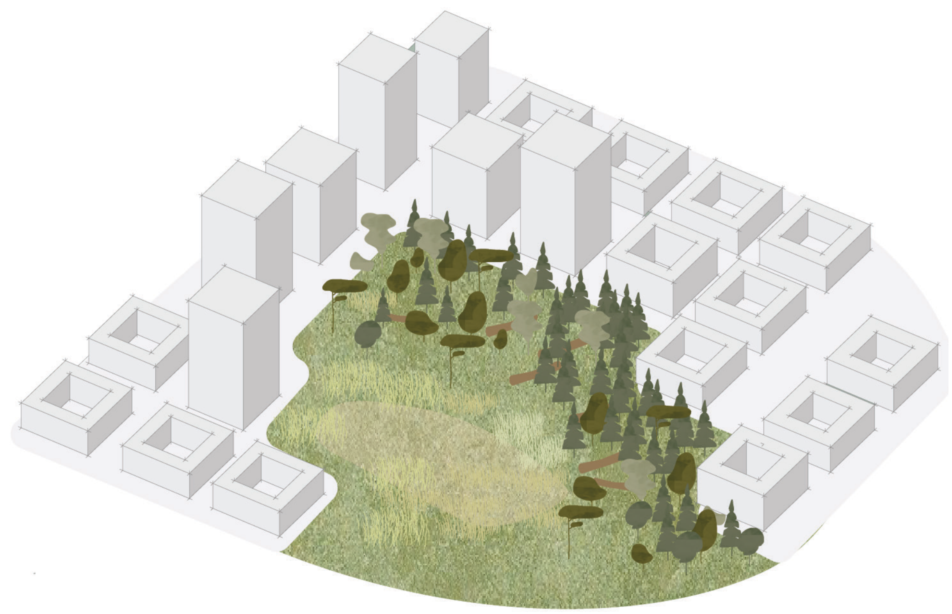
'Extinction debt'

Extinction debt occurs when species living in urban areas don't reproduce at a necessary rate for the long-term survival of the population. Their habitats may be isolated from other habitats and cannot spread or be reached by new individuals to re-colonize (Persson, 2021b)

Land sparing or land sharing?

Urban green structure comes in different sizes and shapes. The size, layout and distribution of a green area will determine its level of biodiversity, recreational value as well as what ESS it can provide (Persson, 2021b). How it is distributed can be conceptualized in 'land sharing' or 'land sparing'. The first one describing an urban landscape with low density and development and therefore creating an intermix with nature. Land sparing refers to an urban landscape that has a higher density and therefore keeps larger green areas intact, avoiding exploitation. Different species react differently to these urban development scenarios (ibid.). In fact, a land sparing scenario, where large green areas are separated from built structure, might gain a larger diversity of species and more sensitive species (Sushinsky et al., 2013) . Contrarily, a land sharing scenario, where green spaces and built structure are integrated, might increase numbers of common species, often generalists (see generalists and specialists explained on page 52). As previously discussed, it is the urban expansion of low density residential housing or industrial development (urban sprawl) that is considered having the most negative impact on biodiversity (Persson and Smith 2014). Neither of the scenarios, land sharing or land sparing, solves the need of supporting biodiversity on their own. Where there is a low density urban development, a sharing scenario could create a greener city, increase contact between human and nature and increase connectivity between urban green spaces. Similarly, a high density urban development could keep valuable nature or agriculture intact (Persson and Smith 2014). Therefore, a mix of these scenarios is the ideal distribution of a functional social ecological system.

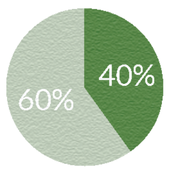
Landsharing
Often low density built structure integrated with green structure



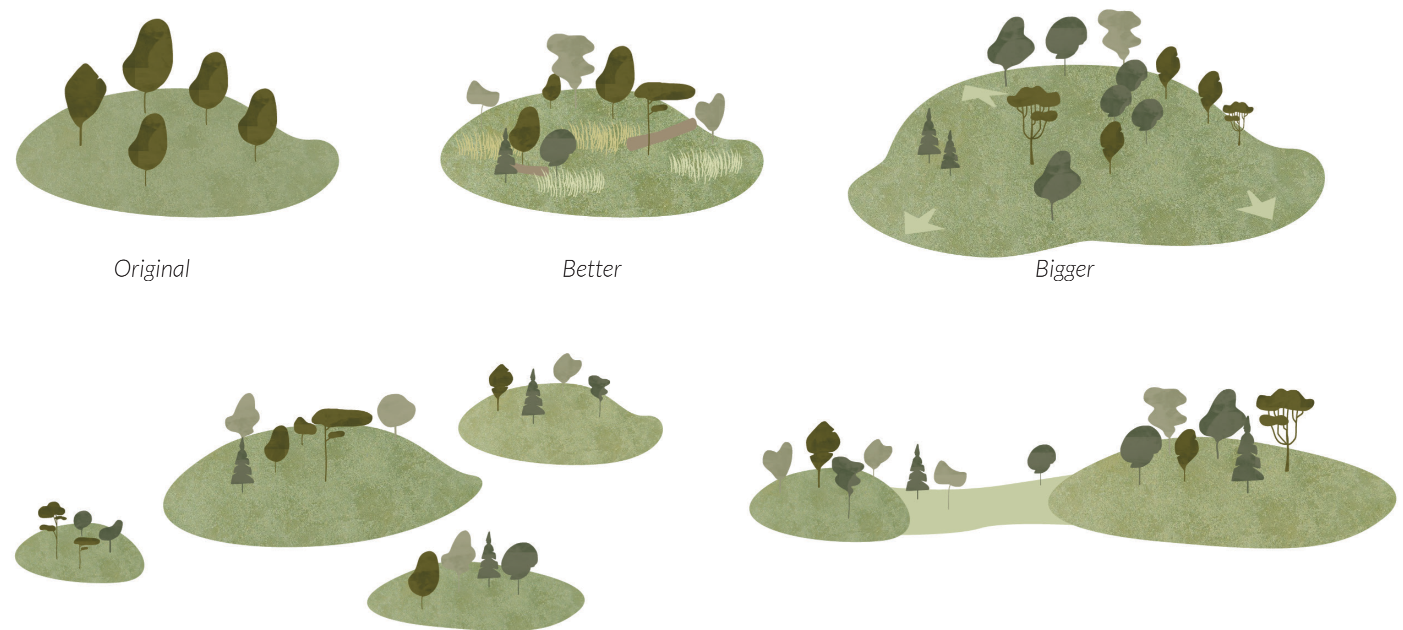
Landsparing
Often higher density, leaving green structures from being exploited

Aesthetics of urban green areas

Urban green areas are often small and fragmented and include open and monotone landscapes with low diversity. During the interviews it became evident that the current aesthetics and expectations of urban green spaces does not fit with requirements of what is ecologically functional for supporting pollination. This is creating a conflict in the social ecological system; what is needed for ecologically functional green spaces and what is expected by people. For example, classic lawns of cut grass are considered to be aesthetically pleasing as it makes the landscape look tidy and clean, Niklas Johansson stated in the interview. However, these types of landscapes are often monotone, composed of only one or a few species and have a considerably low biodiversity (Ignatieva, 2017). Cut grass landscapes take up around 40 and 60 % of urban green areas in Sweden and they are expensive to maintain (ibid.). These areas are customized for recreation such as sports or social activities, but often cut grass landscapes dominate also other non-recreational landscapes such as sideroads, pathways and bike paths (Fransson, et al. 2017). Johansson explains how there are also cultural norms of how green spaces should be maintained and what they consist of; intensive maintenance with a regular cutting, trimming and cleaning of green spaces, usage of the regular high nutritious soil. With a lower intensity of maintenance, different types of grasslands would increase, favoring biodiversity and could decrease municipal costs (Fransson, et al. 2017). In order to meet the requirements for increasing biodiversity, there needs to be a shift in what is considered aesthetically pleasing and how we care for our green spaces. There is a high potential for urban green areas to support urban habitats for pollinators and to create social ecological spaces to cohabit people and pollinators if these aesthetics, cultural norms and expectations of urban green spaces are addressed.



A typical urban park with finely cut grass and large vegetation. Ögårdsparken, Malmö. Photo by author.



Principles for functional ecological landscapes

In order to support pollination in cities different principles can be implemented. One comprehensive report to restore and enhance wildlife in England summarized guidelines in four words: *better*, *bigger*, *more* and *joined* (BBMJ) (Lawton et al. 2010). *Better* referring to increased habitat quality, *Bigger* referring to increasing size of natural areas, *More* meaning to creating more new green areas and *Joined* meaning to create connections between green areas or joining them together. (ibid.). *Better* and *Bigger* are considered the most crucial steps for reproduction and survival of species (von Post et al., 2022). Although, increasing the size of urban habitats is challenging in a dense urban environment. As mentioned earlier, a study suggests that a group of small habitat patches (*More*) can function similarly to one larger continuous habitat as long as they are functionally connected (*Joined*) (Andersson and Bodin, 2009). But how many neighboring habitats are needed? A few studies show that 15-30 neighboring habitats are needed in securing survival of a metapopulation (Bergman and Kindvall 2004). In addition, identifying and highlighting the urban habitats that are significantly valuable is essential for increasing chances of metapopulation survival, rather than randomly picking an urban habitat (ibid.).

Another example, from Södertälje municipality pollination plan, are the four guidelines: *Preserve, Strengthen, Create* and *Cooperate*. These are used to guide for a coherent green structure (Ekologigruppen, 2019). To preserve existing green structures is highly prioritized since ecosystems are complex and it takes time for compensational measures to become of high ecological value. Different implementations at a larger scale will influence several different stakeholders, properties and land owners. Therefore cooperation is also crucial to create a connected green infrastructure (ibid).

Metapopulation

When a population of species is living in a highly fragmented landscape, divided in local groups (subpopulations), they are altogether called a metapopulation (Hanski 1999).

The importance of connecting habitats

There is a high potential for urban planning and design to increase urban green connectivity, which has a large impact on the diversity of pollinators. A study made in Stockholm regarding the correlation between biodiversity and connectivity (Ahrné et al. 2009) showed that the amount of bumble bees increased with increased flowering resources but it didn't largely affect the diversity of bumble bees. However, what negatively affected the diversity of bumble bees was the increased amount of buildings, roads and hard surfaced areas in the surrounding areas. For instance, an allotment garden with a high abundance of flowering species will positively affect the number of individual bumble bees but not the number of bumble bee species (ibid). As mentioned in the introduction, high biodiversity increases resilience, as habitats are more connected they become less sensitive towards interruptions or changes. For all organisms, landscape connectivity is important in two scales; day-to-day movement, for example foraging and nesting (this will be further explained on page 51) and population dynamics: to be able to spread to new habitats or re-colonize (Andersson and Bodin, 2009). Fragmentation not only occurs when there are buildings or highly trafficked roads but also when habitats or resources within a habitat are too far apart (Borgström et al. 2018). Therefore, habitat connectivity is needed in two scales; for moving between habitats (spreading) and reaching different important resources throughout the species life cycle (nesting and foraging).

A way of describing urban green structures is to view them as "islands" and the habitats that act as sources of biodiversity can be described as the "mainland". The biodiversity of these islands (urban green structures) is dependent on their sizes as well as the distance to the "mainland" (Persson and Smith 2014). This theory highlights the importance of having natural biodiverse habitats within a close proximity to urban green structure. Another way of describing how islands of urban green structures create a network of habitats is by the metapopulation theory (ibid.). Within an urban habitat network, species not only spread from the "mainland" to the "islands" but from island to island. It is the spreading between these urban habitats that keep the entire population alive (Persson and Smith 2014). Particularly newly restored green areas (islands) are sensitive since and reliant on surrounding habitats for resources. In contrast, larger and older habitats with a diverse landscape (mainland) are not as reliant on connectivity to increase their biodiversity (Persson and Smith 2014). At the same time, through connection, older urban habitats could act as an important source of biodiversity for younger, not yet established urban habitats (ibid.) As discussed earlier, a group of small patches of green structures can fulfill the requirements of the habitat demands if these are within a close distance and connected (Andersson and Bodin, 2009). The level of connectivity and isolation of an urban habitat can be calculated by measuring the distance to the nearest neighboring green structure or by measuring the amount of green area within the surroundings (ibid.)

There are three ways to increase connectivity within a habitat network; (a) to increase amount of habitat, (b) to create green corridors (alternatively stepping stones) between the habitats or (c) to make the surrounding environment easier for species to travel through (Persson and Smith 2014).

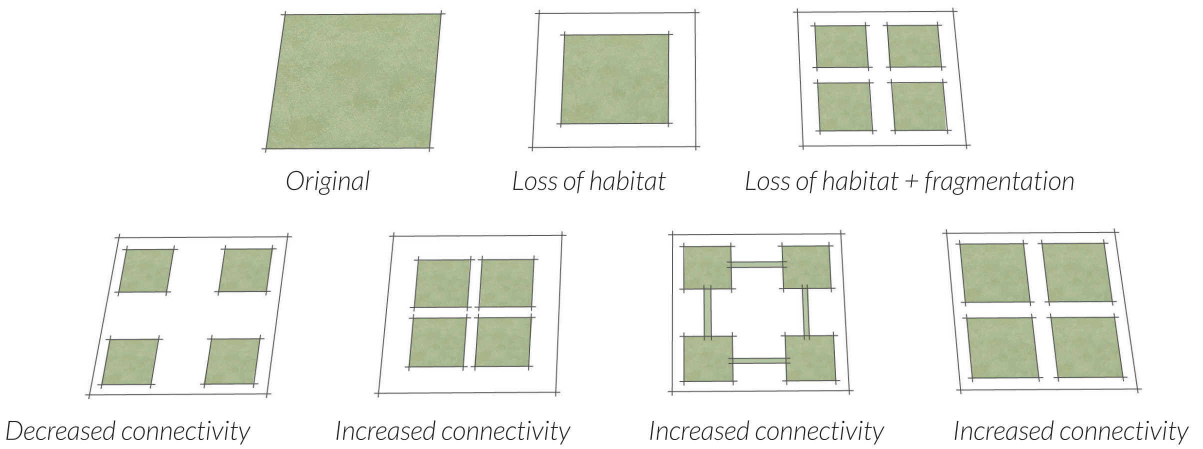


Figure 9
Habitat connectivity is affected by different forms of structures. The diagram is remade from a original version by Ola Olsson (n.d.)

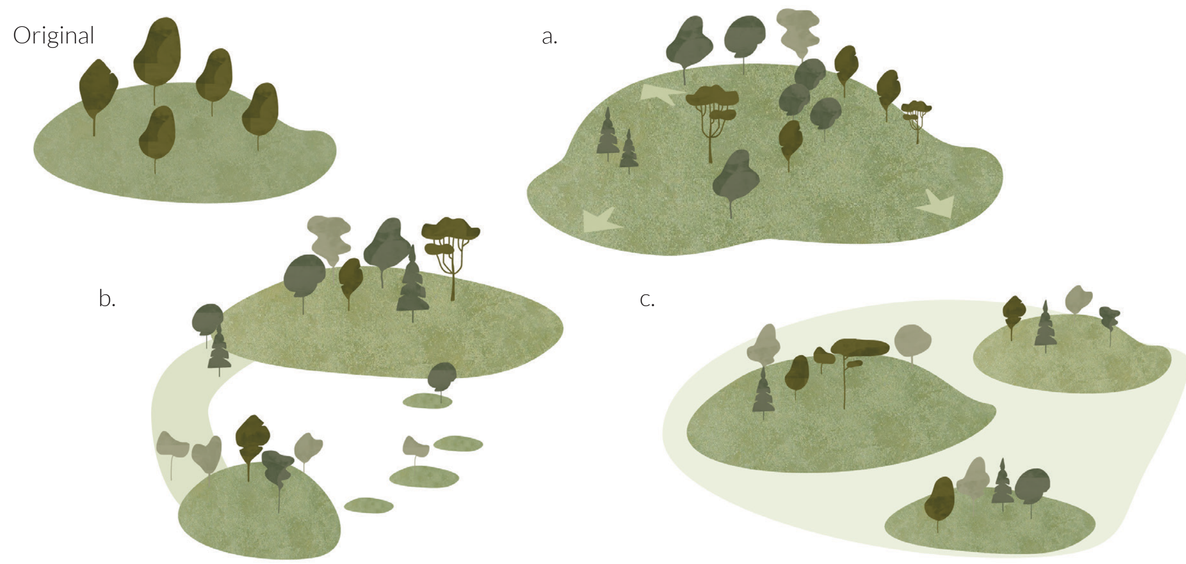


Figure 10
Three ways to increase connectivity within a habitat network. Illustrations remade from an original version by A. S. Persson

The right resources in the right place

To create urban habitats that meet the requirements to support pollinating insects we must consider the entire urban habitat network and ask not only “where?” but “what?”. Using the surrounding landscape as a base and source of inspiration is a great tool to create well composed urban habitats. In order for an urban habitat to gain high qualities it has to be customized to the local conditions and match surrounding qualities (Larsson, 2023). This regards access to different resources: water, nutrients, sun exposure, wind exposure, heat exposure and stress (Fransson, et al., 2017). Adding resources that cannot be found in the surrounding area, chances are small that they will be found by the relevant species. As discussed earlier, connectivity is crucial for urban habitat quality and thus placing suitable resources within reachable distances is key. For instance, adding sand to a garden where there are no sandy qualities in the surrounding area, chances are small that a sand-relient species will find that particular spot (Länsstyrelsen Västmanland, 2022)

Healthy and biodiverse cities

Positively, supporting biodiversity also increases social qualities in cities, enhancing urban habitats that cohabit people and pollinating insects. It is commonly known how contact with nature increases human well-being and actually increases life expectancy (Skärbäck and Grahn, 2015). Urban green environments that allow for active recreation such as sports and play are great for increasing physical and mental health. Nevertheless, one study shows that wild, biodiverse and natural urban nature has a significantly calming effect on people that increased well-being. The same study shows that there is a low access and occurrence of these types of wild urban green structures (Skärbäck and Grahn, 2015). A high diversity of species not only have significant positive effects on ecosystems but also on human life (Hooper et al., 2012). Another study that could confirm this result demonstrated how a high diversity of bird species increased human well-being (Methorst et al., 2021). Therefore, integrating ecosystem planning in urban design creates synergies of supporting urban biodiversity and human well-being (ibid.)

When placing nesting qualities, like an insect hotel, far away from foraging resources it is unlikely that the targeted species will find it. Photo by author.

Figure 11
Wild nature has a lot to offer for a childs playful mind.
Photo by Olle Tiderman (2016), modell: Theo Tiderman

THE CONTENT AND CARE OF GREEN SPACES

Urban green areas have a high potential to enhance its ecological qualities to enable pollinating insects to spread and thrive. These areas highly depend on how they are maintained (Aronson et al. 2017) and what they contain. A high use of non-native plant species and an intense maintenance results in a lower quality of habitats and biodiversity (Ignatieva and Hedblom 2018). Since natural processes often take time, it is essential to have a long term perspective and plan for how the habitat can develop over time.

Vegetation and soil

In order to support the diversity of wild bees and other pollinating insects, we have to start with the diversity of plants and soil. The urban soil is highly affected by pollutants from traffic, industry, stormwater, pesticides, fertilizers and this negatively affects ground living organisms, such as fungi (Persson and Smith 2014). Fungi have an essential ecological function that often gets disturbed in urban environments, even using non-native plants can affect fungi negatively (ibid). The quality of the soil is a key factor for balancing moisture and nutrients in the habitat. Permeable soil (soil where water passes through easily) can be used to create a dry environment and impermeable soil can be used to create a moist environment. For a moist environment, soil containing a lot of organic materials and/or clay can also be used (Fransson, et al. 2017). The goal here is to match the soil with the environment's qualities and the needs of the vegetation. For example, if there is no drainage for water to run off, it is more suitable to adapt the area for a moist habitat.

Green roofs and facades

During an observation in Malmö, bumble bees were found more frequently on green roofs compared to green facades and closed yards. Even small green areas on the sixth floor had bumble bees foraging for nectar (Haaland, Fransson, Kruuse, Emilsson, Malmberg, 2018). Green roofs have shown to be an important complementary biotope for foraging bumble bees (Haaland, 2017).

These are some examples of pollinator fabourable plants

SOURCES OF NECTAR AND POLLEN

Name	Common name eng/swe	Time of flowering
Trees		
Salix spp	willow/pil	may-june
Prunus avium	cherry/körsbär	april-may
Prunus padus	bird cherry/hägg	may-june
Sorbus intermedia	whitebeam/oxel	june
Sorbus aucuparia	rowan/rönn	may-june
Prunus domestica	plum/plommon	april-may
Malus domestica	apple/äpple	may-june
Bushes		
Rubus plicatus	blackberry/björnbär	june-aug
Frangula alnus	alderbuckthorn/brakved	april-july
Sambucus nigra	elderberry/fläder	may-june
Crataegus ssp	hawthron/hagtorn	may-june
Rubus idaeus	rasberry/hallon	june
Corylus avellana	hazel/hassel	april-may
Lonicera periclymenum	hockeysuckle/vildkaprifol	june-july
Ribes uva-crispa	krusbär	april-may
Ribes alpinum	mounatin currant/måbär	may-june
Rosa dumalis	glaucous dog rose/nyponros	june-july
Prunus spinosa	blackthron/slån	may
Ribes ssp	redcurrant/vinbär	may-june
Perennials/annuals		
Knautia arvensis	field scabious/åkervädd	may-aug
Centaurea scabiosa	greater knapweed/väddklint	juli-sep
Anthyllis vulneraria	kidneyvetch/getväppling	june-aug
Hieracium umbellatum	hawkweed/flockfibbla	juli-sep
Trifolium spp	clover/klöver	june-aug
Lotus corniculatus	bird's-foot trefoil/käringtand	june-aug
Campanula rotundifolia	scottish bluebell/blåklocka	juli-sep
Achillea millefolium	yarrow/röllika	june-july
Ajuga reptans	bugle/revsuga	may-june
Carduus spp./Cirscium spp.	thistle/tistel	july-sep
Centaurea cyanus	cornflower/blåklint	june-sep
Convolvulus arvensis	åkervinda	july-aug
Echium vulgare	blåeld	june-july
Eryngium hybridum	hybridmartorn	july-aug
Foeniculum vulgare	fänkål	may-june
Fragraria vesca	smultron	may-july

A study made in Malmö demonstrated that attracting the common types of bumble bees in the urban environment can be quite easy, with the right choice of plants (Haaland, 2017). To increase the diversity of bees we must add a variety of biotopes and more "wild" flowering species (ibid.). One approach to create suitable urban habitats is to imitate existing natural biotopes (Fransson, et al. 2017) When choosing the species of vegetation the general aim is to have as many different species as possible and the same amount of each species (ibid). There are a few general guidelines when choosing vegetation:

- Choose a wide range of pollinator-favorable plants: plants that are high in pollen or nectar.
- Choose the right shapes of flowers: some flowers that are produced to be aesthetically pleasing can be quite challenging for pollinators to pick up nectar or pollen from.
- Have a broad flowering season: different pollinators are active in different parts of the season and therefore there should be something flowering from early spring to autumn.
- Match the chosen vegetation with the environment: if there is sun or wind exposure and the type of soil there is.
- Primarily use native species: many wild bees have specialized in a certain species (see specialists on page 52)
- As discussed earlier, use the surrounding as a source of inspiration: use what is already in the surrounding landscape.

Native vs non-native plants

Exotic trees are becoming more frequently used in urban environments due to their tolerance of increasing temperatures and droughts. These species provide a range of ecosystem services and diversifies the urban vegetation, increasing the resilience of the landscape (Sjöman et al., 2016). However, according to many ecologists and biologists, exotic species should be used with caution. Native plants are more likely to support local populations and increase their habitats (Fransson, et al. 2017). Exotic plants do rarely increase the vegetational quality of a habitat and there is also a risk that the exotic plant might become invasive and take over (ibid.). The reason for this is that the current species of pollinators has historically adapted to the local flora, some more specifically than others.

Maintenance

Re-adapting maintenance can be a simple method to support pollination in urban habitats. Urban areas that often function as hotspots for pollinators, such as allotment gardens, grasslands and wastelands have either a diverse or very low intensity in maintenance. A well planned and designed habitat should not demand a high level of maintenance (Fransson, et al. 2017). In fact, if the vegetation is carefully chosen it will establish quickly, hindering external species to establish. It is important that the chosen vegetation quickly covers the soil, to minimize the risk of external species to root (ibid.).

Some general guidelines for maintaining a suitable maintenance:

- Have a lower intensity of maintenance and allow for natural processes to occur, the focus is not only aesthetics but ecological functionality.
- Leave dead plant mass such as trees, leaves and grass. Unless the goal is to create a meadow or grassland, then removing the cut grass is needed.
- Whatever survives, survives; some plants might not settle and root and that can be allowed.
- Focus on function and character rather than species; depending on surrounding landscapes, it might be allowed for new species to be introduced into the mix, as long as they grow aggressively.
- Make sure that one species doesn't have an unwanted dominance and exceeds the other species, remove invasive species.
- Leave a certain area of sandy ground open and exposed, this particular environment is especially important for sand-relient species.
- Increase ecological knowledge and map out of the different organisms' needs.

Lately, grasslands or meadows have become popular, since these biotopes are particularly great for pollinators. These are quite hard to establish in the current soils that normally are high in nutrients. It is important not to add but to remove nutrients by mowing and cutting the area once a year, in the late summer or early fall (Fransson et al., 2017).

This type of low intensity maintenance can actually be a way to decrease costs. Different municipalities in Sweden have established new strategies of maintenance that are adapted for supporting pollination and enhancing biodiversity, one example is presented on the next page. These changes have not exceeded their current budget, even when buying new tools, the costs have leveled out since there is less work each year (Naturskyddsföreningen, 2020b).

A) A fully flowering meadow, Stockholm. B) Dead wood is often home to many different species, Gothenburg. C) Fallen trees, Gothenburg. D) Insect hotel, Gothenburg. Photos by author

Transformation and restoration

There are different levels of implementations to support urban biodiversity. This example demonstrates how different measures were taken to support pollinating insects and increase biodiversity to an area;

Figure 12
One of the sandy flowerbeds during the winter in Nybro Municipality (Hansson, 2021)

Figure 13
A fully blossoming flowerbed by the railways in Nybro Municipality. (Hansson, 2021)

Nybro municipality has worked many years with nature conservation in the urban and rural environment. In an article (Hansson, 2021), municipal planners explain how they have made different types of implementations such as exposing sand in industrial areas and changed their maintenance of green areas. This included lowering the frequency of cutting grass and removing larger plants that risk taking over. The municipal ecologist explains in the article that the changes have neither increased costs or work but rather changed how they work and raised knowledge (ibid.). Communication with local politicians have also been key in this process. Generally, the soil around the municipality is naturally very sandy which means that changes required less maintenance but still gave really good results in supporting pollination (ibid.)

SUMMARY OF INTERVIEWS

In this page I have summarized the interviews with key statements and messages of each conversation.

Landscape architect

Landscapes are not static but change all the time. We as landscape architects create a design but what happens after we hand in our project? Maintenance is key for creating spaces with high ecological value. How much do allow for natural processes? What is allowed to grow here? What is considered a “weed” here? We, as landscape architects, must dare to take more control over maintenance. Create your own maintenance program that allows for natural processes!

Researcher within biodiversity and social ecological urbanism

Look at green infrastructure and ecosystem services as an insurance company - if we pay a small amount regularly, when the crisis is here we can afford to cover the damage. Meaning, if we invest in food secure, stormwater safe and resilient cities we are much more likely to handle future natural disasters like floods and heat waves.

Environmental expert and green planner at a private firm

In order to create a pollination plan you need good and correct geographical documentation. Find and identify important areas. Inventories on sites are also crucial in order to confirm our findings. What does this site have that can support pollinators?

It is important for landscape architects to work interdisciplinary, it is impossible for one expertise to answer all questions.

Biologist at the municipality

To contribute to enhancing urban habitats for wild bees in Gothenburg we perform regular inventores, turn cut grass into meadows and leave dead wood. Unfortunately, there is a lack of suitable machines to maintain meadows. Gothenburg only started creating a pollination plan but never finished, it would be really valuable to have a simplified strategy to work with wild bees.

- Highlight other topics than wild bees in your work; ecosystem services, nice environments for humans, to increase the weight of your topic.
- The hard truth is that the strategies for traffic and infrastructure will always be prioritized over ecological plans.
- We don’t need more guiding documents.

Researcher, expert on wild bees

The challenge is to integrate the ecological perspective in urban planning, often these ideas are added later which can lead to a huge loss ecologically. There is no need to always build new green areas, instead, find suitable areas for lighter implementations. Financially there are different ambitions, translate the implementations into steps, step 1 is cheapest and carries less effort. Advertise your concept with different steps, maybe not all steps are possible to do at once.

- Today the aesthetics of green spaces are cut grass and trimmed hedges, if you want to create a more natural and “messier” environment, there need to be information that explains the function.
- The shorter the distance between foraging sites and nesting sites, the better. Try not to exceed 200 meters.

Parks maintenance worker

The challenge with working with natural green spaces and supporting biodiversity is that there is often a lack of a comprehensible long term plan. Different property owners have different priorities and sometimes it is the “wrong people” who make the decisions.

Practically it is really hard to create a typical meadow in a typical park environment, the soil is too nutritious and other, more dominant, species will root and compete with the more sensitive species. To remove the topsoil is not that easy either. It takes time to establish a diverse meadow; year by year, you mow the grass and slowly decrease the nutrition. That is why working with diverse vegetation needs a long term perspective.

Researcher, biologists/ecologists

There is a high potential to support bees and other species (other than humans) in cities. We can shape the urban landscape in order to create thriving habitats. We don’t know exactly how bees move in cities or what limits them. They do follow green areas. Bees need resources of nectar and pollen but also places for nesting. Most wild bees live in sandy grounds which is why we should create more environments like these.

It helps to think that we need as many natural environments as possible in the city. Look at your site from an ecological perspective, work on what is already growing on the site. Avoid doing the same everywhere, make it diverse in different ways: topography, levels of moisture and levels of vegetation.

WILD BEES AND THEIR LIFE CYCLES

Different wild bees have a variety of survival strategies and are differently sensitive. They are active during different parts of the season and hours of the day and can be divided into spring-, early summer-, summer- and late summer-flying species (Naturvårdsverket, n.d.a). Different parts of the life cycle require a diversity of specialized interplays between plant, insect and habitat. The interplay between different species comes in many different forms and sometimes several species are involved in a complex interplay (Borgström et al., 2018).

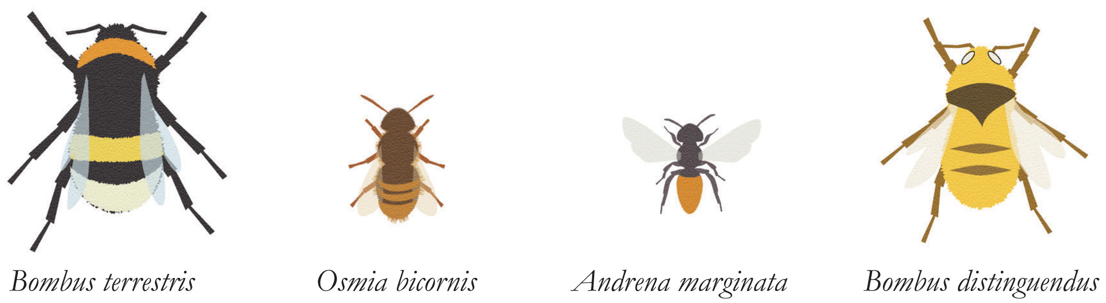
Female and male bees

In a colony of bumble bees there is one queen and her workers, which are all female. The queens are the only ones that produce offspring. Male bumble bees live shortly in the nest before they start focusing entirely on spreading their smell to attract new queens to mate with. Another difference between male and female bees is also that only females sting.

Nesting

Most of the wild bees are solitary bees and different wild bees have different levels of solitariness. This means that they don’t create societies or live in groups, every individual female builds a nest on her own and prepares it with food for her eggs (Naturvårdsverket n.d.a). There are levels of solitariness between the different species, bee expert Anna Person explaines in an interview (Holmberg, 2020), some solitary bees build their nests together (Halictus and Lasioglossum) and help each other with the construction of the nest. They share the entrance to the nest but build their own cells for their larvae (Linkowski, Cederberg, Nilsson, 2004). Persson states how other species of solitary bees have a complete solitariness and live and build their nests on their own (Holmberg, 2020). 42% of the solitary bees build their nests in hollow plants or holes in wood made by other insects. The other 58% build their nests in the ground which is often sandy, sun exposed ground with a very low vegetational coverage. These species cannot penetrate a thick root system or use high nutrient, moist or dense clay to build their nests in (Borgström et al., 2018).

Bees have a rich variety of colors, shapes and sizes. Illustration by author.

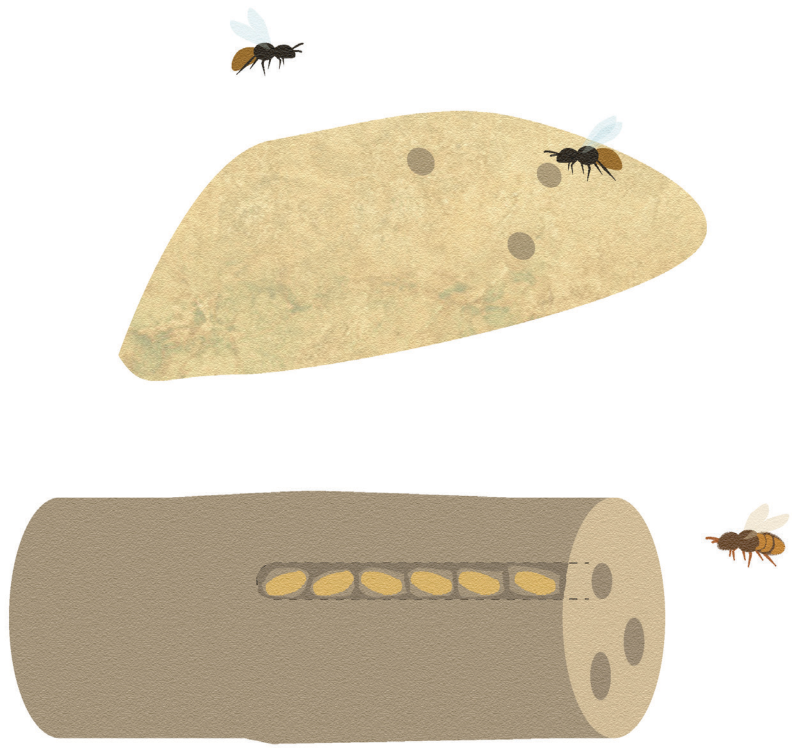


In contrast to solitary bees, bumble bees are social bees and live in colonies. Every spring a new colony starts when the overwintering and fertilized bumble bee queen wakes up (Mossberg and Cederberg, 2012). Some species of bumble bees find hollows in the ground, they often use an abandoned mouse nest. Other species choose to build their nests above ground, in piles of leaves or grass or even in hollow trees, bird nests or house walls (ibid.). Bumble bee nests are still a bit of a mystery, building nests for them is a great challenge and they seem to choose everywhere else than what humans build for them, Johansson states in the interview.

Lastly there are parasite bees. Two thirds of the Swedish bees species collects food to their offspring on their own but there is another group of species that lives on taking food from other bees or laying their eggs in other bees nests (Linkowski, Cederberg, Nilsson, 2004).

The life cycle of a solitary bee

Most of the solitary bee species only produce one generation per year. Some species of solitary bees hibernate during winter just like bumble bees and with other species it is only the offspring, the developing bees inside the nests, that hibernate. Species like Andrena, Nomada, Osmia and Colletes lie fully formed during the winter in the nests that their mothers built, waiting to hatch in the spring. Other species (Halictus, Lasioglossum, Sphecodes and Ceratina) that hatch in late summer hibernate in their original nest, dig themselves down in the ground or crawl into hollow plants (Linkowski, Cederberg, Nilsson, 2004).



42% of solitary bees live in wooden hollows, the other 58% live in sandy grounds. Illustration by author.

Foraging

Wild bees can be divided into two groups: specialists and generalists (Naturvårdsverket, n.d.a). Specialists visit one type of flowering species and are often dependent on these for survival while generalists visit many different flowering plants (Borgström et al., 2018). For example, a bee found in the urban green parts of Gothenburg (Artportalen, 2021), the small scabious mining bee (*Andrena marginata*, guld-sandbi in Swedish) is an endangered solitary bee that is specialized on the plant family Disacaceae (Artfakta, 2018). Bumble bees are generally generalists, they visit many different species of flowering plants (Borgström et al., 2018)

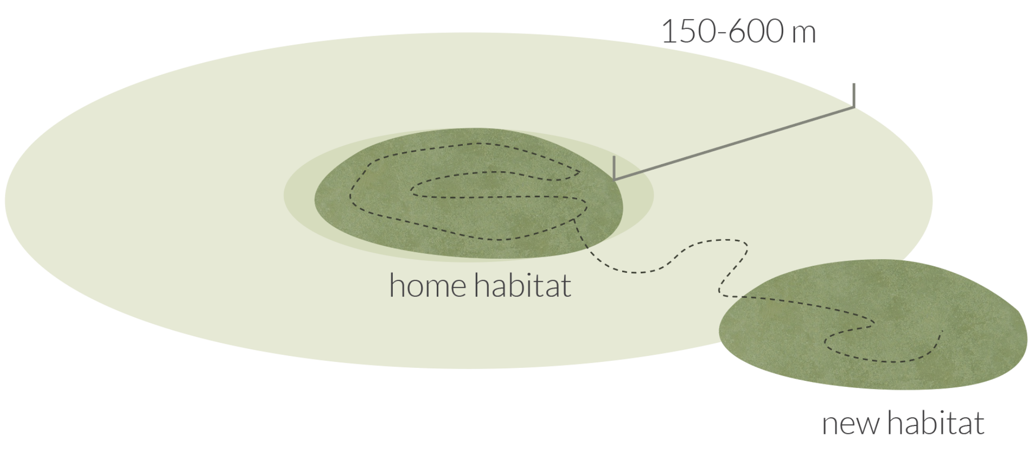
Sense of smell and air pollution

Bumble bees are very reliant on their sense of smell (Mossberg and Cederberg, 2012). They use it to find and differentiate flowers but also for mating and to find back to their nests (ibid.). Air pollution in the urban landscape has shown to interfere with the bumble bee's detection of smells such as flowering plants (McFredrick et al., 2008). This may lead to bumble bees spending more time searching for green patches than by foraging, in environments where floral patches are further apart, making them more dependent on visual cues (Berghauser Pont et al. 2017).

Bees navigation and movement

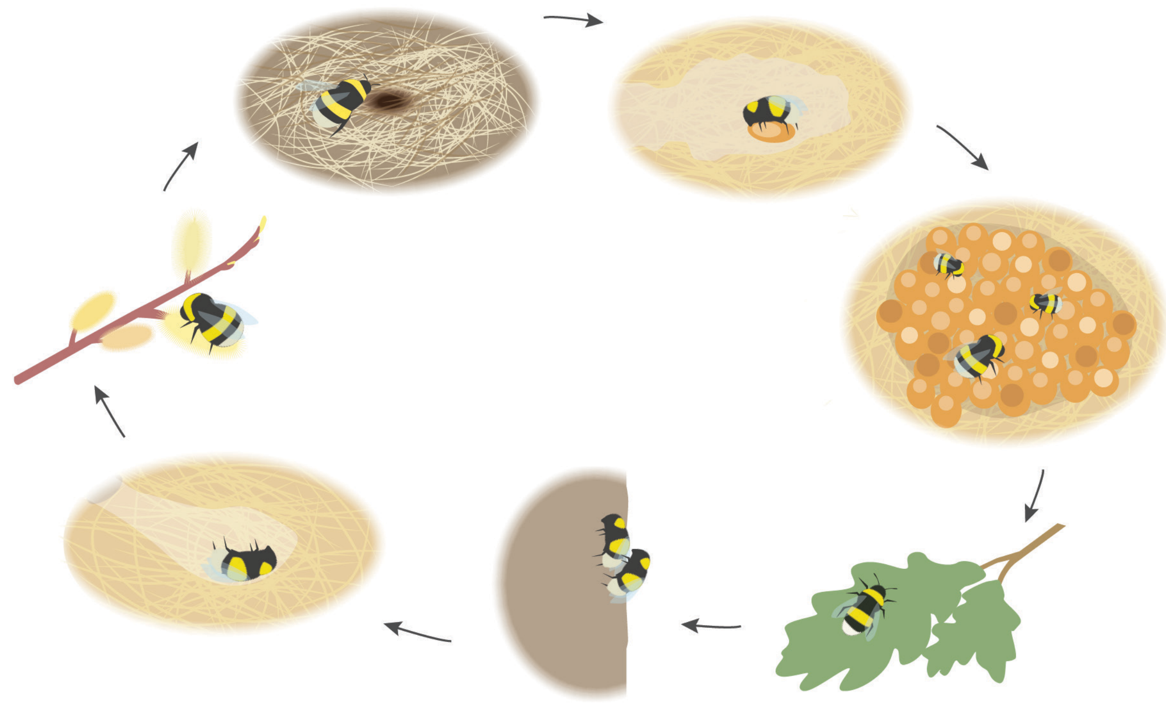
There is a wide range of how far wild bees actually can or will travel, specific numbers are still in debate. Different wild bees travel different distances and how far it can travel generally depends on the size of species. Bumble bees that are larger can therefore travel further than smaller species (Naturvårdsverket, n.d.a). As discussed earlier, landscape connectivity is important in two scales: day-to-day movement and to move or re-colonize a new habitat. It is mainly the search for nectar, pollen and nesting sites that makes a bumble bee travel through the landscape (McFredrick et al., 2008). From a day-to-day movement (foraging within a habitat), the distance should not exceed 200 meters Johansson explains in the interview. One study found that the maximum foraging range for wild bees was 150-600 meters (Gathmann and Tscharntke, 2002). Physically, bees can travel quite high but won't do so if there is nothing attracting them or if there is no reward to collect, Åsa Green explains in the interview. That is why buildings can act as barriers in the urban environment.

Two scales of movement, one is within the current habitat and the other is traveling to a new habitat. Illustration by author.



The life cycle of a bumble bee

The life cycle of a bumble bee is annual and only the queen hibernates. Early in the spring, the queens wake up and start looking for food. Springtime offers a lower supply of nectar. Sell, willow, tussila layers, crocuses, Christmas roses and daffodils are the first supply the queen bee finds. After satisfying the first need of nectar, she can start searching for a suitable nest. After a suitable nest is found in the ground, in a pile of leaves or in a house wall she starts to build a bed for her eggs. There the egg develops into larvae, followed by a pupa and lastly it has grown into a fully formed bumble bee. During the summer, the colony grows with several generations of worker bees. The worker bees share tasks around the nest, they help produce wax, feeding larvae, collecting pollen and collecting nectar. During the high season of summer new males and queens are hatched. Males that leave their nests go out quickly in search for new queens to mate with, once a queen has mated she crawls down into the ground to begin her hibernation. The old queen dies around mid summer while workers and males live around 3-4 weeks before they die (Mossberg and Cederberg, 2012).



The lifecycle of a bumble bee. Illustration by author.

FOCUSING ON SPECIFIC SPECIES

In order to support biodiversity, focusing on a few species can be a helpful method. The idea is enhancing a habitat for one or a few species also benefits many other species.

Indicator species

An indicator species is a species that sets certain requirements of its environment (Jordbruksverket, 2003) and measures the conditions of that environment (Larsson, 2017). They can indicate qualities of a habitat such as levels of humidity, soil quality and vegetation. Indicator species are used to represent a larger group of species (Fransson, et al. 2017; von Post et al., 2022). Performing regular inventories of the chosen species increases the chances of an early discovery of changes or decline in a population and can therefore be followed by a strategy to prevent biodiversity decline (Johansson, 2020). Some species use different types of biotopes for different parts of their life cycles or needs, therefore using an indicator species is helpful since they can indicate the quality of an entire landscape rather than a one type of biotope (von Post et al., 2022). Using an indicator species to restore or enhance a biotope starts with mapping out the needs of the indicator species in all parts of their life cycle. For example, to enhance the quality of a habitat it is not enough to only plant flowering species rich in pollen since it only regards one need (feeding). There needs to be a consideration of all needs such as places and resources for nesting and spreading as well (Fransson, et al. 2017).

What species are then suitable as indicator species? Often more sensitive species that have higher requirements of their environments indicate a higher biodiversity and are therefore suitable as indicator species. Sensitive species are often specialists and have a higher risk of ending up on the red list of endangered species. Focusing on these species makes sense since their needs of resources are so specified that it makes them less flexible and adaptable to changes than their generalist neighbors.

There are many different terms that overlap meaning and use within the subject of focus species. Other words that came up during the research; "target species", "focus species" and in Swedish; "indikationsart", "signalart", "övervakningsart", "naturvårdsart", "nyckelart", "ansvarsart" and "paraplyart".

REDLISTED WILD BEES IN SWEDEN

Aglaoapis tridentata kilbi	NT
Andrena alfkenella alvarsandbi	NT
Andrena batava batavsandbi	VU
Andrena bimaculata rapssandbi	VU
Andrena bluethgeni dådresandbi	EN
Andrena chrysopyga stäppsandbi	CR
Andrena curvungula blåklockesandbi	NT
Andrena dorsata ryggsandbi	RE
Andrena gallica raggsandbi	RE
Andrena gelriae väpplingsandbi	EN
Andrena gravida fruktsandbi	VU
Andrena humilis slåttersandbi	VU
Andrena labialis märgelsandbi	NT
Andrena marginata guldsandbi	NT
Andrena morawitzi fältsandbi	CR
Andrena nanula dvärgsandbi	VU
Andrena nigrospina sotsandbi	VU
Andrena nitida nyponsandbi	VU
Andrena niveata franssandbi	EN
Andrena nycthemera flodsandbi	VU
Andrena similis ginstsandbi	EN
Andrena thoracica kustsandbi	RE
Anthophora plagiata humlepälsbi	EN
Anthophora retusa svartpälsbi	NT
Biastes truncatus pärlbi	VU
Bombus alpinus alphumla	NT
Bombus balteatus fjällhumla	NT
Bombus cullumanus stäpphumla	RE
Bombus distinguendus klöverhumla	NT
Bombus hyperboreus tundrahumla	NT
Bombus lapponicus lapphumla	NT
Bombus monticola berghumla	NT
Bombus muscorum mosshumla	NT
Bombus pomorum frukthumla	RE
Bombus pyrrhopygus polarhumla	NT
Bombus ruderatus fälthumla	RE
Bombus veteranus sandhumla	VU
Coelioxys conoideus storkägelbi	CR
Coelioxys lanceolatus lansettkägelbi	NT
Coelioxys mandibularis ängskägelbi	NT
Coelioxys obtusispina thomsonkägelbi	VU
Colletes fodiens hedsidenbi	NT
Colletes marginatus klöversidenbi	NT
Dasypoda argentata silverbyxbi	RE
Dasypoda suripes guldbyxbi	RE
Dufourea halictula monkesolbi	VU
Dufourea inermis klocksolbi	EN
Dufourea minuta fibblesolbi	CR
Epeolus marginatus rödfiltbi	VU
Halictus eurygnathus klintbandbi	NT
Halictus leucaheneus stäppbandbi	EN
Halictus quadricinctus storbandbi	CR
Halictus sexcinctus sexbandbi	RE
Hoplitis mitis klockgnagbi	NT
Hylaeus difformis franscitronbi	VU
Hylaeus gracilicornis slankcitronbi	RE
Hylaeus pfankuchi rörcitronbi	NT
Hylaeus pictipes väggcitronbi	NT
Hylaeus signatus resedabi	NT
Lasioglossum aeratum guldsmalbi	NT
Lasioglossum boreale fjällsmalbi	VU
Lasioglossum brevicorne stäppsmalbi	VU
Lasioglossum lucidulum glanssmalbi	VU
Lasioglossum nitidiusculum släntsmalbi	NT
Lasioglossum quadrinotatulum reliktsmalbi	EN
Lasioglossum sexmaculatum kantsmalbi	NT
Lasioglossum sexnotatulum åssmalbi	RE
Lasioglossum xanthopus rostsmalbi	EN
Megachile lagopoda stortapetserarbi	NT
Megachile pyrenaea klinttapetserarbi	NT
Melecta luctuosa praktsorgbi	RE
Melitta melanura storblomsterbi	CR
Melitta tricincta rödtoppebi	NT
Nomada argentata silvergökbi	EN
Nomada armata väddgökbi	VU
Nomada baccata sandgökbi	EN
Nomada facilis fibblegökbi	CR
Nomada fuscicornis mörkgökbi	VU
Nomada guttulata droppgökbi	NT
Nomada integra slåttergökbi	EN
Nomada obtusifrons fröjdgökbi	VU
Nomada opaca bryngökbi	NT
Nomada sexfasciata storgökbi	RE
Nomada similis ölandsgökbi	VU
Nomada stigma fransgökbi	NT
Nomada subcornuta fältgökbi	VU
Osmia disjuncta tajgamurarbi	DD
Osmia maritima havsmurarbi	EN
Osmia niveata klintmurarbi	RE
Osmia svenssoni fjällmurarbi	DD
Panurgus banksianus storfibblebi	VU
Rophites quinquespinosus blomdyrkarbi	RE
Sphecodes cristatus kölblodbi	RE
Sphecodes longulus dvärgblodbi	NT
Sphecodes niger svartblodbi	VU
Sphecodes spinulosus taggblodbi	CR
Stelis phaeoptera stampansarbi	VU

Regionally Extinct (RE), Critically Endangered (CR), Endangered (EN), Vulnerable (VU),
Near Threatened (NT), Data Deficient (DD) and Least Concern (LC).
SLU Artdatabanken (2020). Rödlistade arter i Sverige 2020. SLU, Uppsala

SPECIES IN FOCUS

Small scabious mining bee [Sand bee], *Andrena marginata*

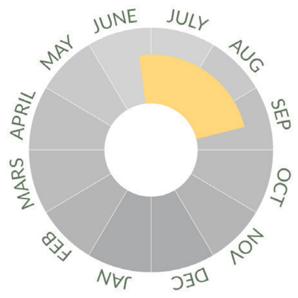
Status: endangered

Nesting places: small aggregations in dry sun-exposed sand with little to none vegetation.

Feeding places: dry meadows and moist beach meadows.

Plant families: specializes on Devil's-bit [Succisa pratensis], Knautia arvensis, Scabiosa canescens and Scabiosa columbaria

Special demands: a small population of the sand bee needs a continuous presence of approximately 200 individuals of Devil's-bit to cover the need of pollen (Larsson 2006)



females are active from the end of June to mid September, the males live only in the beginning of this season where they mate with the females.

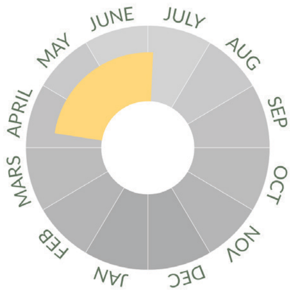
Figure 14
A female Sand bee. Photo by Krister Hall (SLU Artdatabanken)

The two species I chose to focus on have different life cycles, needs and levels of sensitivity. The sand bee is considered to be a suitable indicator species since it indicate a high biodiversity (Johansson, 2020), it has also been sighted in urban green areas in Gothenburg which makes it even more suitable for this analysis. The red mason bee has also been sighted in the urban landscape of Gothenburg but much more frequent.

The Sand bee is specialized on Succisa pratensis and Knautia arvensis but these flowers are also attractive for other wild bees.

Red mason bee, *Osmia bicornis*

Status:	thriving
Nesting places:	hollows in sun-exposed wood
Feeding places:	dry, sandy meadows or grasslands
Plant families:	(generalist) cherry tree, pear, apricot, plum and apple.
Special demands:	deep hollows with a diameter of 7-8 mm



Active season is during april until end of june. Males wake up one week before the females.

The nests need to be sun-exposed for the conditions to be ideal for the Red mason bee

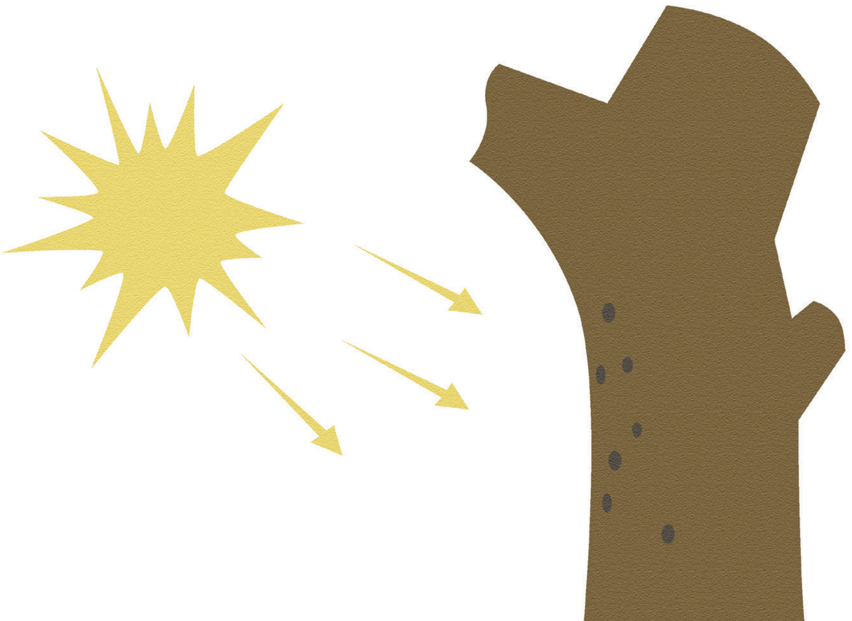


Figure 15
A female Red mason bee. Photo by Krister Hall (SLU Artdatabanken)

Both the Sand bee and the Red mason bee has been found in urban green areas in Gothenburg (see chapter 5). The red mason bee has been found more frequently which is expected due to the Sand bees being endangered. The Red mason bee was primarly chosen to compare with the Sand bee since it's not sensitive or need the same resources for foraging or nesting.

All it takes to build a nest is a hole, sand and skill. Photo by author.

THE SITE: GOTHENBURG

Gothenburg is built on a rich variety of landscapes and topography. The city has a high biodiversity because of the diverse landscape (Göteborgs Stad, 2022). The region includes marine environments along the entire coast such as the archipelago, rivers, streams and over 70 lakes. The landscape varies with forests, agricultural lands and urban environments. Some particularly valuable types of nature are the deciduous forests and the beaches along the coasts and streams (ibid.).

Plans and strategies

Gothenburg's plans and strategies for biodiversity are connected to the global, regional and national goals. In Gothenburg's strategy for green infrastructure the global threats to biodiversity are highlighted and their goals to support and promote are ambitious (Göteborgs Stad, 2022). The plan includes ecological, social and economical goals. Several strategies and goals are presented in their green strategy document:

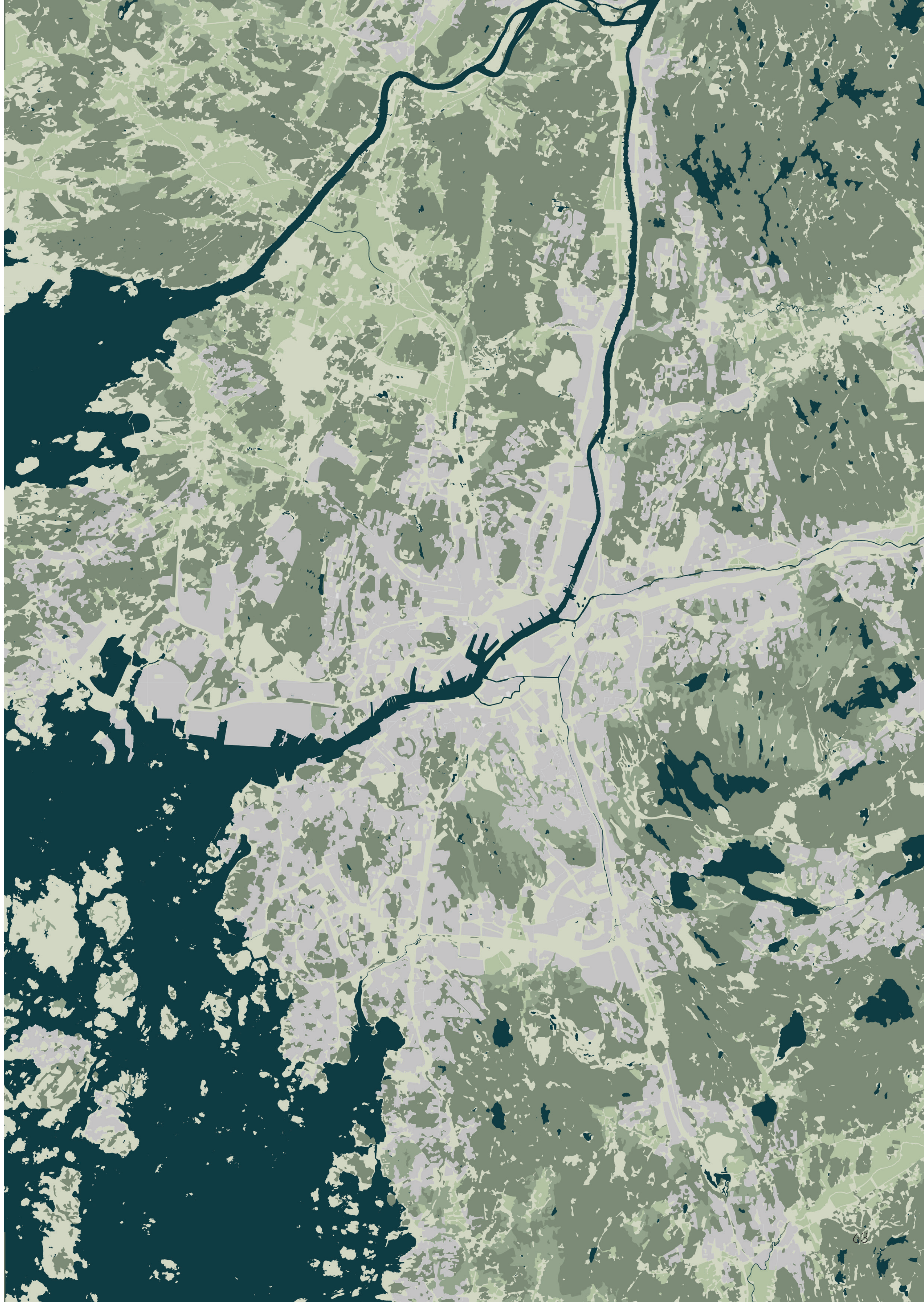
- develop and protect the green wedges
- strengthen blue-green passages
- develop appropriate maintenance for green structure
- support a robust green structure in the hard-surfaced city
- Supporting, strengthening and preserving ESS: plan for biodiversity, keep a variety of species and develop semi-urban farming, to name a few.
- Ecology should be integrated in the urban planning

In a yearly report, a nature protection organization (Naturskyddsföreningen) sends out a questionnaire to all municipalities regarding their work with pollination. Gothenburg had second best results the year of 2020, receiving particularly positive response for their cooperation with many different stakeholders such as organizations, companies and schools (Naturskyddsföreningen, 2020a). Since 2014, Gothenburg has brought a plan, handbook and strategy that focuses on biodiversity, ESS and how to support pollination (Naturskyddsföreningen, 2020b). Further they have worked with:

- Making inventories of areas of grass to increase the size of flowering grasslands.
- Increasing usage of lower nutrient soil to replace the regular nutrient soil
- Introduced species like poppyflower, cornflower and other pollinator-loving plants
- Created areas for open sandlands

At a regional scale, the County Administrative Board of Västra Götaland (Länsstyrelsen) has an action plan focusing on wild pollinators. It's a comprehensive plan that includes the entire region of Västra Götaland, noting different measures to take in both rural and urban landscapes (Länsstyrelsen Västra Götalands Län 2019).

Biodiversity and nature loss is clearly recognised in all documents, highlighting the importance of preserving, developing and planning for biodiversity and pollination. Though, strategies and detailed implementations are missing. Gothenburg does not have a pollination plan but there is an interest to create one. Even though the green strategy plan might be ambitious, there is no positive effect on urban biodiversity if the requirements aren't transferred into a detailed plan (Persson and Smith 2014). There is still a knowledge gap, a lack of methods and technical tools to follow up with the suggested measures (ibid.).



RESEARCH SUMMARY

Two concepts of urban development:
- Land sharing; low density areas with integrated green structures, can increase connectivity
- Land sparing; high density areas, keeping natural areas intact, can perserve biodiversity.

Principles for functional ecological green areas:
- Better; increase quality
- Bigger; increase size
- More; add more green areas
- Joined; connect them

Connectivity of habitats is crucial for biodiversity. Principles for increasing connectivity:
- Increase size or amount of habitats
- Add green corridors or stepping stones
- Increase quality of matrix (surrounding landscape)

We can categorize wild bee needs intro three categories:
- Nesting; to lay eggs or hibernate
- Foraging; collecting pollen and nectar from flowers
- Spreading; to reach resources within a suitable range and to move to new habitats.

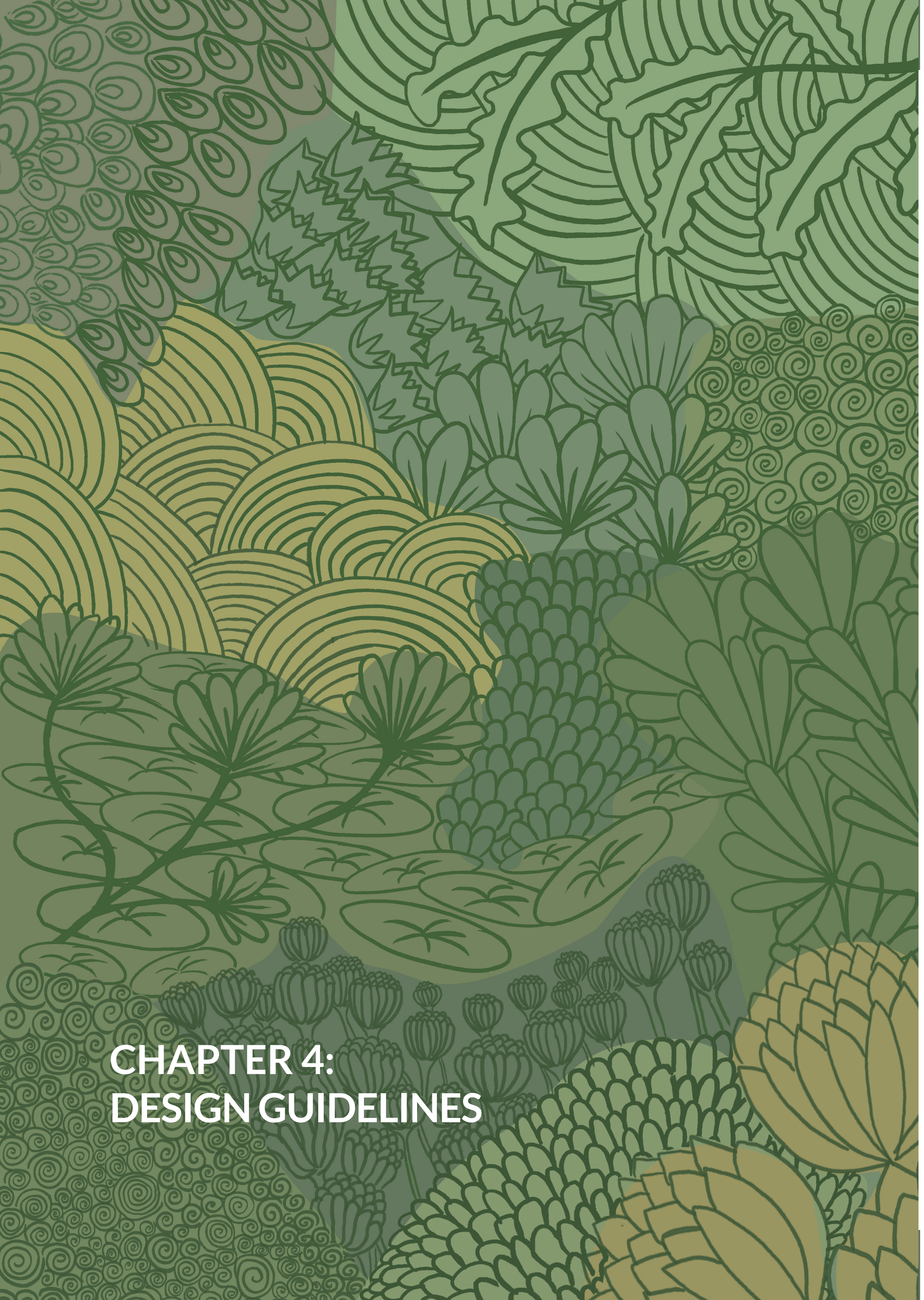
Other:
- To support pollination, we must consider the entire habitat network.
- Match the project area with surrounding landscape.
- Biodiversity increases human well-being
- Maintenance that allows for natural processes is crucial for supporting pollinators.
- A high diversity in plants and soil is important to enhance overall biodiversity.
- Using an indicator species is a great tool to specify certain needs of insects.
- By gaining one sensitive species, other will gain.

Conflicts and synergies in social ecological systems

Conclusively, in regards to supporting pollinating insects in a social ecological system there are conflicts and synergies that have been discussed. There is great potential to support, enhance and develop urban habitats for pollinating insects if synergies are identified:

Conflicts:
- Expectation, aesthetics and cultural norms of urban green spaces
- Land use, urban sprawl and densification (though densification is also seen as a way of keeping natural land intact of exploitation)

Synergies:
- High biodiversity increasing human well-being
- Some species of wild bees gain from the stress that humans have on the landscape.



CHAPTER 4: DESIGN GUIDELINES

OVERVIEW

In this chapter, two design and plan guidelines are presented;

- quality-connectivity
- cohabitation

These are based on the literature study and interviews from the previous chapter and are meant to visualize the findings. This chapter is meant to answer the questions of “what?” and “how?” regarding supporting a social-ecological system through planning for pollination. Firstly, knowing the conditions of the urban landscape is essential in order to know what and where implementations are suitable.

Chapter 5 and 6 contains the landscape analysis and the plan and design and these are meant to answer the question “where?”. Furthermore, the guidelines, analysis and plan and design are meant to contribute to answer to the thesis questions;

- *What are the requirements to support pollination in cities and what potential do cities currently have?*
- *How can urban planning and design at different scales enable for pollinating insects to spread and thrive?*
- *How can these urban habitats for pollinators cohabit with people and social spaces in cities?*

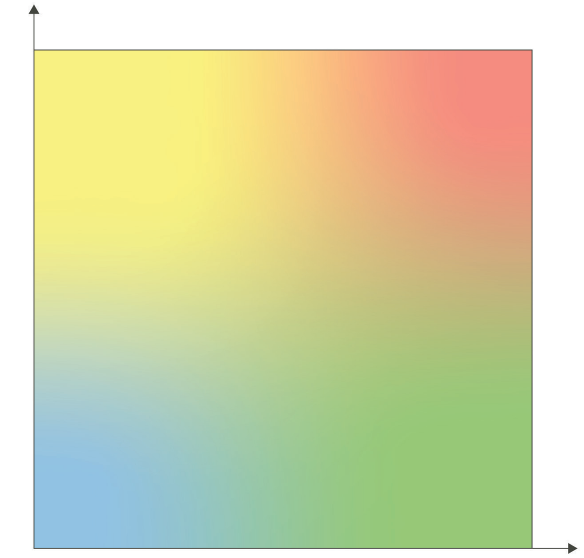
DESIGN GUIDELINE: COHABITATION

The first guideline regards the social-ecological aspects of planning for pollination. As cities grow, there is an increased demand for increasing density. In addition, as species decline and biodiversity is threatened, there is an increased demand to protect and enhance biodiversity. And as mentioned in the previous chapter, density can interfere with biodiversity which requires well-planned and proper urban planning and design.

Planning for pollination requires approaching the urban landscape as a social-ecological system where each dimension requires different urban morphologies. Some urban areas are more suitable to increase biodiversity while retaining a low density/centrality, this area would be placed in the green part of the graph. Other areas are more suitable to increase density/centrality while also retaining a low biodiversity, perhaps due to an increased need of residential buildings, for example. This type of area would be placed within the yellow part of the graph.

Just as there are central nodes in the social dimension, there are hotspots in ecological dimensions and these can occasionally overlap. That requires particular care and sensitivity towards both dimensions. Finding what needs to be done where is key in order to create a social-ecological system that regards both dimensions.

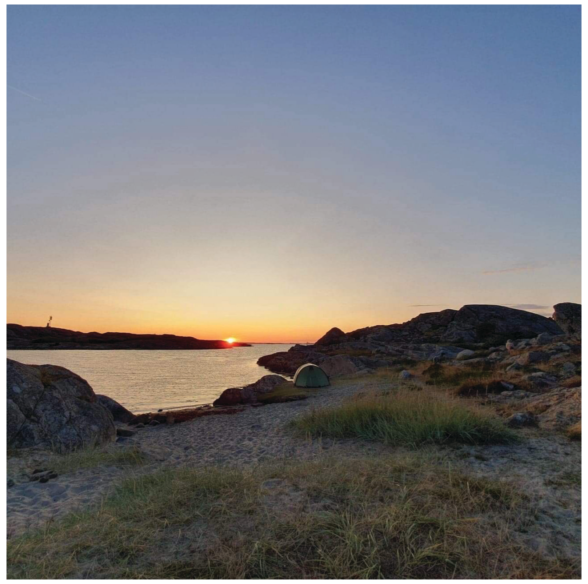
This guideline is meant to visualize findings from the literature study and interviews in order to support the social-ecological system and to speculate on how, what and where cohabition is more or less suitable. The Social axis refers to the level of density or flow of people (centrality). To find synergies within the two dimensions, the centrality refers to non-motorized traffic since highly trafficked roads act as barriers. The ecological axis refers to the level of biodiversity.



As mentioned, increased density often interfers with biodiversity. Therefore the closer an area gets to the red part of the graph, where there is high centrality/density and biodiversity, the more challenging the design and planning becomes. What type of area that reaches the highest level of both dimensions is hard to imagine, if it even is possible.

These photos are reference photos of the highest and lowest values for both the social and ecological axis.

A reference landscape of the lowest ecological value in Gothenburg. Photo by the author

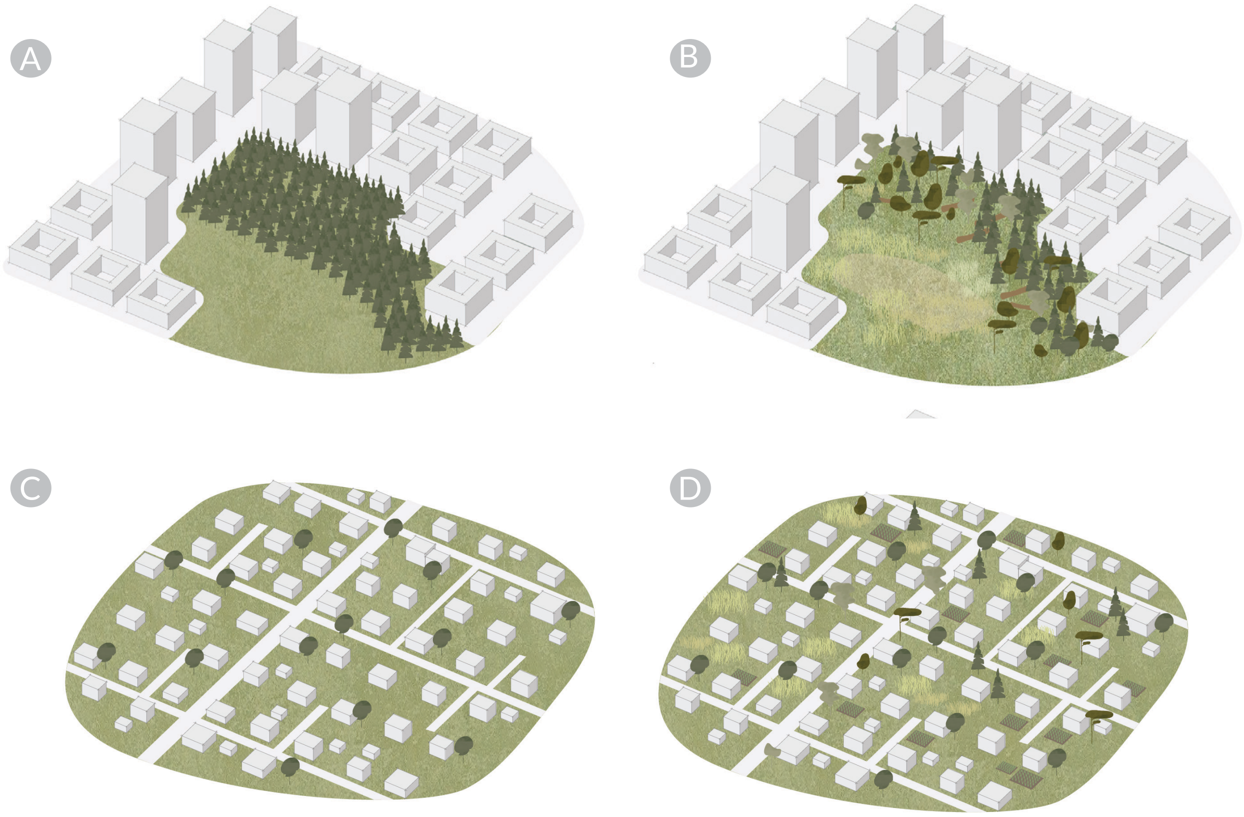


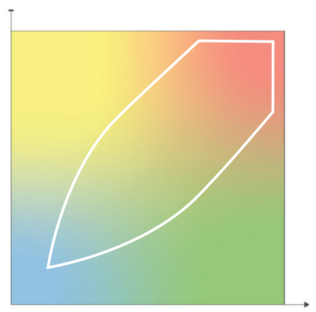
A reference landscape of the highest ecological value in Gothenburg. Photo by the author

A reference landscape of the lowest social value in Gothenburg. Photo by the author

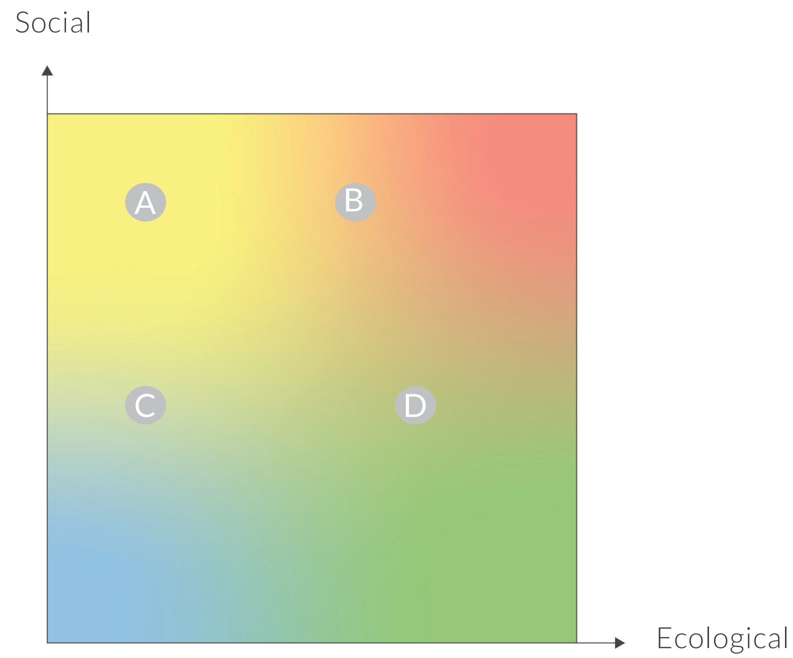
A reference landscape of the highest social value in Gothenburg. Photo by the author

Social value refers to the level of density and/or centrality of pedestrians and bikes while ecological value refers to the level of biodiversity.





Cohabitation occurs where there enough of both social and ecological value. For cohabitation to functional, both social and ecological needs need to be equally met.



To demonstrate this we can use the two urban development scenarios from the previous chapter; land sparing and land sharing. Area A refers to the land sparing scenario with high density buildings, in this example the green area is homogeneous since it was a former production forest next to a park. Area B represents the same area but after increasing biodiversity. Area C refers to the scenario of land sharing with low density buildings integrated with green structure. Though in this example the area is quite newly built and biodiversity was not implemented in the planning. Area D represents the same area where biodiversity was implemented in the planning. As the graph is showing, area B has the highest fulfillment of the requirements to increase density while at the same time increasing biodiversity. Furthermore, area D has the highest reach in fulfilling the need to increase biodiversity.

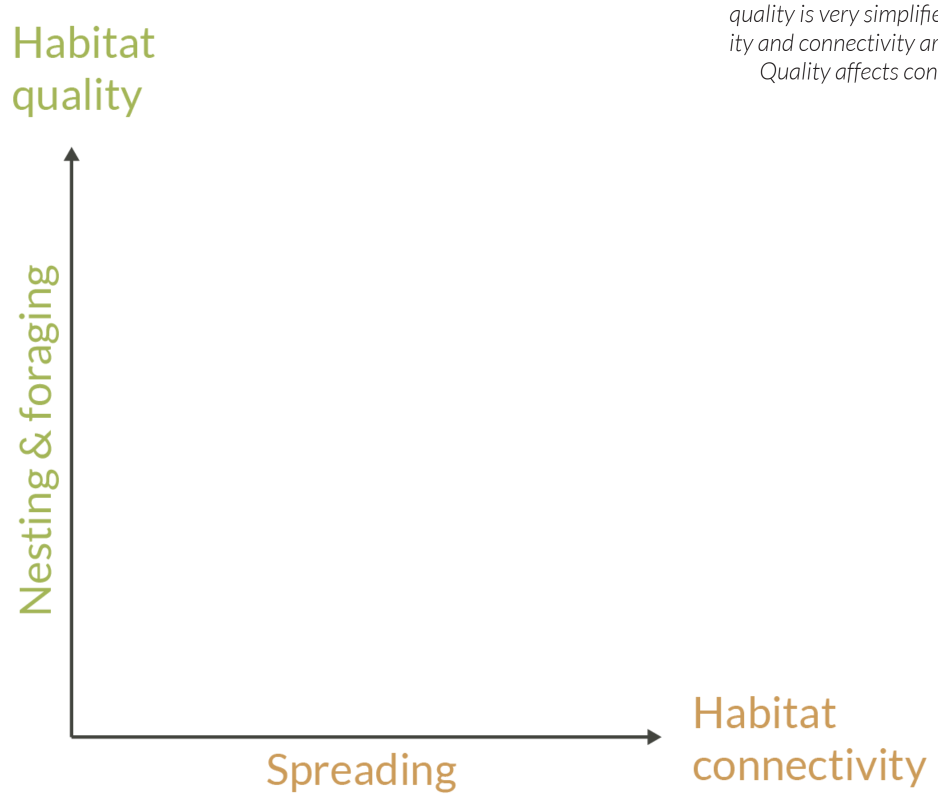
Conclusively, each part of the graph fulfills different functions and requirements with the exception of the blue area where we have neither a high density/centrality or biodiversity. The function of these types of areas could be put into question as there are alarming numbers of declining species, threatening biodiversity and an increased demand of higher density. Though, these types of areas are quite common today, one example shown in today's typical park environments on page 34.

To create cohabitation everywhere might not be needed but when it is indeed created it must be done well-planned and done with care. As mentioned in the previous chapter, land sharing and land sparing gain different ecosystem services and groups of species. As land sharing is said to enable connectivity and land sparing is said to protect biodiversity. These aspects can be used to match the need of both social and ecological dimension. In other words, where there is a need to protect biodiversity, increasing density is suitable and where it is needed to increase connectivity, a lower density might be suitable.

DESIGN GUIDELINE: QUALITY AND CONNECTIVITY

This guideline is visualized through a XY-graph and a rose graph and based on the literature study and interviews regarding needs of wild bees. Habitat quality regards to the needs of nesting and foraging while habitat connectivity regards to spreading. Though, this is a simplified categorisation since all needs are relatively intertwined. Biodiversity is linked to both Quality and Connectivity but could be more easily measured through the presence of certain species, as mentioned on page 54. The needs of nesting, foraging and spreading are achieved through the presence of certain resources and their availability, as mentioned in the previous chapter. By measuring the number of resources (Quality) and their level of availability (Connectivity) we can determine the entire quality of the habitat. Increased presence of suitable resources, increases the **Quality**. Increased size of green structure or closer distance to neighboring green areas, increases **Connectivity**. Note that this thesis did not have the capacity to, in detail, measure the site's resources and their availability but when the guideline is demonstrated in the street-scale it is based on speculations.

This way of illustrating network quality is very simplified since quality and connectivity are interwined. Quality affects connectivity and vice versa



This type of simplification of wild bees needs (nesting, foraging and spreading) is an attempt to weigh different habitats and find what implementations are needed to increase their overall quality. This guideline can be used in different scales to describe several habitats and their connections as well as one individual habitat. In the rose graph beneath, quality and connectivity are expressed as a group of slices where the size of each slice is determined by the presence of resources or their availability. Each slice represents one parameter to determine level of connectivity or quality.

By placing an area within the XY-graph we can see the relation between habitat connectivity and quality and weigh them equally. This refers to placing the right resources in the right place, as mentioned in the previous chapter. The point is the importance of high connectivity and quality in order to enhance the entire urban habitat network. If urban habitats contain suitable resources but are disconnected, the ecological functionality is lost. Similarly, if urban habitats are connected but contain little or no suitable resources, ecological functionality is lost.

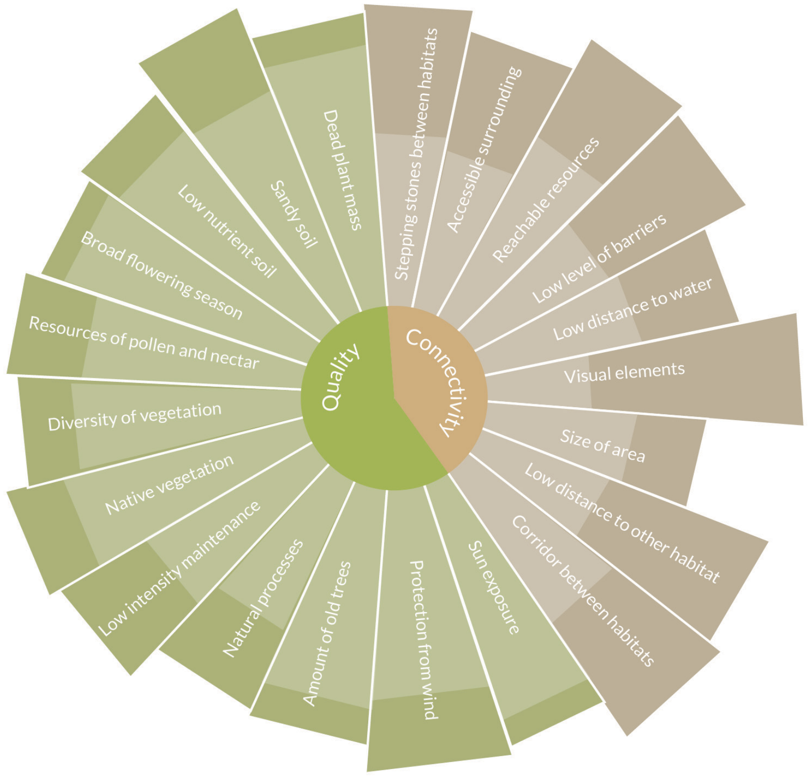
Determine the level of Quality

- What is the soil made out of? Are there any pollutants?
- Is there a diversity of vegetation? How much native vegetation?
- Is there a variation in the landscape? A dryer and a more moist area?
- How is the maintenance? Does it allow natural processes?

Determine the level of Connectivity

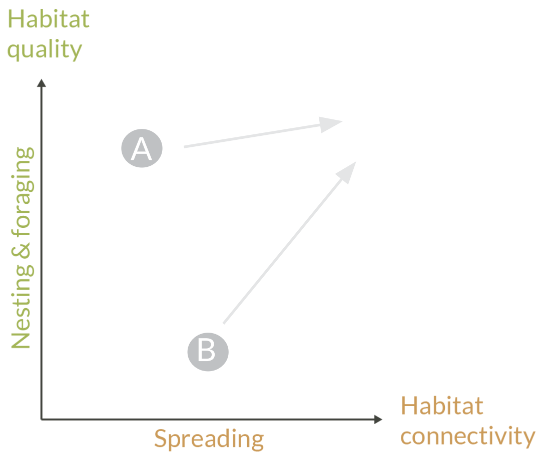
- Measure distance to nearest green area.
- Measure amount of green area within surrounding
- Measure size of green area

Slices in lighter opacity shows previous situation while slices in higher opacity shows situation after implementations. Note that the brown slices, representing Connectivity are in the previous situation much lower than the slices representing Quality. After implementations, the slices on each side of the rose graph are more balanced.



For example, a small green area (area A) has a broad flowering season of native plants and a high presence of suitable resources such as sandy, nutrient-poor soil and dead plant mass. However, with recent densification of buildings in the surrounding area, potential connections to other green areas have decreased. Implementations needed are to foremost increase connectivity since populations inhabiting the area risk being subject to 'extinction debt' (explained on page 32).

Implementations focus on increasing connectivity by adding smaller, green spaces in the close proximity that could act as corridors or stepping stones. As well increasing the matrix (surrounding landscape), making it more accessible by pollinators increases connectivity (page 37).

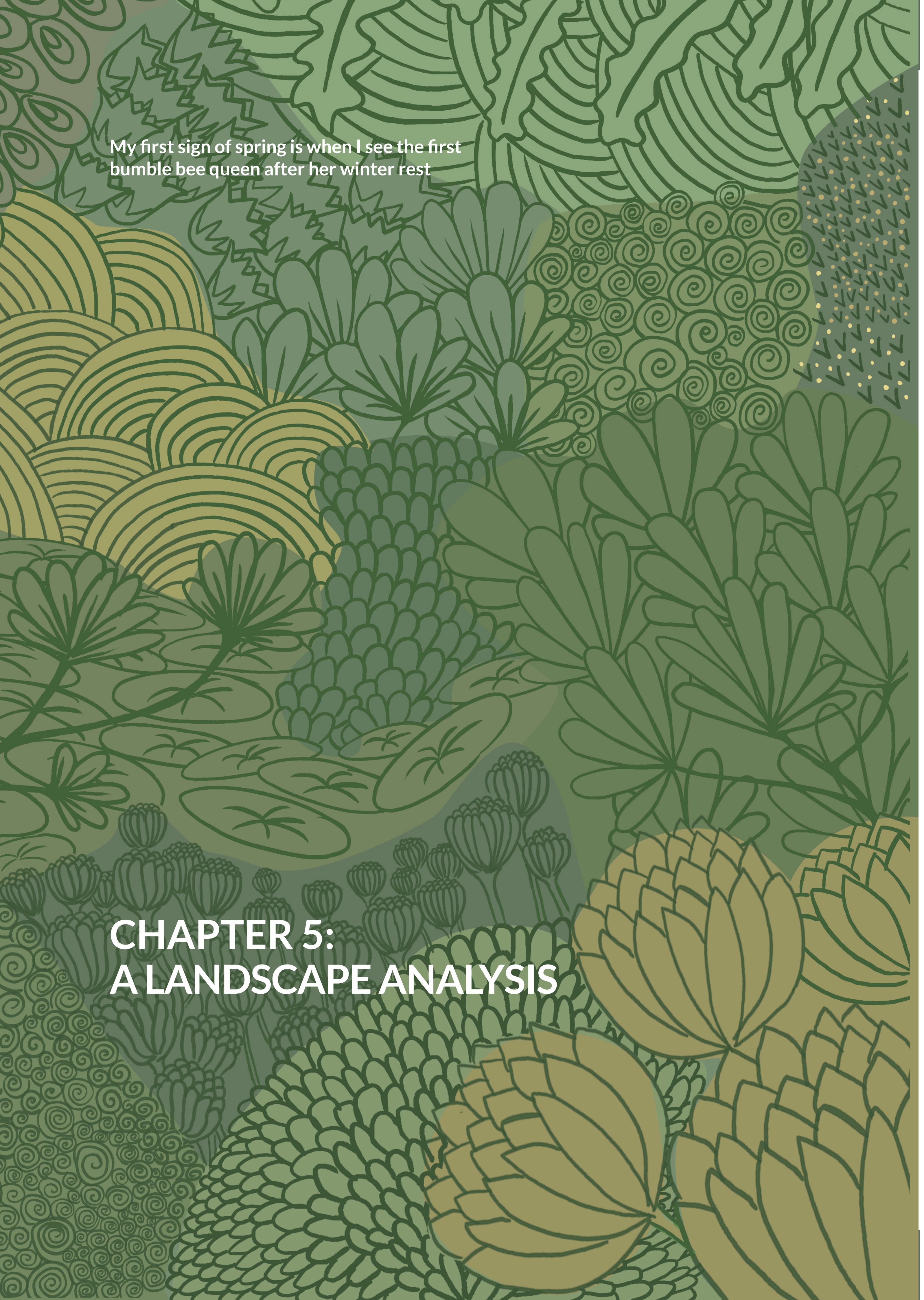


These examples are speculative and meant to demonstrate the guideline. Ideally, the guideline would include further detailed methods to measure the different parameters in order to determine level of Connectivity and Quality.

The second example, a large urban green area (area B) surrounded by built structure has a high amount of old trees but there is a lack of diverse, native vegetation. There is a neighbouring green area within a close proximity but not visually connected. The maintenance is regular and intensive and does not allow for natural processes to occur.

Implementations needed are primarily focused on increasing quality and secondly to increase connectivity. To increase quality maintenance is changed to a lower intensity and dead plant mass are left to decompose, increasing biodiversity. In a few places, the nutrient-rich topsoil is removed, exposing the nutrient-poor subsoil beneath. Native species with a broad flowering season are being introduced to increase resources of pollen and nectar.

The goal is to move one or a group of urban habitats towards the upper right corner of the XY-graph to enable for pollinators to spread and thrive (high Connectivity and Quality)



My first sign of spring is when I see the first bumble bee queen after her winter rest

CHAPTER 5:
A LANDSCAPE ANALYSIS

PREPARING A LANDSCAPE ANALYSIS

This chapter includes the process and result of making the landscape analysis and is meant to answer the question of “where?” in regards to supporting the social-ecological system in Gothenburg. The listed and used data is based of the research in chapter 3. The analysis includes social aspects such as built structure and centrality of motorized and non-motorised networks. The ecological aspects include a landscape of biotopes as mentioned in the method.

These are my indicator species, the landscape analysis was primarily based on the needs of the Sand bee but in the street-scale design part the Red mason bee is also highly considered. This is by adding resources that meet both of the species needs.

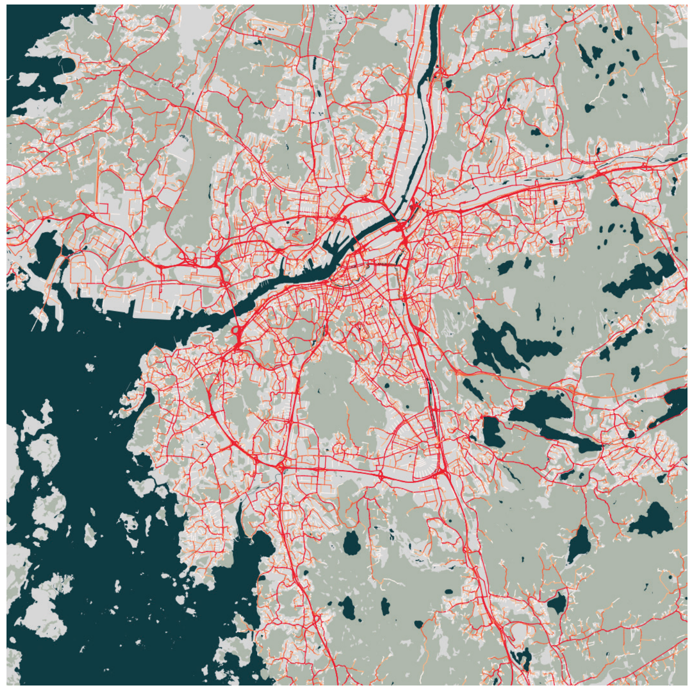
HABITAT NETWORK ANALYSIS

The habitat network analysis was based on a land cover basemap where the different biotopes were weighted by parameters. The weighting was based on the literature study, the interviews as well as the continuous contact with Oskar Kindvall who is the co-creator of the plug-in. The habitat quality and connectivity is integrated into the analysis by the parameters, quality is represented by the foraging and nesting sites while connectivity is represented by foraging range and the level of barriers. The parameters are approximations and not measured in detail, Kindvall assisted me with feedback and we could reflect on how the result gave a realistic representation. We compared the result with reported findings of the two species and these seemed to match quite well. This process was iterative and took a few turns in order to find a presentable result.

The gray column represents the different biotopes, resources or urban structures. The red and yellow represent the different parameters of nesting (reproduction), foraging (quality) and barriers (friction). Quality parameters are set from 0 to 10. Reproduction parameters were set from 0 to 1. Friction parameters function so that they are compared to one another, the maximum weight is set by the highest weight and minimum weight is 1. Red column represents the Red mason bee and yellow represents the Sand bee. Since the two species have different needs and levels of sensitivity, the parameters look different.

Landscape of biotopes
This map show the land cover basemap that was used for the analysis. The variation of colors represent the different types of land cover and biotopes.

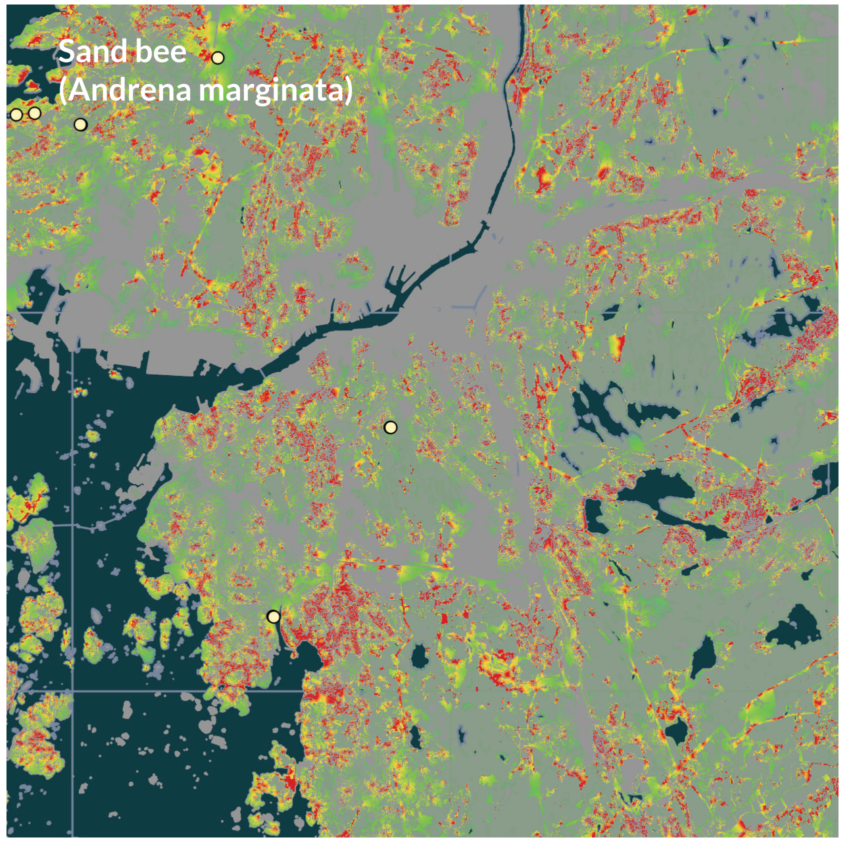
Urban form and street network
This map show the centrality of the motorised street network, it is measured using angular betweenness (5km).

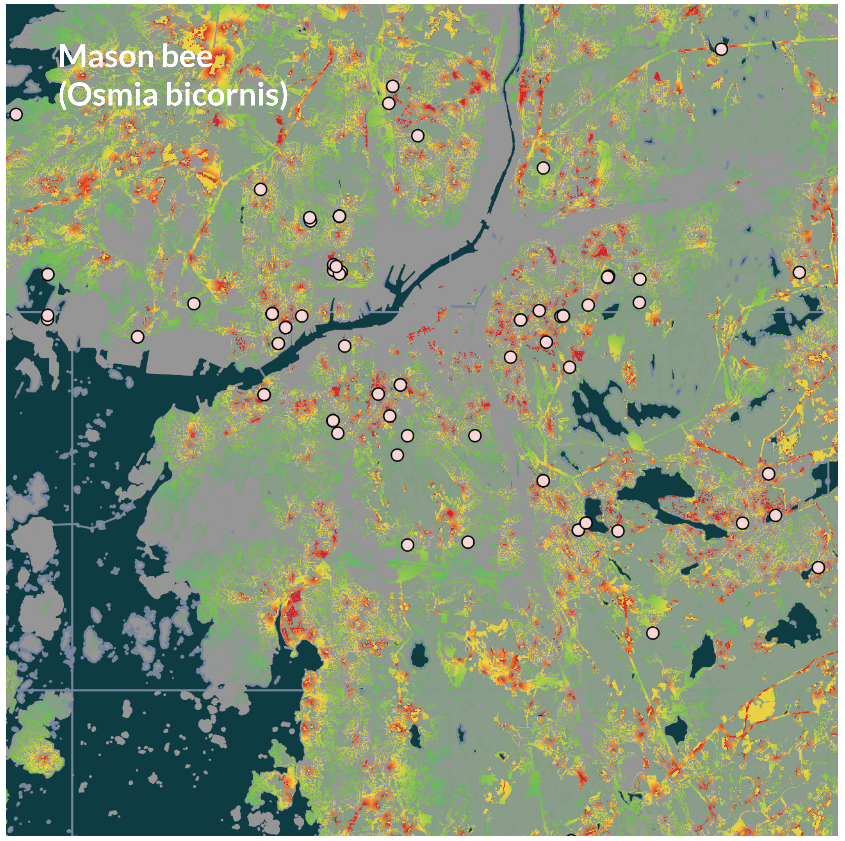


1:250 000

	Guldsandbi			Rödmurarbi		
BiotopeName	Quality	Repro-duction	Friction	Quality	Reproduc-tion	Friction
1.1.1. Tallskog/Pine forest	0	0	70	0	0	70
1.1.2. Granskog/Spruce forest	0	0	100	0	0	100
1.1.3. Barrblandskog/Mixed coniferous forest	0	0	100	0	0	100
1.1.4. Lövblandad barrskog/Mixed forest	0	0	7	0	0	7
1.1.5. Triviallövskog/Deciduous forest	0	0	7	0	0	7
1.1.6. Ädellövskog/Deciduous hardwood forest	0	0	6	0	0	6
1.1.7. Triviallövskog med ädellövinslag/Deciduous forest with deciduous hardwood forest	0	0	7	0	0	7
1.1.8. Temporärt ej skog (inkl hyggen)/Temporarily non forest	5	0	1	5	1	1
1.2.1. Tallskog/Pine forest	0	0	5	0	0	5
1.2.2. Granskog/Spruce forest	0	0	100	0	0	100
1.2.3. Barrblandskog/Mixed coniferous forest	0	0	100	0	0	100
1.2.4. Lövblandad barrskog/Mixed forest	0	0	10	0	0	10
1.2.5. Triviallövskog/Deciduous forest	0	0	10	0	0	10
1.2.6. Ädellövskog/Deciduous hardwood forest	0	0	10	0	0	10
1.2.7. Triviallövskog med ädellövinslag/Deciduous forest with deciduous hardwood forest	0	0	10	0	0	10
1.2.8. Temporärt ej skog (inkl hyggen)/Temporarily non forest	4	0	1	4	0	1
6.1. Sjöar och vattendrag/ Inland water surfaces	0	0	100	0	0	100
6.2. Hav/ Marine water surfaces	0	0	100	0	0	100
2. Öppen våtmark/Open wetland	6	0	1	6	0	1
3. Jordbruksmark/Arable land	0	0	1	0	0	1
4.1. Övrig öppen mark utan vegetation/Non-vegetated other open land	5	0	1	5	0	1
4.2. Övrig öppen mark med vegetation/Vegetated other open land	9	0	1	10	0	1
5.1. Exploaterad mark, byggnad / Built-up areas	0	0	100	0	0	100
5.2. Exploaterad mark, ej byggnad eller väg /Artificial surface, excluding built-up areas and roads	0	0	50	0	0	50
5.3. Exploaterad mark, väg /Roads	0	0	2	0	0	2
301. Koloniområde	10	0	1	10	1	1
302. Skyddsvärda träd (>20 cm diameter)	3	0	1	10	1	1
303. MS network High traffic	0	0	50	0	0	50
304. Skogsbryn 10m (löv o barr)	5	0	1	10	0	1
305. Sandig jordart öppen mark	10	1	1	8	0	1
306. Buildings above 10m	0	0	100	0	0	100
307. Buildings below 10m	0	0	2	0	0	2

Note that the list is shortened and simplified for presentational purposes.

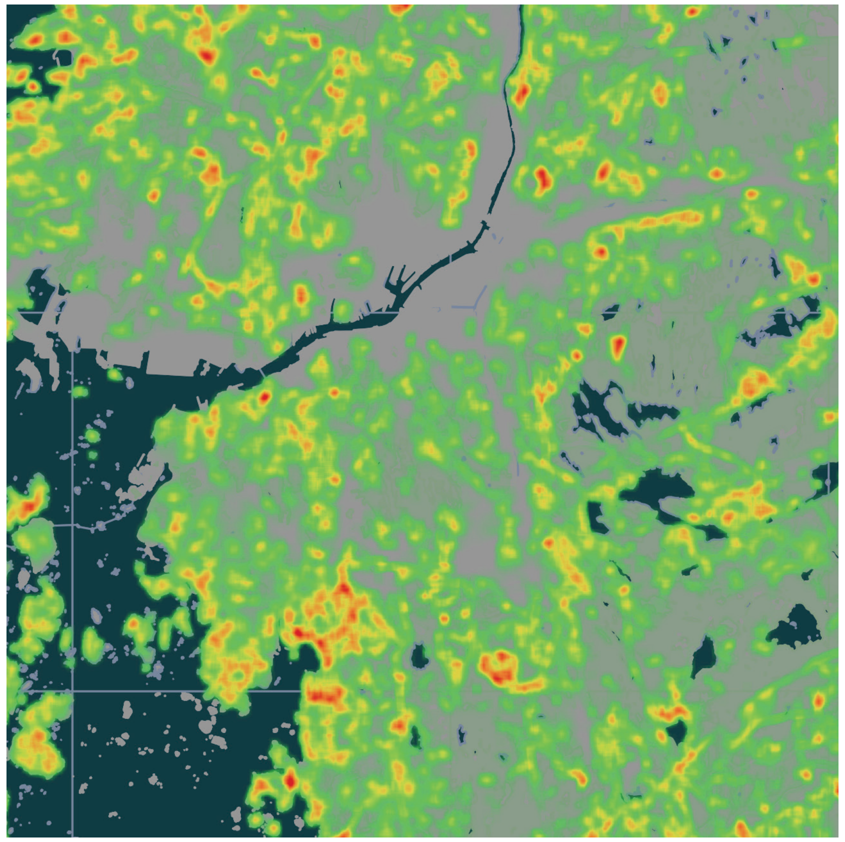


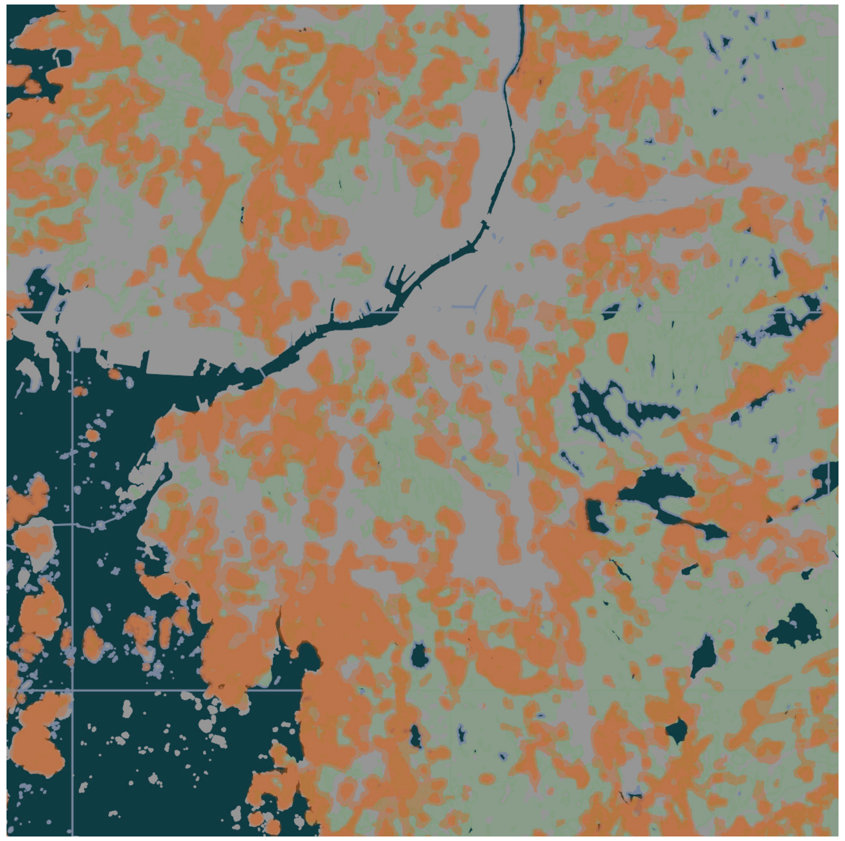


1:200 000

Habitat network

These maps are the result of the analysis and based on several maps that represent nesting sites, foraging sites etc (see appendix). Habitat quality and connectivity is integrated in the analysis through the parameters. These maps show the relationship between different sites for nesting and foraging and their level of connection (increased level of barriers decrease connection as mentioned in chapter 3). The maps also show reported findings (Artportalen.se) of the different species. The landscape looks slightly different for the Sand bee and the Mason bee since they need different resources for nesting and foraging. They also fly different distances. From this stage I chose to use the map representing the habitat network of the Sand bee since it is considered a suitable indicator species, as previously mentioned.





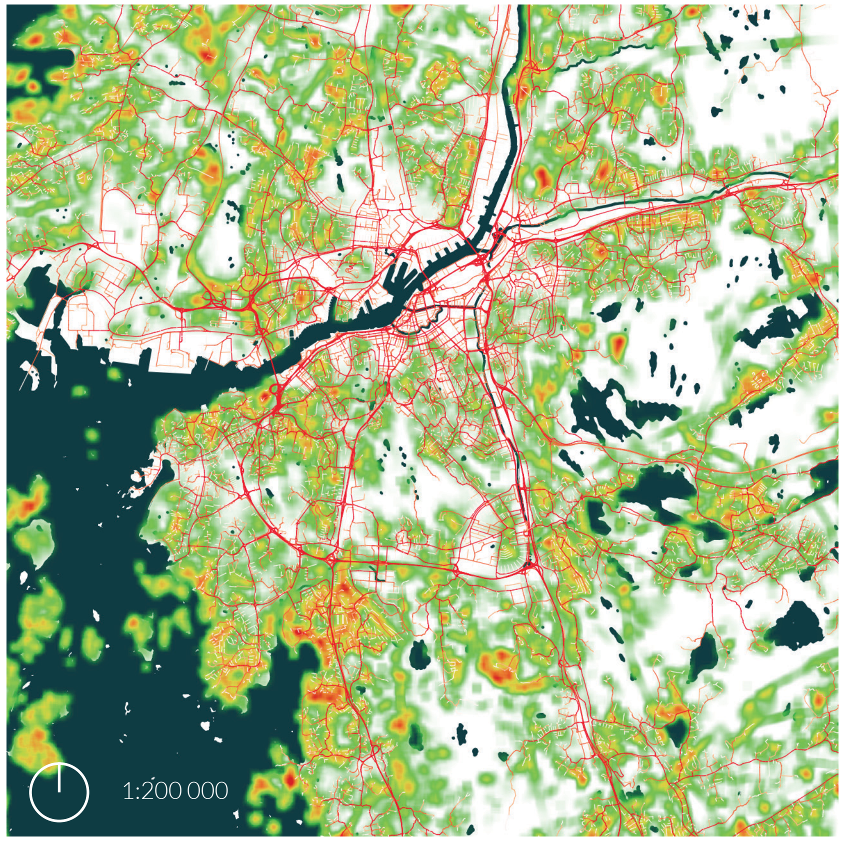
1:200 000

Habitat heatmap

These two maps show the habitat network of the Sand bee but is now generalized in GIS. The hotspots (yellow-red areas) show areas where resources for foraging and nesting overlap or are within close distances (high availability of important resources for the different needs). This map clearly shows how the hotspots are connected and where there is a lack of connection. The city center of Gothenburg has barely any hotspots which was expected due to its high density and lack of natural green areas. The lower map showing hotspots in red is later used as a basemap for the city-scale design.

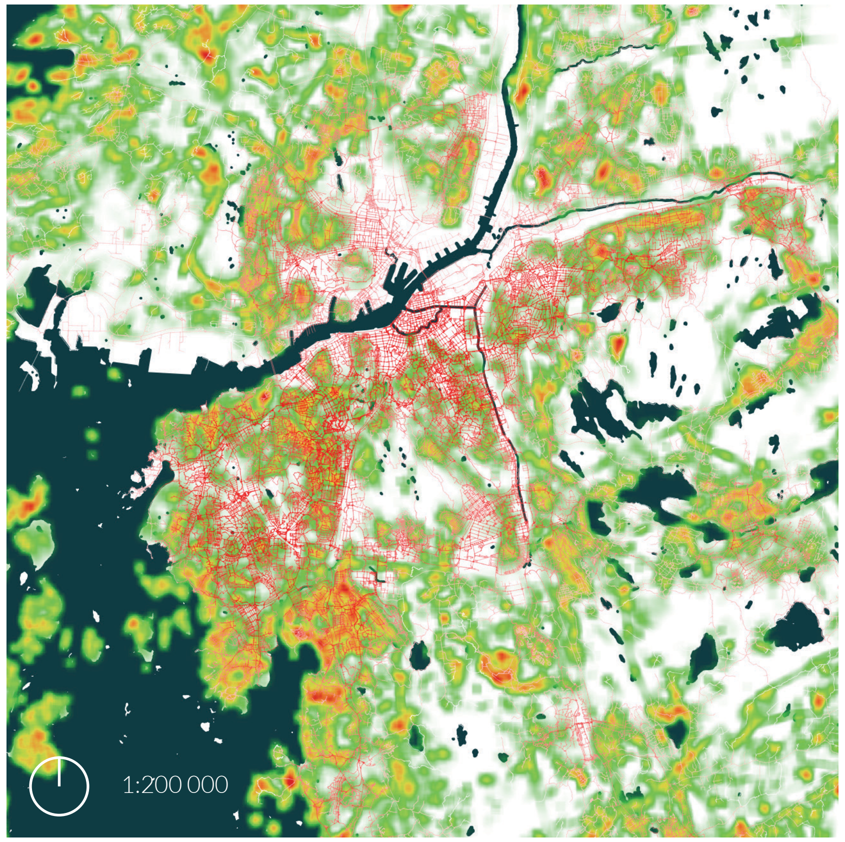
Note that these maps show a potential habitat network and do not necessarily reflect reality. The reason for that is because the used data for nesting sites for the Sand bee was sandy subsoil, which refers to soil beneath the ground surface. That means that the sand is necessarily not exposed, which is a requirement for the Sand bee to nest.

SOCIAL ECOLOGICAL NETWORK



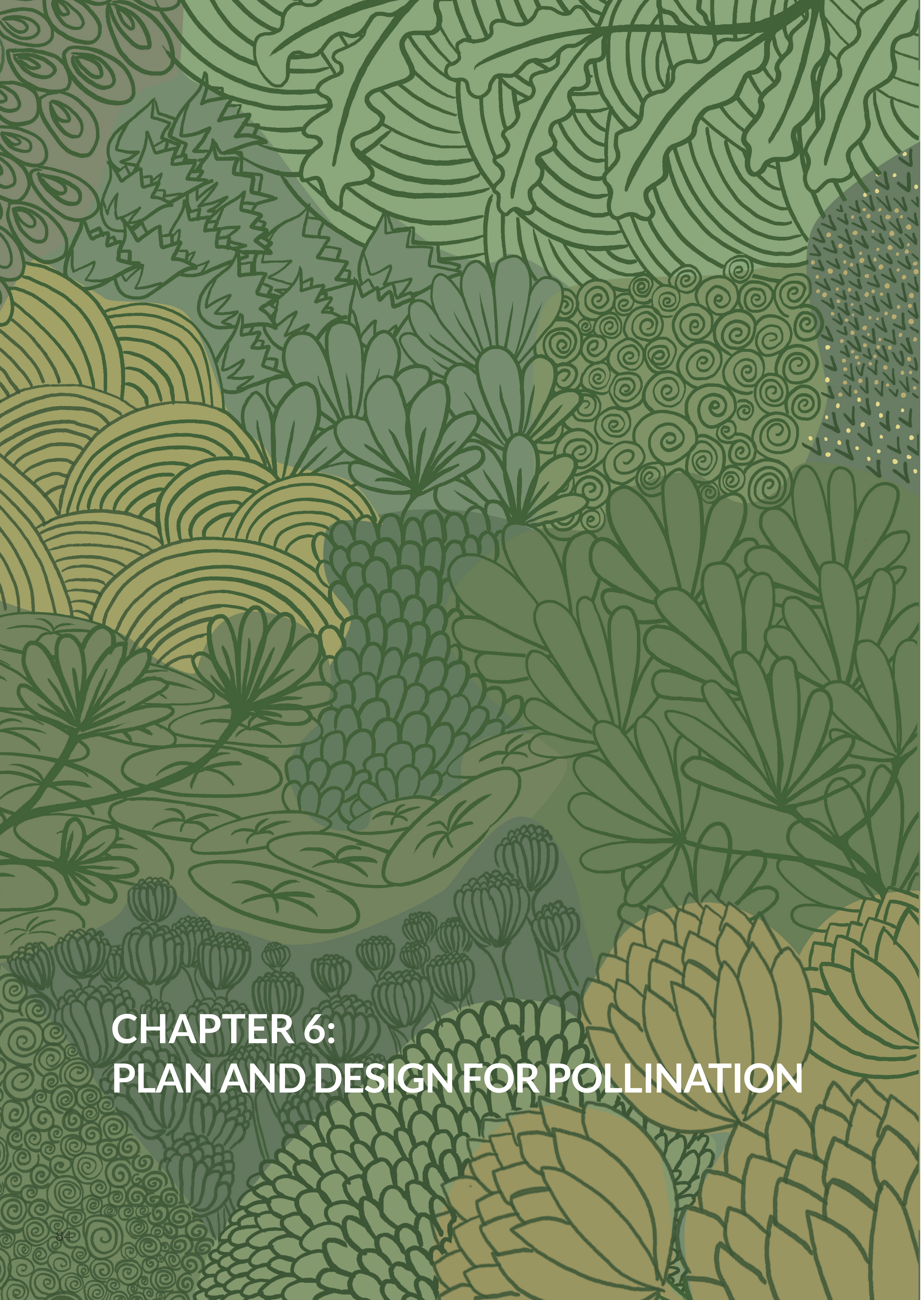
- Motorized network: angular betweenness 5k (red lines)
- Habitat heatmap (green-yellow-red)

We are now adding the social dimension onto the ecological dimension through a centrality network. The social network is represented differently on each of the two maps; centrality in motorized and non-motorized networks. Areas of high centrality and hotspots are occasionally overlapping, as mentioned in the Cohabitation guideline. With these maps we can identify where these overlaps occur and find synergies in the social-ecological system. The motorized network contributes to fragmenting the landscape, as mentioned previously, we can still see areas where high centrality of the motorized network is overlapping hotspots within the habitat network. These areas could be particularly interesting to work with in order to create synergies.



- Non-motorized network: angular integration 2k (red lines)
- Habitat heatmap (green-yellow-red)

This chapter presented a map of the habitat network of Gothenburg. We got two different results from each species which was expected. By focusing on the main indicator species (Sand bee) we could find areas that are particularly interesting to protect, enhance or develop urban habitats. Through this result we can identify hotspots, their connections and lack of connections. Through adding the social dimension we can identify synergies and conflict within the social-ecological system. Where there are overlaps of high centrality and habitat hotspots, these areas are particularly interesting to focus on, as is my attempt in the next chapter.

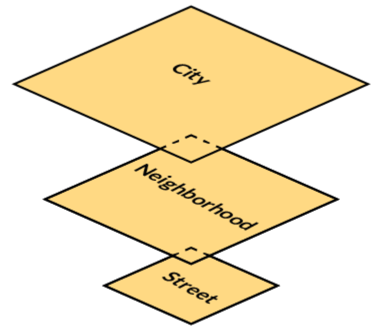


CHAPTER 6:
PLAN AND DESIGN FOR POLLINATION

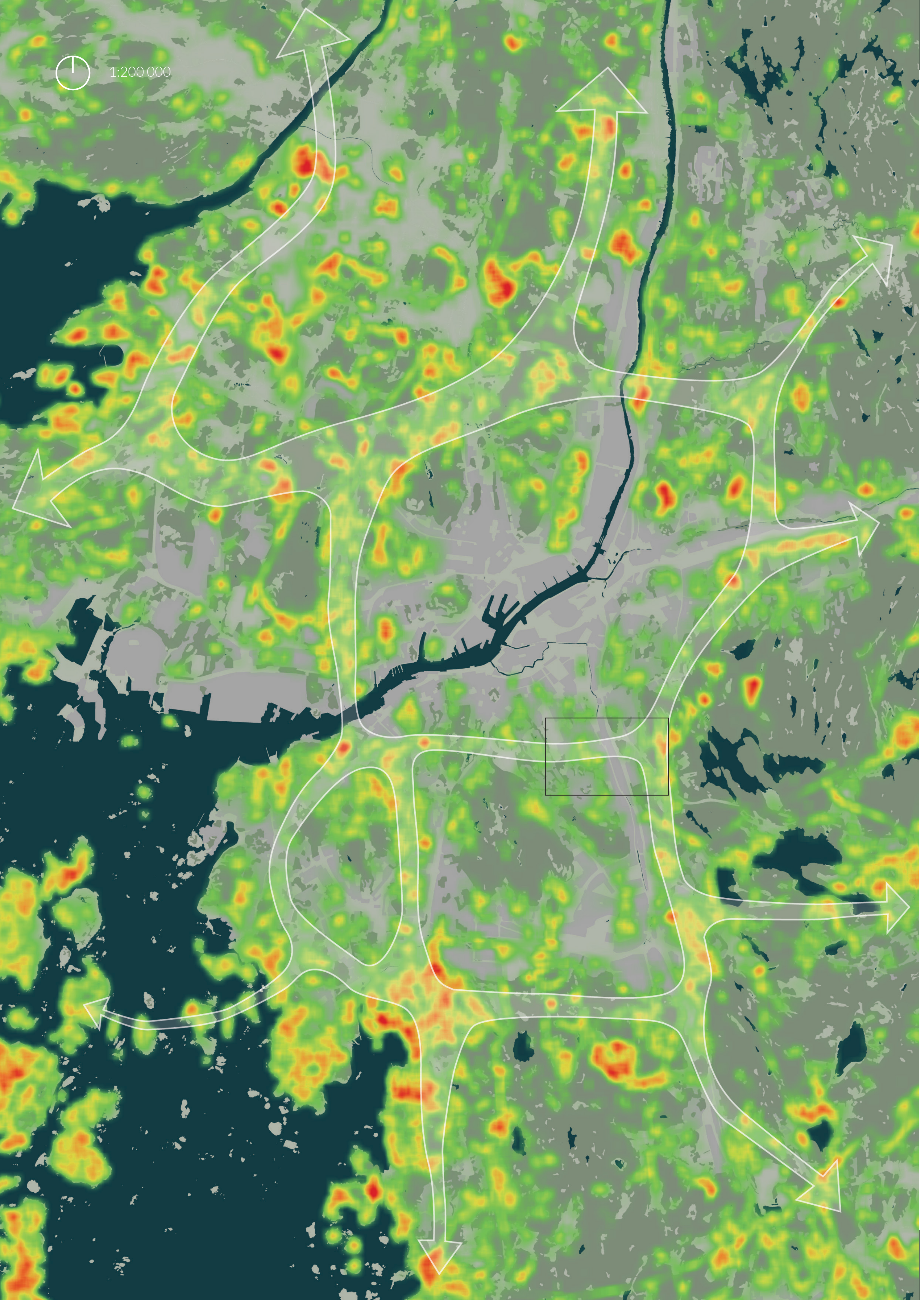
OVERVIEW

This chapter includes a plan and design for pollination in three scales and is based on the landscape analysis from the previous chapter. This step means to start assessing the resul from the analysis by creating a design that aims to support the social-ecological system through planning for pollination. This step is important as it is the decision-making part of the process where both the analysis, the literature study and the interviews are translated into a design.

First, based on the habitat heatmap from the analysis, a city-scale design shows a potential habitat network of hotspots and its connection in Gothenburg, creating a pollination plan. Secondly, an area is identified as the focus area for the neighborhood-scale. This area is particularly interesting as it covers a potential key area of the entire habitat network to enhance the connectivity at large. Thirdly, another focus area within the neighborhood-scale is identified. This represents the street-scale and is presented in two scenarios. The first scenario primarily focuses on ecological connectivity while the second scenario means to increase both social and ecological qualities.



Planning and designing for pollination includes all three scales just as the quality of one urban habitat is dependent on its context and its entire habitat network.



CITY-SCALE

High Low Hotspots; level of quality and connectivity

Connectivity structure

Focus area for neighborhood-scale

This city-scale map presents a potential habitat network for wild bees of Gothenburg and is based on the habitat heatmap from chapter 5 (landscape analysis). As mentioned in chapter 3, several green patches can function as one large green area if they are well connected. These patches (as I call hotspots) have now been identified in the analysis and my attempt in this chapter is to find where these could be connected. Depending on the need to increase density or centrality, the placements of these hotspots can guide where increased density should be done with care of completely avoided. As mentioned in the Cohabitation guideline, sometimes increasing both centrality/density and biodiversity is needed in the same area and this city-scale design gives an overview so that density does not interfere with a particular important habitat connection.

The relationship between habitat quality and connectivity is crucial for a functional habitat network to enable insects to spread and thrive, as mentioned earlier. Habitat quality is represented by the basemap through the weighted parameters from the previous chapter and at this scale, habitat quality is less detailed. Connectivity is similarly represented by the basemap but also very central at this scale since it is meant to guide connectivity at a larger scale.

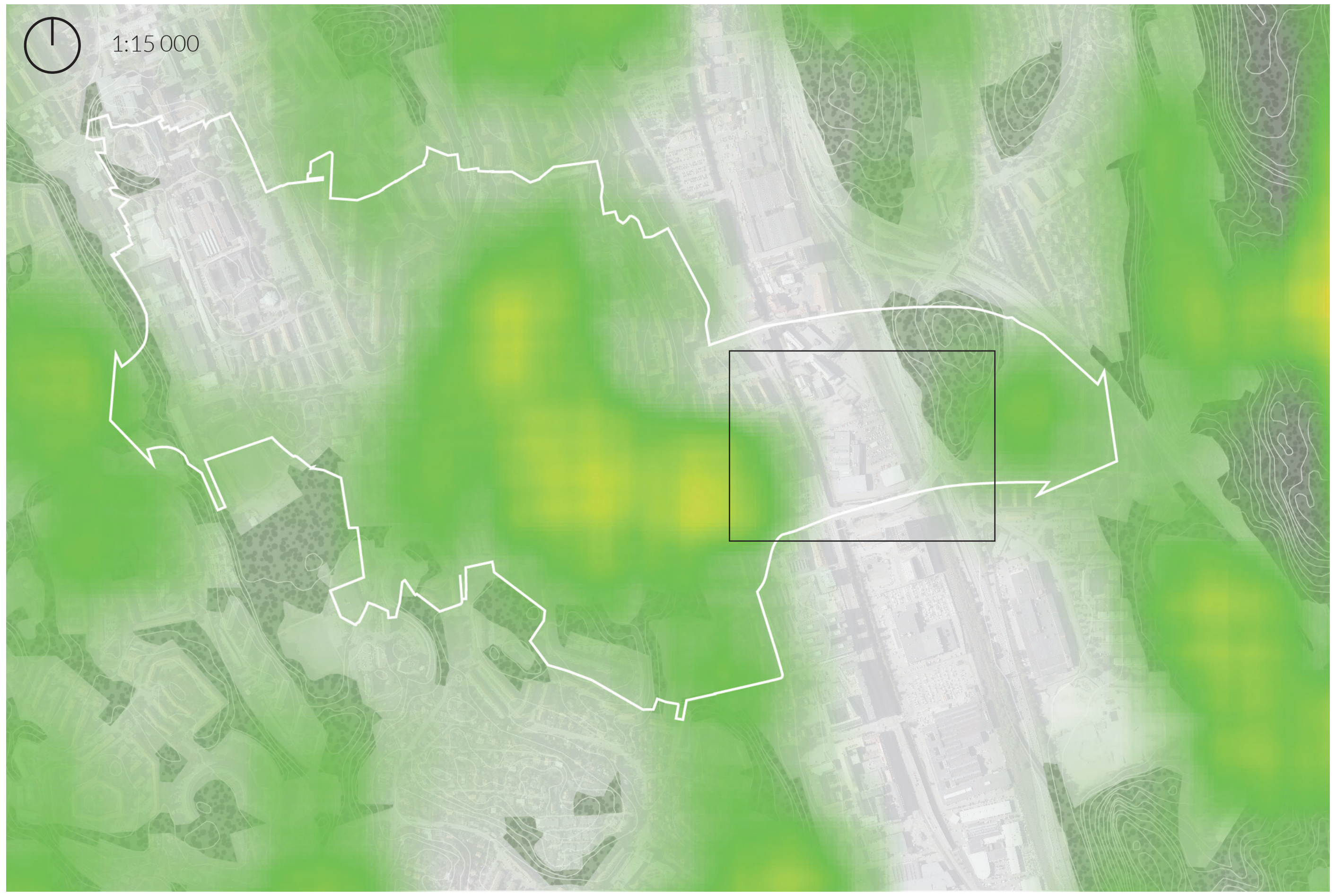
The plan includes:

- Hotspots; areas that are particularly valuable for implementations to protect, enhance or develop the urban structure to support pollinators.
- Connectivity structure; areas where hotspots function as connectors at a larger scale. This structure connects through the city, within and reaches out to the rural parts of Gothenburg.

As mentioned, the basemap shows clear hotspots, their connections and the lack of connections. Since this map is a potential habitat network and necessarily not a replica of the reality, both hotspots and the areas between these could be interesting to highlight. The goal with this design of the habitat network is to guide which areas to prioritize. The gray square shows the area in which I chose to focus on for the next design scale; neighborhood. The reason I chose this area is because of the highway that separates a long row of hotspots. Creating a connection between these two hotspots could have an important function for the entire habitat network.

NEIGHBORHOOD-SCALE

This design scale is meant to guide implementations in detail but are still quite general. This scale covers three larger hotspots and gives an overview of how they could be connected. The project area covers different plots and these are divided by type (single households, larger residential, public or commercial) and by habitat quality/connectivity. Different implementations are needed depending on the type of property. For single households, implementations are to communicate the strategy of pollination planning, as mentioned earlier, communication is an important tool to create change in green structure and to support pollination (see page 46 . Implementations for larger residential, commercial or public plots include communication as well as detail plan guidelines that support wild bees needs: foraging, nesting and spreading. Habitat quality and connectivity is represented here as Habitat plots and Connector plots where Habitat plots focuses primarily on foraging, nesting and day-to-day movement while Connector plots focuses more on spreading between habitats. Habitat plots are placed inside the hotspot and Connector plots are placed between hotspots, see map on the left. This is a simplified categorization and all needs should be considered within these areas.



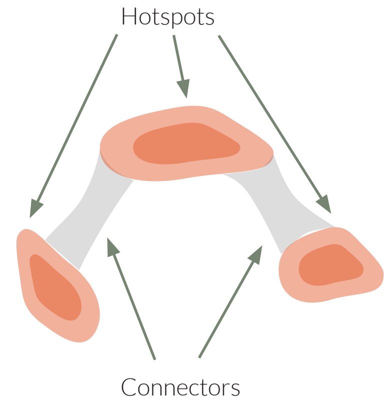
Hotspots

Project area neighborhood-scale

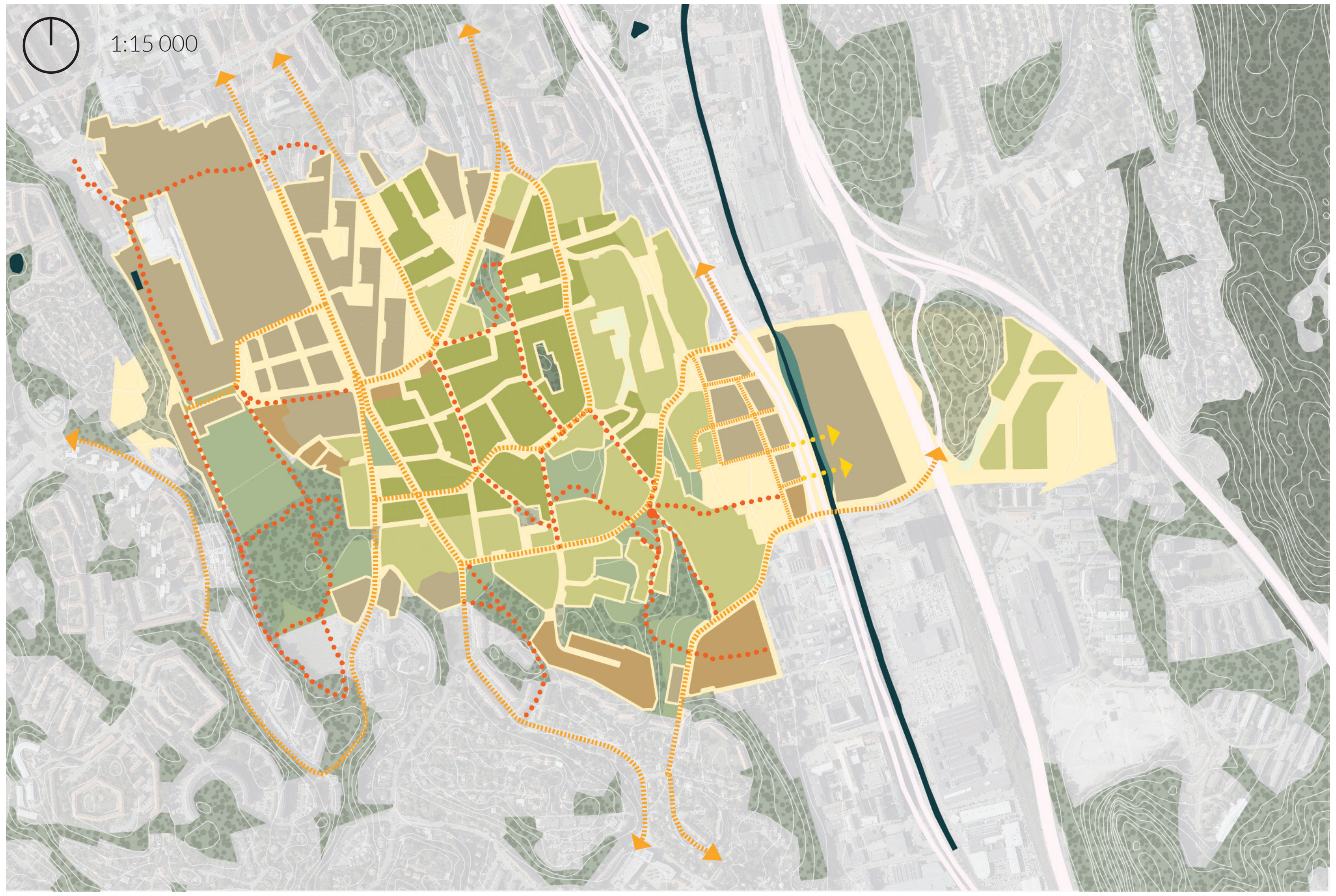
Focus area for street-scale

The focus area for street-scale is chosen as it is the link between two large hotspots. At large, this connection is crucial for the entire habitat network as is shown in the city-scale design.

Increased density should be avoided within the hotspots or done with care (well integrated) of the habitat quality and connectivity. As mentioned, there are great health benefits with increased biodiversity, therefore there is high potential to create thriving social spaces within the hotspots as well as the Connector plots.



Hotspots and connectors have different functions, habitats mainly need high resources and connectivity for day-to-day movement. Connectors mainly increase the possibility to spread between habitats.



Quality plots: commercial, public or larger residential

Quality plots: single households

Connectivty plots: commercial, public or larger residential

Connectivity plots: single households

Public parks

Project area

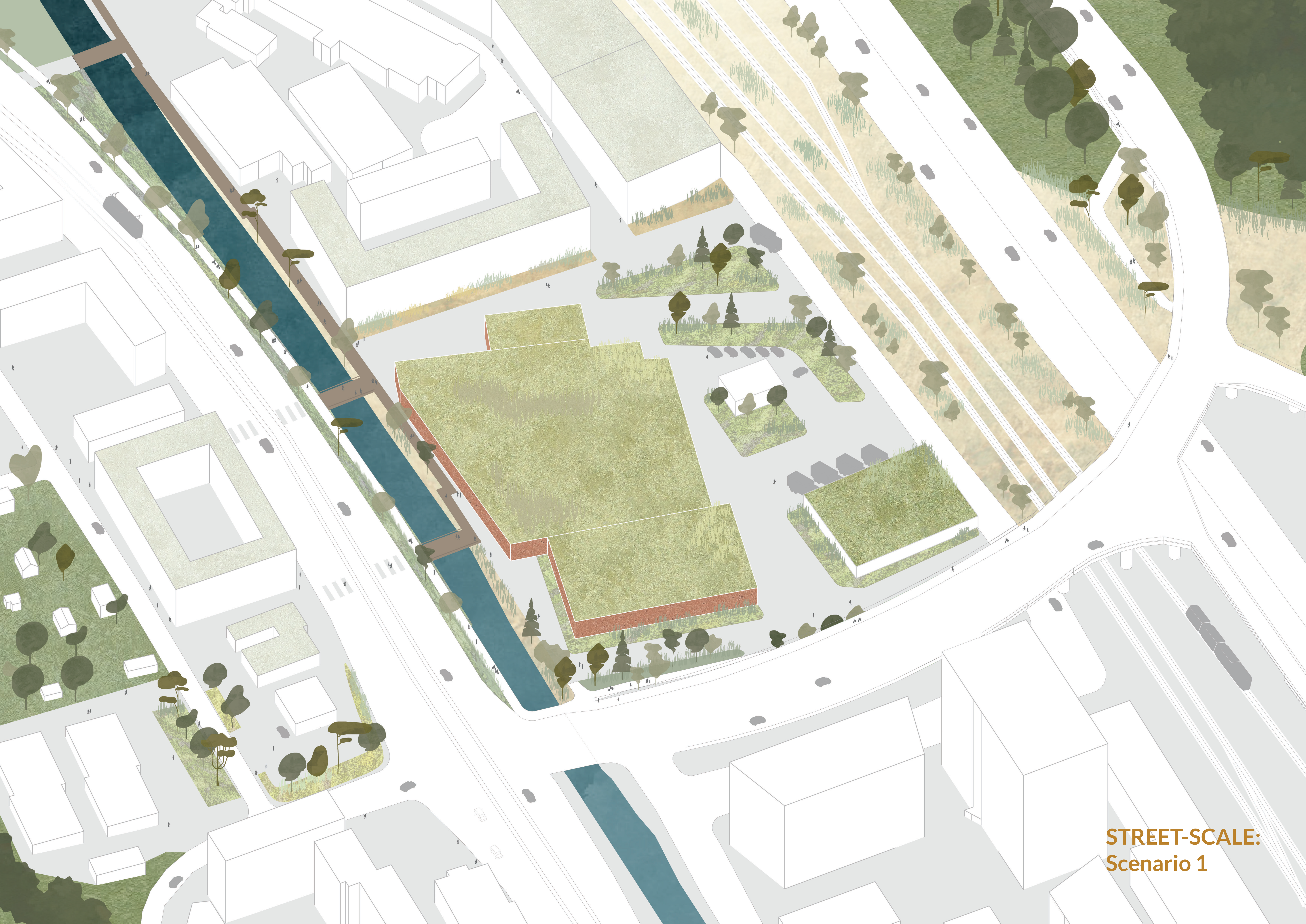
Forests

Green streets for cars

Green for pedestrians

New pedestrian bridge

Main roads


STREET-SCALE:
Scenario 1

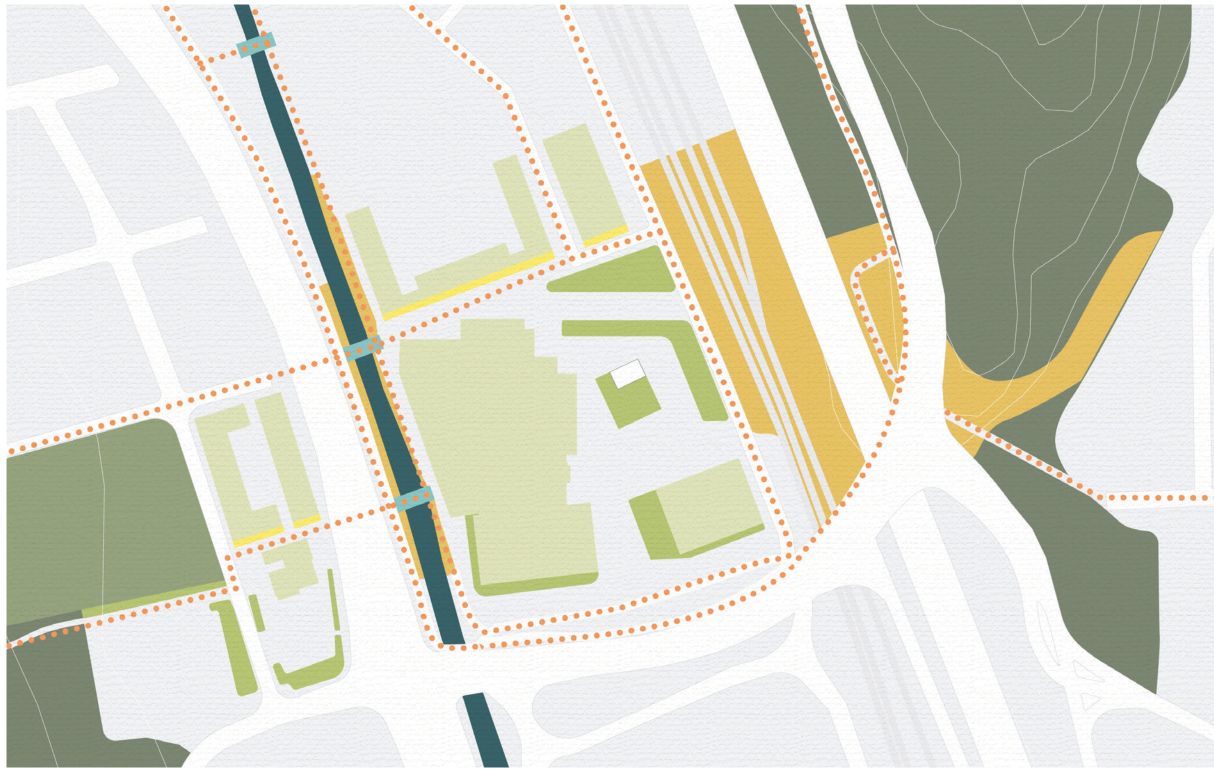
Current situation

The area is largely affected by the highly trafficked roads, Mölndalsvägen and the highway, that act as strong barriers. There is a motorized bridge passing over the highway, leading towards Borås. The intensity of traffic eliminates the possibility of a connected corridor so instead I added visual elements and stepping stones. The area is considered an industrial area with a neighbouring large wasteland in the form of railwaytracks..

The proposal suggests both high and low level of implementations. The low level implementations regards to having a biodiversity focused maintentance of the wasteland surrounding the railways. The high level implementations regards to adding green patches within the industrial areas as well as green roofs on the large flat buildings; these mimic biotopes such as dry and sandy grasslands, beachy biotopes and sedum. The vegetation within the railway is removed and opened up to make space for sun-exposed soil. The maintenance around the railway only requires keeping the area open.

Key characteristics of the area

+ Railway and industrial area - wastelands
+ Allotment garden
+ Passing river
+ Sandy subsoil
- Large hard surfaced areas
- Highly trafficked roads



Proposal

- Current decidious and coniferous forest
- Allotment garden
- Green roofs as classic sedumbiotopes
- Sandy dry meadow
- Wasteland biotopes. Requires only maintenance to remove aggressive vegetation from establishing.
- Classical meadows with solitary bushes and trees.
- Pedestrian and bike network
- New pedestrian bridges
- River

Sandy and dry meadows are a key element in this landscape. Here grows Succisa pratensis, Knautia arvensis, Scabiosa canescens and Scabiosa columbaria.

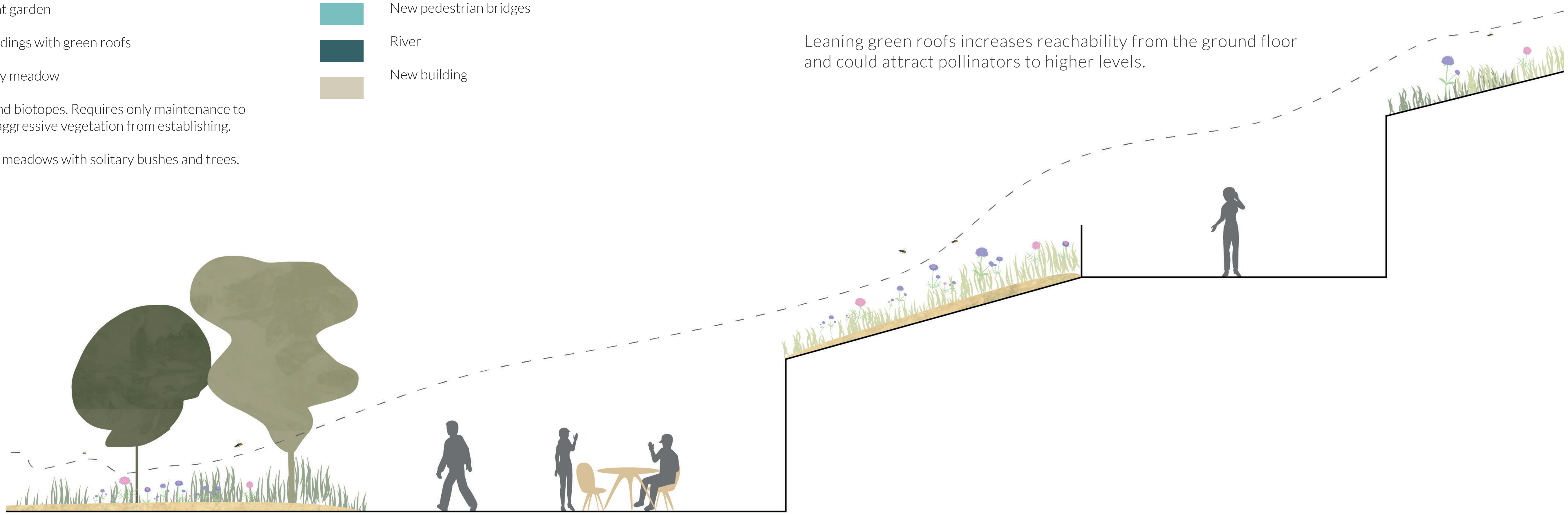
STREET-SCALE:
Scenario 2

Proposal

- Current deciduous and coniferous forest
- Allotment garden
- New buildings with green roofs
- Sandy dry meadow
- Wasteland biotopes. Requires only maintenance to remove aggressive vegetation from establishing.
- Classical meadows with solitary bushes and trees.
- Pedestrian and bike network
- New pedestrian bridges
- River
- New building

As cities grow, there is a demand for increasing density, which is what Scenario 2 is based on. The implementations to increase quality and connectivity are identical to Scenario 1, though in this scenario, the social aspects are equally weighted in. The previous industrial area has transformed into a mixed use area where new buildings have been added as well as an increase of floors to current buildings. There is an active ground floor and previous private parking spaces are made public.

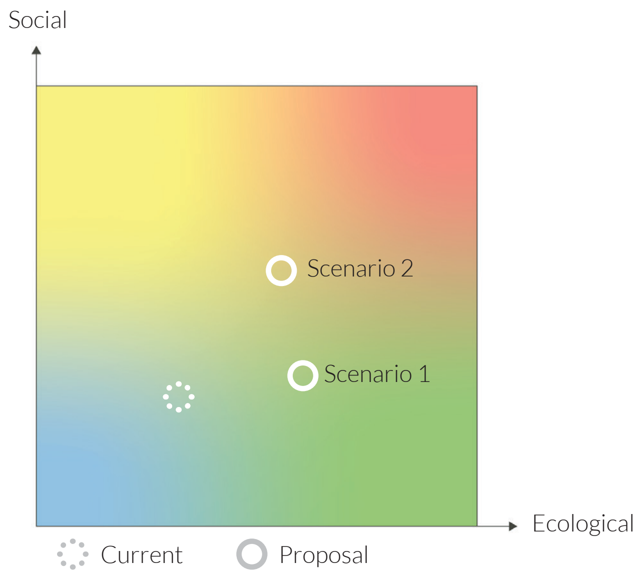
Leaning green roofs increases reachability from the ground floor and could attract pollinators to higher levels.




1:2000
Scenario 1


I-VII
I-VII
I-VII
XVII
Scenario 2

Cohabitation guideline



Scenario 1
The implementations for scenario 1 mainly focuses on increasing ecological qualities. The slight increase of social quality is due to the added pedestrian and boardwalk along the river. Neither the building density nor the motorised network is changed.

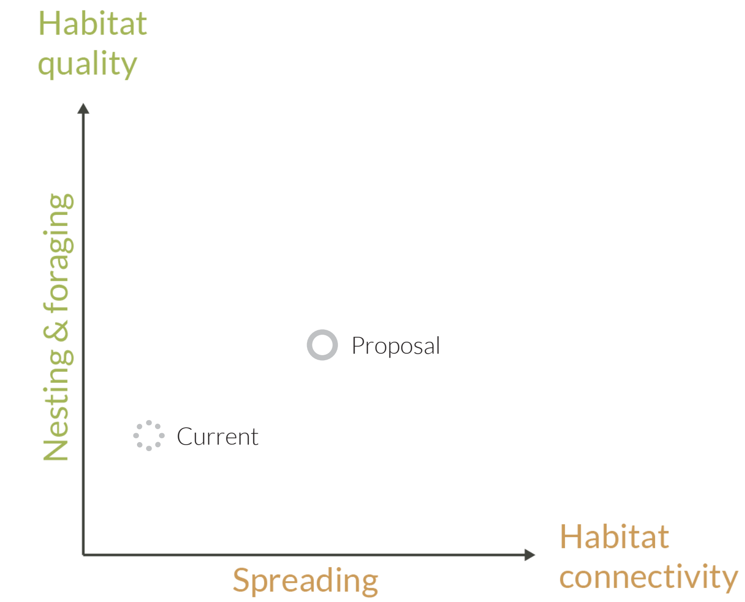
Currently the area is used primarily as an industrial area and due to the highly trafficked roads, the surrounding network is quite high in centrality. Though the area itself has a low density, the potential to increase ecological values are high. Current and future urbanization might push areas like these into increasing density, which is discussed in Scenario 2.

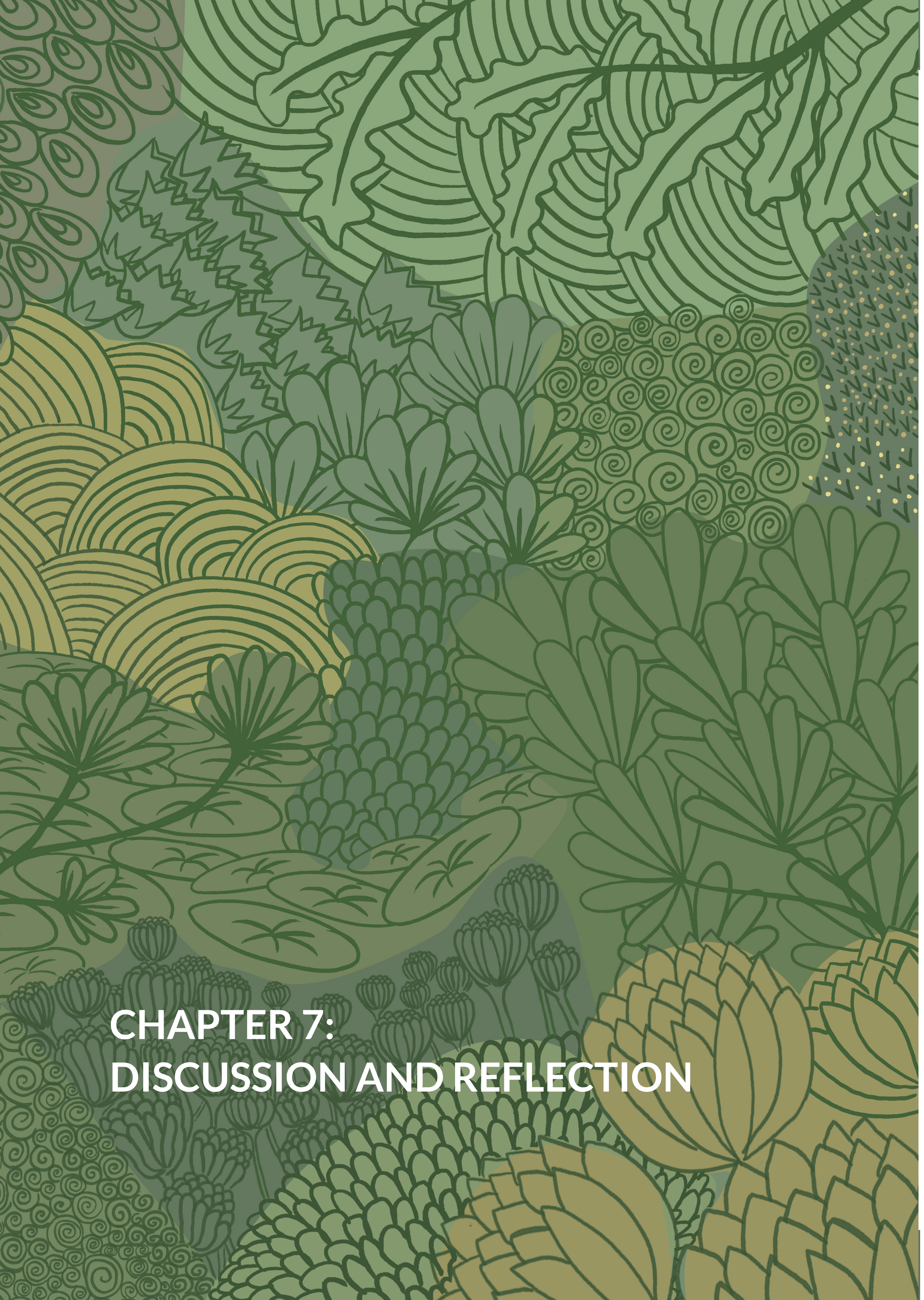
Scenario 2
The implementations for Scenario 2 regards increasing both ecological and social qualities. The social quality refers to increasing density by increasing floors to current buildings as well as adding new residential and commercial buildings. The non-motorised network is also slightly changed by removing the bikepath from the large bridge and adding a new bridge, only for bike and pedestrian traffic running over the highway. The ecological implementations are just like the ones from Scenario 1 but they might be slightly decreased due to the change of density.

Note that these values are my own speculations and not based on actual measurements. Ideally each parameter from the Qualirt/Connectivity and Cohabitation guideline would have been calculated; distances, amount of trees, density and sun exposed ground...

Quality/Connectivity guideline

The current situation of the site is low in Connectivity due to the barriers and quite mid-low in Quality. Since the site is located between two hotspots, implementations are to foremost increase Connectivity and secondly quality. Both scenarios have the same implementations, though the result is slightly different as Scenario 2 increases density leading to increased green roof area.





CHAPTER 7: DISCUSSION AND REFLECTION

Conclusion and discussion

There are great potentials to plan and design for thriving urban habitats in order to protect pollinating insects and support the social-ecological system. Pollination is a crucial ecosystem service and wild bees are considered the most efficient and important group of pollinators. The alarming numbers of declining species should be a wake-up call to re-imagine how we shape, distribute, maintain and care for our urban green spaces. It is evident that the city can facilitate its habitat network if it is well-planned and properly designed. There are many advantages in integrating ecosystems in the practice of urban design just like social systems always have been.

This thesis has been developed to answer the following questions:

- *How can an urban ecological network with local interventions and connections enable pollinating insects to spread and thrive?*
- *How can urban habitats for pollinators cohabit with people and social spaces in cities?*
- *What are the potential for urban habitats and the connections between these in securing wild bees?*

Firstly, the urban form, distribution and content of built structure and green infrastructure highly affect the social-ecological system. The two development concepts “land sharing” and “land sparing” contextualizes how high versus low density urbanization affects nature and green infrastructure. Neither of them is the solution on their own to the decline and loss of biodiversity but a combination of them could protect sensitive natural land and increase urban biodiversity. Land sparing suggests to increase density and keep natural land intact of exploitation and can gain more sensitive and uncommon species. Land sharing suggests to integrate green structure with low density buildings, therefore increase contact between human and nature (creating cohabitation between pollinators and people) and potentially increase urban habitat connectivity. This way of urban development can gain generalists and more common species. These concepts could be used where there is a need for increasing connectivity or protecting an area with high biodiversity (mainland). The most important aspect is that in both of the concepts, biodiversity and pollination should be integrated to increase their ecological function.

To secure species of wild bees we must support, enhance and develop biodiversity which itself leads to increasing resilience. Ecological knowledge is fundamental in order to understand urban habitat networks and urban biodiversity. Focusing on one or a few species (indicator species) can guide us to support entire groups of species and to increase biodiversity. A suitable indicator species could be sensitive, suggesting a red listed species. The first step is to map out the needs and life cycle of the indicator species. In this thesis I focused on the Sand bee, Andrena marginata, and for comparison; the Red mason bee, Osmia bicornis. The three general needs of wild bees are foraging (collecting pollen and nectar), nesting (building nests for eggs and hibernating) and spreading (day-to-day movement or colonizing new habitats). Navigation and movement in the urban landscape is challenging for wild bees as large buildings, large hard surfaced areas and highly trafficked roads act as barriers. For wild bees to be able to spread and thrive, each of these needs are fulfilled with high habitat quality (biotic and abiotic factors) and high connectivity.

Habitat connectivity and quality are key factors that are intertwined and dependent on each other. Connectivity itself is fundamental in order to increase biodiversity. To increase both connectivity

and quality of urban habitats; there need to be enough suitable resources and within reachable distances. Implementations are needed in both a city-scale and local scale; we must treat the entire network of habitats as well as the individual habitats.
There are a few concluding implementation to increase urban habitat quality for wild bees:

- Soil: sandy, low nutrition substrate is preferable for pollinator-favorable vegetation as well as for nesting of many species.
- Vegetation: aim for a diverse combination of native, pollinator-favorable plants and add plants that certain species are specialized on.
- Maintenance: decrease intensity, allow for natural processes to occur and leave dead plant materials.

There were a few general implementations to increase urban habitat connectivity for wild bees found in the research:

- Make the urban habitats bigger; simply by increasing existing urban green spaces, the distance between the habitats decreases.
- Use green corridors
- Use stepping stones
- Increase quality of surrounding environment
- Decrease barriers; avoid new built structure on important nodes and connectors.

As mentioned, treating the entire network of urban habitats is as crucial as treating the individual habitat. GIS is a suitable digital tool for creating a comprehensive map of the entire ecological network of a city. Through using the plug-in tool in the GIS analysis I found that Gothenburg has many potential areas to further protect, support or develop habitat network quality and connectivity. I generalized the result of the analysis and created a "heatmap" that I used in the design part. I also used reported findings from Artportalen.se to complement the analysis. Secondly I used a plug-in tool (Place Syntax Tool) to generate density and centrality of Gothenburg. I then compared the result with the habitat heatmap;

- The research regarding highly trafficked roads acting as barriers matches the analysis made in GIS; high centrality of the motorized network clearly creates gaps in the habitat heatmap. However, there are many exceptions where high centrality overlaps with habitat hotspots.
- Areas of high centrality of the non-motorized network seemed to overlap with habitat hotspots in a few areas in Gothenburg.
- As expected, areas of high density (specifically the city center) show up as large gaps within the habitat heatmap.
- Large green areas with forest biotopes also show up as large gaps within the habitat heatmap, as expected.

As it is commonly known of the many health benefits that humans gain from contact with nature, the areas where hotspots are overlapping with high centrality show potential for being shaped into thriving urban habitats that increases human well-being. Thus, resulting in a thriving cohabitation. The challenge is evidently to combine high biodiversity with high density, this subject is still speculative and would need further study.

Based on the literature study and the interviews, I created two guidelines to visualize the result and guide me in the next step; Quality/Connectivity and Cohabitation. Quality/Connectivity focuses entirely on the ecological dimension and is meant to visualize the balance of qualities (resources for foraging and nesting) and the level of connectivity (the reachability of resources). Cohabitation is meant to visualize the relation between the social and ecological dimension. The two scenarios for the street-scale design represents two different levels of density. Scenario 1 focuses primarily on ncreasing habitat quality and connectivity. This scenario includes adding stepping stones, green roofs and facades. Scenario 2 has the same ecological implementations as Scenario 1 but increases building density as well as changes the local non-motorized network.

In regards to supporting pollination and enhancing a social-ecological system there are a few conflicts and synergies identified;

Conflicts:

- Expectation, aesthetics and cultural norms of urban green spaces
- Land use, urban sprawl and densification (though densification is also seen as a way of keeping natural land intact of exploitation)

Synergies:

- High biodiversity increasing human well-being
- Some species of wild bees gain from the stress that humans have on the landscape.
- Integration of green structure in urban design and ecosystem thinking in urban planning

Finally, as cities expand, the demands increase of how we distribute, shape and plan the built structure and green infrastructure. This will highly affect the urban habitat network qualities, connectivity and overall urban biodiversity. Working interdisiplinary and inviting ecology into urban planning seem to be needed in order to understand the urban habitat network. The city is a living thing and we must treat it as such. Therefore, integrating ecosystem thinking in urban planning and habitats in urban design can enable for pollinating insects to spread and thrive as well as gain the entire social-ecological system.

Method and process

The theoretical framework of social-ecological urbanism, landscape ecology and habitat ecology composed the fabric of this thesis. Keeping the thesis within the delimitation was difficult at times but led to many interesting and important discoveries. The interviews guided my work through inspiration and important ecological knowledge regarding ecological urbanism, pollination and wild bee ecology. Though, ideally, I would have wanted to reflect on the result of my work with one of the ecologists/biologists or experts to discuss the outcome. I came across many interesting studies regarding the aspects of urban habitats for pollinators and urban biodiversity but still there are knowledge gaps within these fields.

The thesis questions, working multiscalar (city, neighborhood and street-scale) and context of Gothenburg were the framework for this thesis. As I began this thesis, I had brought previous knowledge of pollination and knew that working in different scales were both needed to find relevant results.

The GIS plugins used in this thesis were great tools for creating a comprehensive plan of an urban habitat network and of its relation to the built structure and infrastructure. Ideally, there would be site visits with inventories of plants and wild bees to complement the digital analysis. The data I used contained a detailed description of the different types of landscapes in Gothenburg. Though, for the chosen species of wild bees, I needed more specific data that simply is not available today. For example, areas with exposed sand. Some areas in the data of open vegetation could include both cut grass as well as villa areas. This is not entirely wrong but according to the literature study and interview, villa areas generally function as hotspots. Therefore, the result can only be as accurate and detailed as the data you use.

Final thoughts

This thesis has been both a rewarding process but also a serious awakening. Before the thesis I was well aware of the global crises but now I fully understand the responsibility and potential of architecture and urban planning. The decline of species and biodiversity is alarming, the consequences of ‘business as usual’ are critical and this path should not be an alternative. We need to change how we do things and we need to change it now. As a landscape architect student I am entering the professional world during a time of crises but also of change and innovation. Even though there is still much we do not know regarding urban ecology and the human-pollinator interaction, there is great potential for cities to become hosts of thriving urban habitats, and the social gains could be even higher. We can begin by treating the city as a living system with many different inhabiting species and use the simple framework of diversity.

REFERENCES

Ahrné, K., Bengtsson, J., and Elmqvist, T. (2009). Bumble bees (Bombus spp) along a gradient of increasing urbanisation. PLoS ONE. Vol. 4 (5): e5574. Doi: 10.1371/journal.pone.0005574

Andersson, E. and Bodin, Ö. (2009). Practical tool for landscape planning? An empirical investigation of network based models of habitat fragmentation. Ecography. Issue 32, pp.123-132. Doi: 10.1111/j.1600-0587.2008.05435.x

Aronson, M.F., Nilon, C.H., Lepczyk, C.A., Parker, T.S., Warren, P.S., … , La Sorte, F.A. (2016). Hierarchical filters determine community assembly of urban species pools. Ecology, 97(11), 2952-2963. Doi: 10.1002/ecy.1535

Artportalen, Fyndinformation, Guldsandbi, Andrena marginata, 2021-08-16. Plats: Klippträdgården, Göteborgs botaniska trädgård https://artportalen.se/Sighting/102752194

Baines, J. C. (1986). The Wild Side of Town: How You Can Help and Enjoy the Wildlife Around You. BBC Publications.

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Morse, H., ... Memmott, J. (2019). A systems approach reveals urban pollinator hotspots and conservation opportunities. Nature Ecology & Evolution, 3, 363–373. https://doi.org/ 10.1038/s41559-018-0769-y.

Baldock, K. C. R., Goddard, M.A., Hicks, D. M., Kunin, W.E., Mitschunas, N., Morse H., … Memmott, J. (2019) A systems approach reveals urban pollinator hotspots and conservation opportunities. Nature Ecology & Evolution 3, 363-373. https://doi.org/10.1038/s41559-018-0769-y

Barthel, S., Colding, J., Ernstson, H., Erixon, H., Grahn, S., Kärsten, C., Marcus, L., Torsvall, J. (2013). Principles of Social-Ecological Urbanism - Case Study: Albano Campus, Stockholm. Stockholm, Sweden: Stockholm Resilience Centre.

Barua, M., and Sinha, A. (2020). Cultivated, Feral, Wild: The Urban as an Ecological Formation. Urban Geopgraphy. Doi: 10.1080/02723638.2022.2055924

Berghauser Pont, M., Ahrné, K., Gren, Å., Kaczorowska, A., Marcus, L. (2017) Integrating visibility graph analysis (VGA) with connectivity analysis in landscape ecology. The 11th Space Syntax Symposium (SSS11) (Lisbon)

Bergman, K.O., Kindvall, O. (2004). Population viability analysis of the butterfly Lopinga achine in a changing landscape in Sweden. Ecography, 27(1), 49-58. Doi: j.0906-7590.2004.03629.x

Biggs, R., de Vos, A., Preiser, R., Clements, H., Maciejewski, K., & Schlüter, M. (2021). The routledge handbook of research methods for social-ecological systems [Book]. Taylor and Francis. Doi: 10.4324/9781003021339

Borgström, P., Ahrné, K. and Johansson, N., (2018). Pollinatörer och pollinering i Sverige - värden, förutsättningar och påverkansfaktorer. Stockholm. Naturvårdsverket.

Bäcklin, M. (n.d.). Nödräddad urskog. [2023-03-02] http://www.mattiasbacklin.se/sv/work/4/arbeten

Calluna AB. (2018). Land cover Västra Götaland [Dataset].

Cederberg, B., Hagman, A., Johansson, N., ... & Stenmark, M. (2020). Rödlista 2020 – expertkommittén för steklar. Artfakta. SLU Artdatabanken.

Davidson-Hunt, I.J. and Berkes, F. (2003). Nature and society through the lens of resilience: toward a human-in-ecosystem perspective. Pages 53-82 in Berkes, F., J. Colding, and C.Folke. 2003 (eds). Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press, U.K.

Dearborn, D. C., Kark, S. (2010). Motivations for conserving urban biodiversity. Conservation Biology, 24(2), 432–440. Doi: j.1523-1739.2009.01328.x
Ekologigruppen. (2022). Åtgärdsplan för pollinering i Österåkers kommun - Kunskapsunderlag och åtgärdsförslag med fokus på Åkersberga tätort. https://www.osteraker.se/download/18.4d8ccb9818167a07633a74/1655991963800/%C3%85tg%C3%A4rdsplan_f%C3%B6r_pollinering_%C3%96ster%C3%A5ker_HU.pdf

Ekologigruppen. (2019). Kunskapsunderlag för pollineringsplan för Södertälje kommun: Kartläggning av potentiella livsmiljöer för vildbin samt förslag till åtgärder i tätortsnära miljöer. https://www.sodertalje.se/contentassets/56df01591b8c40d7a89713abf355cdda/kunskapsunderl ag-till-pollineringsplan.pdf

European Commission (2023). Questions and Answers on A New Deal for Pollinators. European Union, 2023, Belgium.

Fischer, L. K., Eichfeld, J., Kowarik, I., Buchholz, S. (2016). Disentangling urban habitat and matrix effects on wild bee species. PeerJ 4, e2729. DOI 10.7717/peerj.2729

Fransson, A., Andersson, J., Kruuse, A., Poppius, U., Nordius Stålhamre, J., , Malmberg, J., John Block, J., (2017) Biologisk mångfald i den täta staden - Tips och erfarenheter kring gröna lösningar. SLU Alnarp, IVL Svenska miljöinstitutet, Malmö stad, Scandinavian Green Roof Institute, White Arkitekter. Malmö: CA Andersson.

Gathmann, A., Tscarntke, T. (2002). Foraging ranges of solitary bees. J Animal Ecol 71: 757–764. Doi: j.1365-2656.2002.00641.x

Goulson, D. (2015). A Buzz in the Meadow: The Natural History of a French Farm. Macmillan.

Goulson, D. (2021). Silent Earth: averting the insect apocalypse. Random House.

Goulson, D. (2013). A Sting in the Tale. London: Jonathan Cape.

Güneralp, B., Reba, M., Hales, B.U., Wentz, E.A., Seto, K.C. (2020). Trends in urban land expansion, density, and land transitions from 1970 to 2010: a global synthesis. Environmental Research Letters, 15(4), 44015. Doi: 10.1088/1748-9326/ab6669

Göteborgs Stad (2022). Göteborgs grönplan - för en nära, sammanhållen och robust stad 2022-2030.

Haaland, C. (2017). Fjärilar och humlor i grönstrukturer i Malmö - En utvärdering inom Vinnova projektet BiodiverCity (fas 3).

Alnarp: Sveriges lantbruksuniversitet.

Haaland, C., Fransson A., Kruuse, A., Emilsson, T., Malmberg, J. (2018) Gröna tak för biologisk mångfald, Movium Fakta #6. Malmö: Movium, Sveriges Lantbruksuniversitet.

Hall., K. (n.d.). Guldsandbi - Andrena marginata. SLU Artdatabanken. [20-02-23] https://artfakta.se/artbestamning/taxon/andrena-marginata-102671

Hall., K. (n.d.). Rödmurarbi - Osmia bicornis. SLU Artdatabanken. [20-02-23] https://artfakta.se/artbestamning/taxon/osmia-bicornis-219422

Hanski, I. (1999). Metapopulation Ecology. Oxford: Oxford University Press

Hansson, E. (2021). Nybro kommun - ett föredöme för naturvårdsinsatser. Natursidan. Collected 2023-04-25, from https://www.natursidan.se/nyheter/nybro-kommun-ett-foredome-for-naturvardsinsatser/

Hahs, A.K., McDonnell, M.J., McCarthy, M.A., Vesk, P.A., Corlett, R.T., Norton, B.A., Clemants, S.E., Duncan, R.P., Thompson, K., Schwartz, M. W ., Williams, N.S. (2009). A global synthesis of plant extinction rates in urban areas. Ecology letters, 12(11),1165-1173. Doi: j.1461-0248.2009.01372.x

Hooper, D. U., Adair, C., Cardinale, B., Byrnes, J., Hungate, B., Matulich, K., et al. (2012). A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486, 105–108. Doi: 10.1038/nature11118

Holmberg, E. (2020, 3 june). #9 Bin, Artpodden [Podcast] Retrieved from https://www.ekologigruppen.se/blogg/artpodden/artpodden-9-bin/

Holmström, G., Hall, K., Berg, A. & Johansson, N. (2018). Andrena – sandbin. Artfakta. SLU Artdatabanken. https://artfakta.se/artbestamning/taxon/andrena-marginata-102671

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES]. (2019). Media Release: Nature's Dangerous Decline Unprecedented; Species Extinction Rates 'Accelerating'. IPBES Secretariat

Ignatieva, M. (2017). Lawn alternatives in Sweden - from theory to practice manual. Sveriges lantbruksuniversitet.

Ignatieva, M., Hedblom, M. (2018). An alternative urban green carpet. Science, 362(6411), 148-149. DOI: 10.1126/science.aau697

Jansson A, Polasky S. Quantifying Biodiversity for Building Resilience for Food Security in Urban Landscapes: Getting Down to Business. Ecol Soc. 2010; 15(3). DOI: 10.5751/ES-03520-150320

Johansson, N. (2020) Guldsandbi - sparsmakad pollenspecialist. SLU Artdatabanken. https://www.artdatabanken.se/det-har-gor-vi/rodlistning/dagens-rodlistade-art/Guldsandbi/

Jordbruksverket. (2013). Utvecklingen av ängs- och betesmarker 1890-2013. Jordbruket i siffror. [20-02-23] https://jordbruketisiffror.wordpress.com/2013/07/26/4699/

Kennedy, C. (2022). Ruderal Resilience: Applying a Ruderal Lens to Advance Multispecies Urbanism and Social- Ecological Systems Theory. Front. Built Environ. 8:769357. doi: 10.3389/fbuil.2022.769357

Larsson, K. (2017). Insekter som signalarter för öppna marker i södra Sverige. Länsstyrelsen i Hallands län, Kristianstad vattenrike. https://www.lansstyrelsen.se/publikation?entry=_2017__4&context=24

Larsson, M. (2006). To bee or not to be – Critical floral resources of wild-bees. Avhandling vid Uppsala universitet. Uppsala. https://www.diva-portal.org/smash/get/diva2:168754/FULLTEXT01.pdf

Lawton, J. H., Brotherton, P. N. M., Brown, V. K., Elphick, C., Fitter, A. H., Forshaw, J., Haddow, ... Wynne, G. R. (2010). Making Space for Nature: a review of England's wildlife sites and ecological networks. Report to Defra.

Linkowski, W., Cederberg, B., Nilsson, A., (2004). Vildbin och fragmentering - Kunskapssammanställning om situationen för de viktigaste pollinatörerna i det svenska jordbrukslandskapet. Svenska Vildbiprojektet vid ArtDatabanken, SLU, & Avdelningen för Växtekologi, Uppsala Universitet.

Länsstyrelsen Västmanlands län. (2022). Receptsamling för biologisk mångfald i parker och trädgårdar. [Brochure]. Västerås. Länsstyrelsen Västmanlands län. [20-02-25] https://www.lansstyrelsen.se/publikation?entry=U_2019__17&context=23

Länsstyrelsen Västra Götaland. (2019). Regional handlingsplan för grön infrastruktur - Västra Götalands Län. [20-02-25] https://www.lansstyrelsen.se/publikation?entry=O_2019_21&context=13

Länsstyrelsen Västra Götaland. (2023). Skyddsvärda träd [Dataset]. https://ext-geodatakatalog-forv.lansstyrelsen.se/PlaneringsKatalogen/GetMetaDataById?id=97d7c820-f382-458c-aeb8-89ca6a519f34_C

Martins, K.T., Gonzalez, A., Lechowicz, M. J. (2017). Patterns of pollinator turnover and increasing diversity associated with urban habitats. Urban Ecosystems 20, 1359-1371. https://doi.org/10.1007/s11252-017-0688-8

Methorst, J., Rehdanz, K., Mueller, T., Hansjürgens, B., Bonn, A., & Böhning-Gaese, K. (2021). The importance of species diversity for human well-being in Europe. Ecological Economics, 181, 106917. https://doi.org/10.1016/J.ECOLECON.2020.106917

Mimet, A., Pellissier, V., Quénol, H., Aguejdad, R., Dubreuil, V., & Rozé, F. (2009). Urbanisation induces early flowering: Evidence from Platanus acerifolia and Prunus cerasus. Int J Biometeorol, 53(3), 287–298. Doi: 10.1007/s00484-009- 0214-7.

Mossberg, & Cederberg, B. (2012). Humlor i Sverige: 40 arter att älska och förundras över. Bonnier fakta.

Müller, N., Werner, P., Kelcey, J., G. (ed.) (2010). Urban biodiversity and design, Conservation science and practice series. Chichester; Wiley-Blackwell.

Naturskyddsföreningen (2020a). Sveriges bivänligaste kommun 2020 - En undersökning bland Sveriges kommuner om arbetet för att gynna vilda bin och andra pollinatörer. Stockholm: Naturskyddsföreningen.

Naturskyddsföreningen (2020b). Sverige surrar 2020 - 18 föregångsprojekt som gynnar pollinatörer i Sveriges kommuner. Stockholm: Naturskyddsföreningen.

Naturvårdsverket (2022). Landskapets förmåga att hålla biologisk mångfald – en indikator för biologisk mångfald och ett planeringsverktyg för prioritering av markanvändning. Stockholm: Naturvårdsverket.

Naturvårdsverket (2023a) LONA - Pollineringsprojekt. [20-02-23] https://www.naturvardsverket.se/bidrag/lona/lona--pollineringsprojekt/

Naturvårdsverket (2023b) Plan för arbetet med att gynna vilda pollinatörer. [20-02-23] https://www.naturvardsverket.se/amnesomraden/pollinering/goda-exempel/plan-for-arbetet-med-att-gynna-vilda-pollinatorer/

Naturvårdsverket (n.d.a). Vilda pollinatörer. [20-02-23] https://www.naturvardsverket.se/amnesomraden/pollinering/vilda-pollinatorer-och-pollinering/vilda-pollinatorer/

Naturvårdsverket. (n.d.b). Sveriges miljömål. [20-03-23] https://www.sverigesmiljomal.se/

Newbold, T., Hudson, L. N., Arnell, A. P., Contu, S., De Palma, A., Ferrier, S., ... & Purvis, A. (2016). Has land use pushed terrestrial biodiversity beyond the planetary boundary? A global assessment. Science, 353(6296), 288-291.

Leclère, D., Obersteiner, M., Barrett, M. et al. (2020). Bending the curve of terrestrial biodiversity needs an integrated strategy. Nature 585, 551–556 (2020). https://doi.org/10.1038/s41586-020-2705-y

Ollerton J, Winfree R, Tarrant S. How many flowering plants are pollinated by animals? Oikos. 2011; 120(3):321–6. Doi: j.1600-0706.2010.18644.x

Olsson, O. (n.d.). Habitatnätverk - verktyg för bin. Biodiversitetsenheten. Biologiska Institutionen. Lunds Universitet https://docplayer.se/211264142-Habitatnatverk-verktyg-for-bin-ola-olsson-biodiversitetsenheten-biologiska-institutionen.html

Persson, A. S., Ekroos, J., Olsson, P., & Smith, H. G. (2020). Wild bees and hoverflies respond differently to urbanisation, human population density and urban form. Landscape and Urban Planning, 204, 103901. Doi: J.LANDURBPLAN.2020.103901

Persson, A. S., & Smith, H. G. (2014). Biologisk mångfald i urbana miljöer: förutsättningar, fördelar och förvaltning. Lund University.

Persson, A. S. (2021). P. 182-195. Why cities need large parks: large parks in large cities. Stockholm: Medströms bokförlag.

Peters, K. A. (2012). Keeping Bees in the City-Disappearing Bees and the Explosion of Urban Agriculture Inspire Urbanites to Keep Honeybees: Why City Leaders Should Care and What They Should Do about It. Drake J Agric L. 597-641.

Porto, R.G., de Almeida, R.F., Cruz-Neto, O. Tabarelli, M., Felipe Viana, B., Peres, C. A., Lopes, A., V. (2020) Pollination ecosystem services: A comprehensive review of economic values, research funding and policy actions. Food Sec. 12, 1425–1442. Doi: s12571-020-01043-w

Rómice, O., Porta, S., & Feliciotti, A. (2020). Masterplanning for Change: Designing the Resilient City (1st ed.). RIBA Publishing. https://doi.org/https://doi.org/10.4324/9781003021490

Samuelson E., A., Gill J., R., Brown J. F. M., Leadbeater, E. (2018) Lower bumblebee colony reproductive success in agricultural compared with urban environments. Proc. R. Soc. B. http://doi.org/10.1098/rspb.2018.0807

SDG [Sustainable development goals] (n.d.). Goal 15: Life of Land. United nations. [20-02-23] https://sdgs.un.org/goals/goal15

Secretariat of the Convention on Biological Diversity (2012) Cities and Biodiversity Outlook. Montreal.

Sjöman, H., Morgenroth, J., Sjöman, J. D., Sæbø, A. & Kowarik, I. (2016). Diversification of the urban forest—Can we afford to exclude exotic tree species? Urban Forestry & Urban Greening, 18, 237-241.

Skärbäck, E., Grahn, P. (2015) Rofylldhet: En Planfaktor att Beakta. Plan, 5, 14–19.

SLU Artdatabanken (2020). Rödlistade arter i Sverige 2020. SLU, Uppsala.

Soliveres, S., van der Plas, F., Manning, P., Prati, D., Gossner, M.M., Renner, S.C, … Allan, E. Biodiversity at multiple trophic levels is needed for ecosystem multifunctionality. Nature. 2016; 536(7617):456–9. https://doi. org/10.1038/nature19092 PMID: 27533038

Ståhle, A. Marcus, L. Koch, D.Fitger, M. Legeby, A. Stavroulaki, G. Berghauser Pont, M. Karlström, A. Miranda Carranza, P. Nordström T. Place Syntax Tool [QGIS Plugin]. KTH School of Architecture, Chalmers School of Architecture (SMoG) & Spacescape AB.

The Nature Conservancy [TNC]. (2018). Nature in the urban century. A global assessment of where and how to conserve nature for biodiversity and human wellbeing. Full report. Arlington, VA: The Nature Concervancy. [20-02-23] https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_NatureintheUrbanCentury_FullReport.pdf

Twerd, L., Banaszak-Cibicka, W. (2019). Wastelands: their attractiveness and importance for preserving the diversity of wild bees in urban areas. J Insect Conserv 23, 573–588. https://doi.org/10.1007/s10841-019-00148-8

Tiderman, O. (2016). Theo Tiderman [Photo].

von Post, M., Stjernman, M., Olsson, O., Angelstam, P., Bergman, K., Ekroos, J., . Smith G., H., Persson S., A. och Andersson, E., (2022). Funktionella landskap för biologisk mångfald, sammanställning från ett kunskapsseminarium. Länsstyrelsen Skåne.

APPENDIX

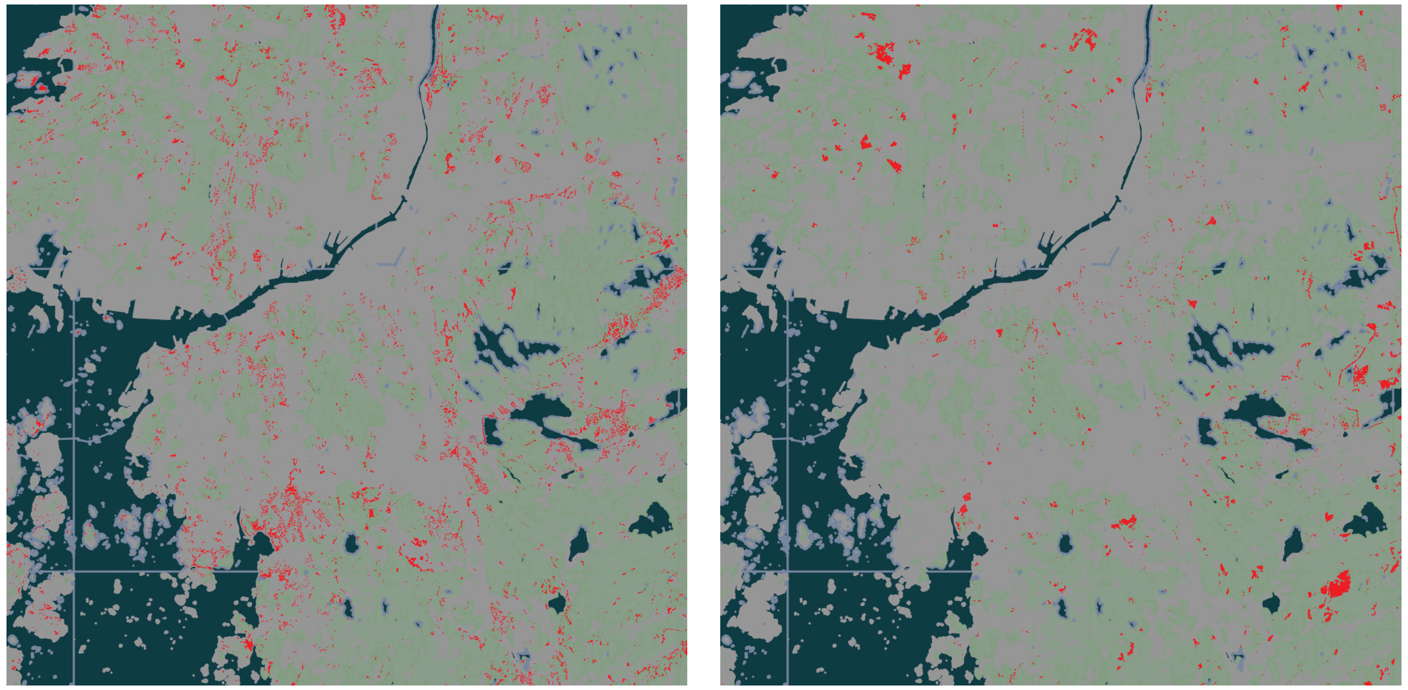
Exhibition

The thesis at display on the physical exhibition at Chalmers school of Architecture May 29th - June 9th 2023.

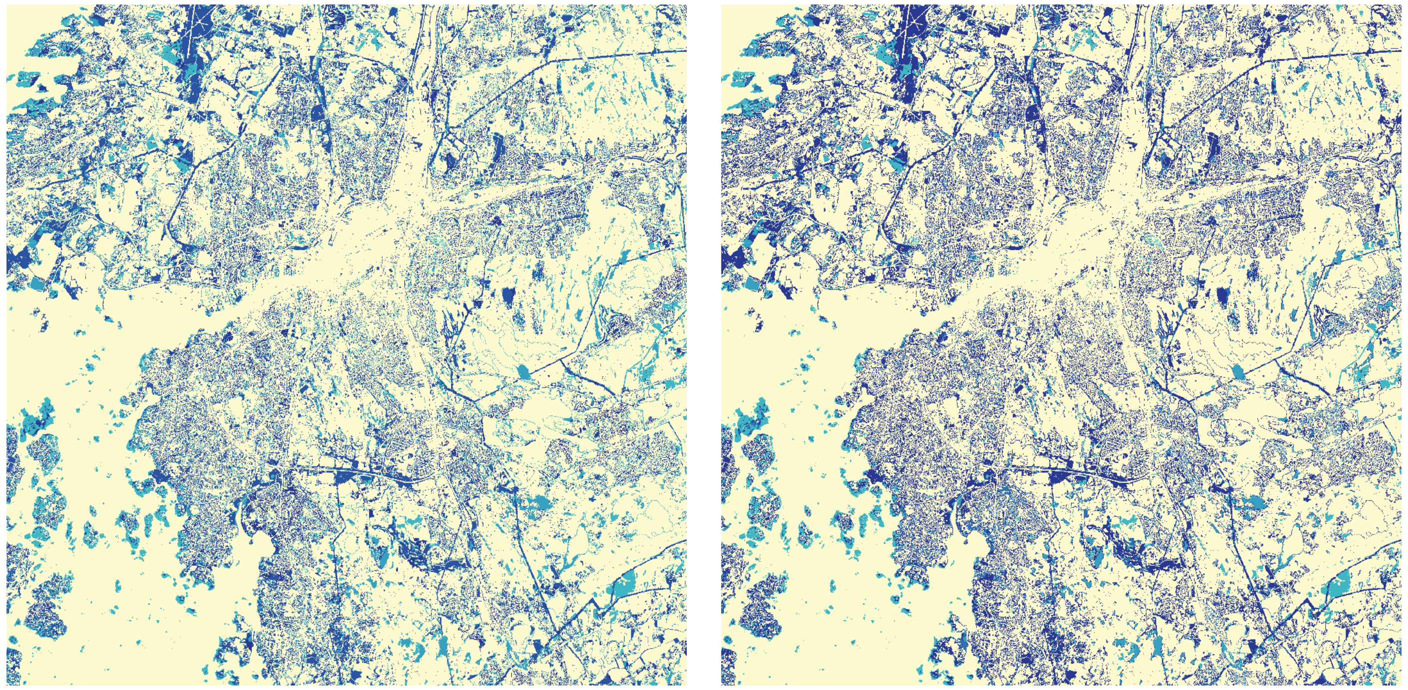
Landscape analysis

Sand bee

Red mason bee



Places for nesting

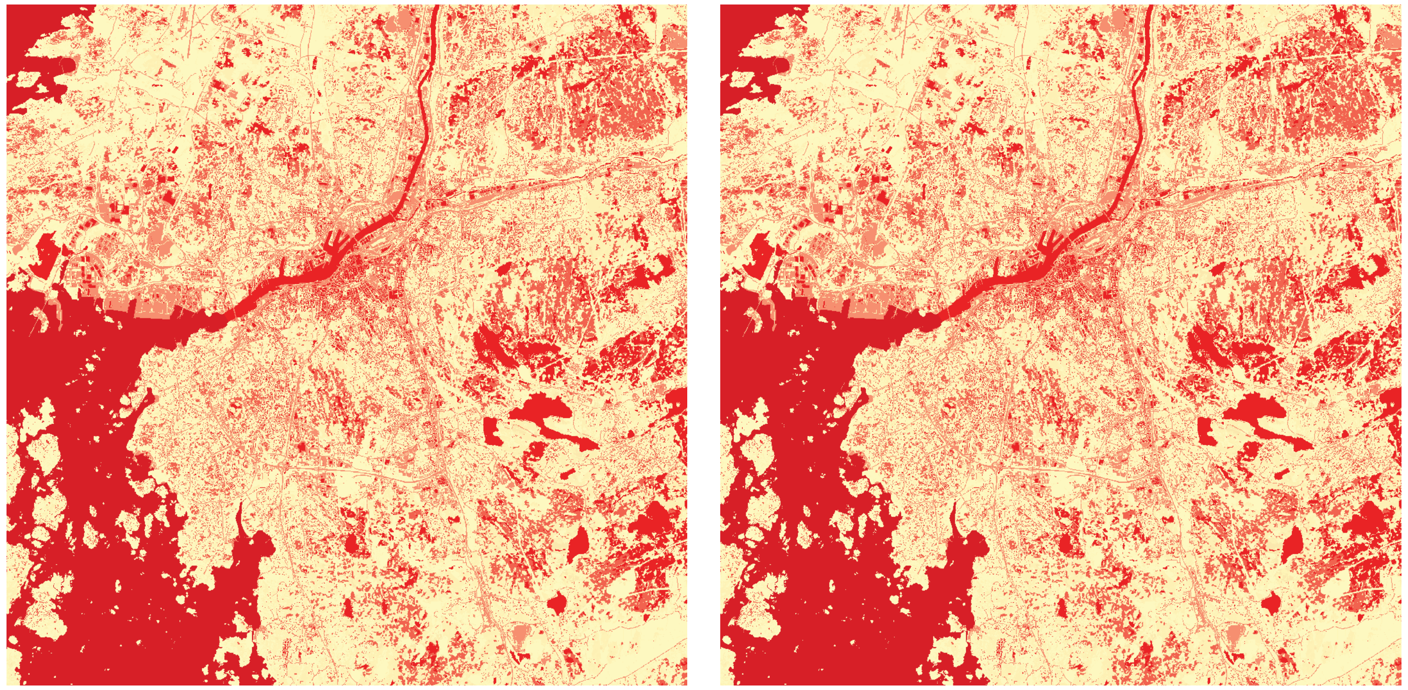


Places for foraging

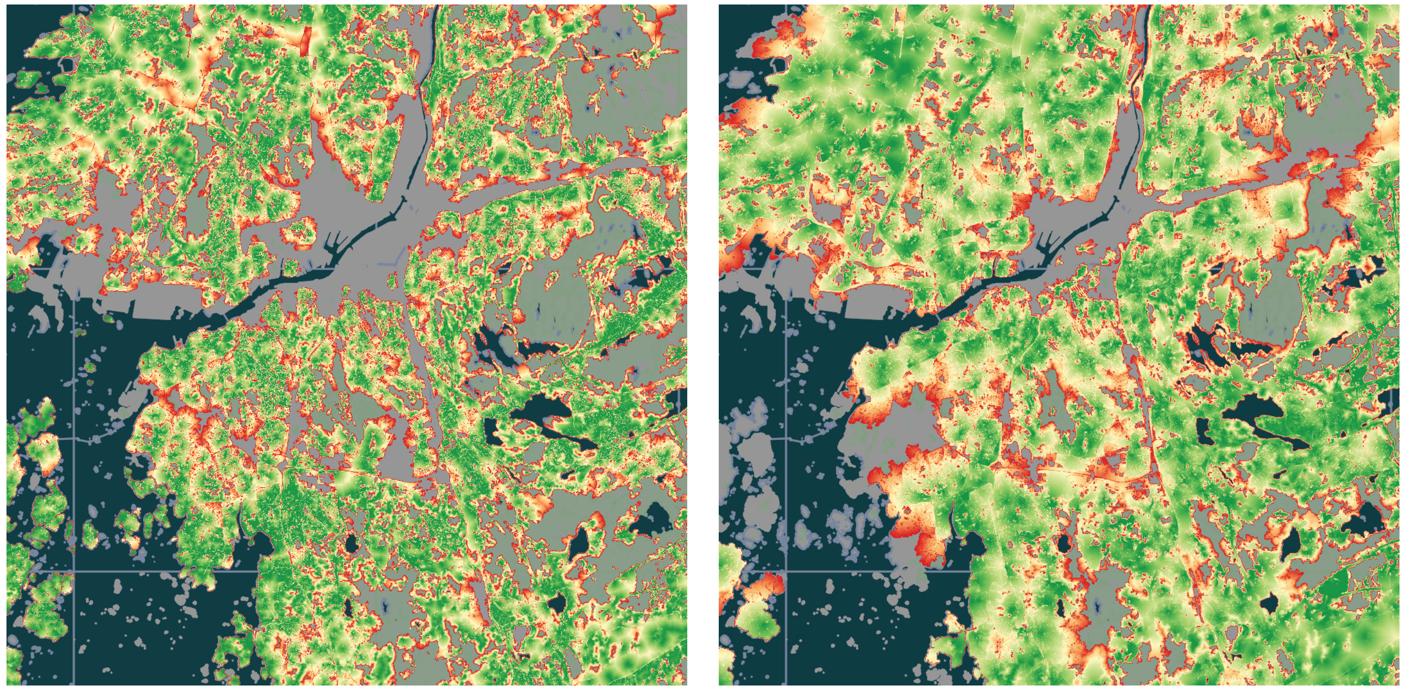
1:250 000

Sand bee

Red mason bee



Barriers



Distance from nesting

1:250 000

CHALMERS
UNIVERSITY OF TECHNOLOGY