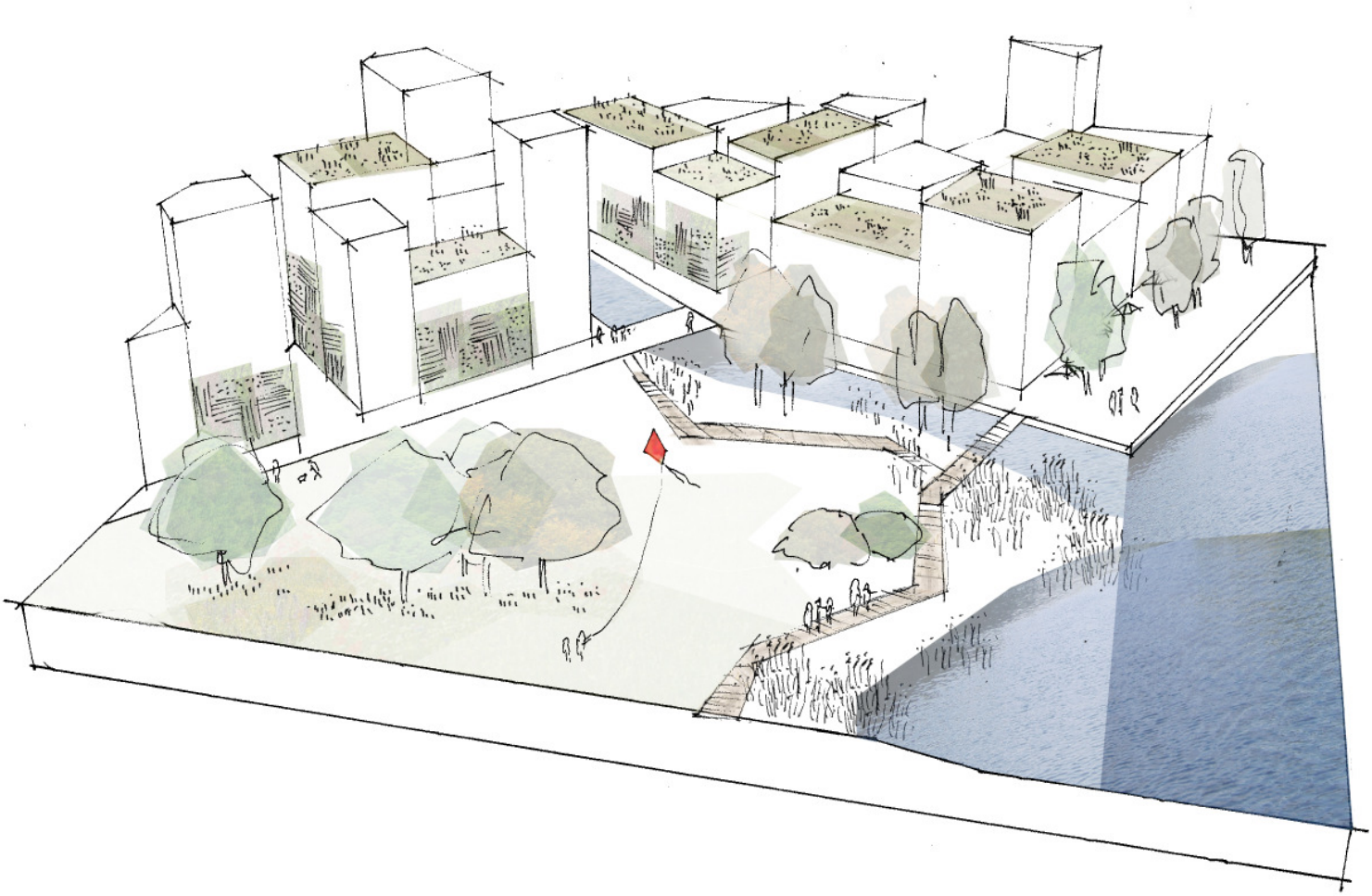

EXPLORING URBAN HABITATS

THE CASE OF FRIHAMNEN

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Master's Thesis at Chalmers Architecture
Master Programme Design for Sustainable Development

CHALMERS
UNIVERSITY OF TECHNOLOGY

Exploring Urban Habitats
The Case of Frihamnen
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ABSTRACT

Our planet has gone through rapid urbanization during the last hundred years. Cities have grown into enormous sizes, forever altering the landscape we live in. These changes have greatly impacted nature on a global scale, but also more directly in urban areas.

This thesis plunges into the fascinating, but complex world of urban nature. It takes a look at the impacts of anthropogenic factors on urban habitats; how existing habitats change or even disappear and how new ones are created because of urban planning and design. The purpose of this thesis is to study the ways an urban area can be ecologically diverse and self-sustaining.

The study area of the thesis is one of the most central harbors in Gothenburg – Frihamnen – which in the coming decades will be transformed into a dense urban quarter. Today the area is in little use and this has contributed to the development of an intriguing ruderal ecosystem likely to be destroyed by construction work in the near future.

Based on contemporary research, this thesis will look at the scenario likely to happen to the urban wildlife at Frihamnen. The thesis discusses that it is possible to mitigate human impacts, but also puts forward methods to improve the urban environment in order to increase biodiversity. The reader will discover that it is possible to create better conditions for a richer and more diverse urban wildlife with thought-through planning and design choices.

GLOSSARY AND ABBREVIATIONS

Anthropogenic – caused or produced by humans.

Archaeophyte – a plant species which is non-native to a geographical region, but which was introduced in "ancient" times.

Biodiversity - in short it is defined as the variation of life, which can refer to genetic variation, ecosystem variation, or species variation within an area, biome, or planet.

Biotope – an area of uniform environmental conditions providing a living place for a specific assemblage of plants and animals. It is almost synonymous with the term habitat. However the subject of a habitat is a species or a population, the subject of a biotope is a biological community.

Conifer – cone-bearing tree, commonly with needles.

Deciduous tree – a tree that seasonally loses its leaves.

Dutch elm disease – disease caused by a fungus that has devastated European and American elm populations.

Ecological trap – it is a habitat that cannot sustain a population, but is still preferred over other available high-quality habitats.

Ecosystem – a community of living organisms in conjunction with the non-living components of their environment (things like air, water and mineral soil), interacting as a system.

Ecosystem services – the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling. These services are the direct and indirect contributors of ecosystems to human well-being and support either directly or indirectly our survival and quality of life.

Edge effect – the changes in population or community structures that occur at the boundary of two habitats.

Extinction debt – the number of species committed to extinction following a forcing event e.g. constructing a residential area, paving a new road, cutting down a forest.

Granivores - seed predators; species that mainly eat different types of seeds.

Habitat – an ecological or environmental area that is inhabited by a particular species

of animal, plant, or other type of organism.

Insectivores - carnivore species that are adapted to mainly eat insects.

Invertebrate – animal species that neither possess nor develop a vertebral column (e.g., insects, snails, clams).

Introduced species – non-native species.

Invasive species – introduced species that adversely affect the habitats and bioregions they invade economically, environmentally, and/or ecologically.

Neophyte – a plant species which is non-native to a geographical region, and was introduced in recent history.

Omnivores - species that are adapted to eat a large variety of food ranging i.e. seeds or insects.

Population – sum of all organisms of the species in a certain area.

Phytophagous – primarily eating plants.

Phytoremediation – the use of plants that mitigate the environmental problem usually occurring in soil, water or air.

Riparian zone – river and its banks.

RSPB - Royal Society for the Protection of Birds, a charitable organisation registered in England and Wales and in Scotland; founded in 1889.

Ruderal habitat – weedy, disturbed by humans.

SLU - Swedish University of Life Sciences.

Species abundance – the number of individuals that make up the species.

Species composition – the number of species that make up a community; equal to species richness.


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FOREWORD

Weaving ecological thinking into my work has been important ever since I finished my landscape architecture studies in 2008. A summer job working on a golf course and seeing its impact on nature had left an unforgettable image to my head. At first I struggled to cope with the complexity of ecology despite best efforts, resulting in simply minimizing the negative impact to nature.

It was an internship in China that really made me aware of the greenwashing slogans of large corporations that work in Asia and how a sustainable project can only be realized as one if everything from the earliest proposal to design, construction and maintenance is sustainable. Further discussions with colleagues, reading, testing and exploring eventually enabled me to work in a way that I could start feeling content about. But understanding there's even more one can do – more possibilities working with ecology, possibilities of enhancing urban environments and making it rich with nature – was what eventually brought me to Chalmers and is echoed in this thesis.

In the summer of 2013 I had the opportunity to do an internship in the Gothenburg Municipal Planning Office. The ideas that were born there started to live their own life and have eventually grown into this thesis.

By no means do I consider this report as a conclusion – it is more of an introduction to what will hopefully be years of exploring and learning from nature, and using these skills to the best of my capabilities in both personal and professional life.

Acknowledgments

There are some people I'd like to thank for helping, inspiring, motivating me during this thesis. Anna-Johanna Klasander for good advice, tips and tutoring me; Lena Falkheden for guiding and inspiring during the whole studies; Ulf Molau and Bengt Gunnarsson from Gothenburg University for interesting lectures and discussions; Oskar Ivarsson for enabling a good work environment; Evelina Eriksson from SBK for discussions; Erik Edvardsson for helping out with birds and photos; Jenny Nyström for motivation and design tips; and Kadri Koppel for motivating, reading, thinking, discussing. Thank you!

Versatility of Urban Nature

Nature in urban areas is much more diverse than the park landscape we're used to seeing and it has the ability to pop-up in very unexpected locations. It can blossom between rocky rail tracks (1), grow on a small ledge (2), find the smallest cracks in asphalt (3), rise through the roof of a building (4) or even be represented by large mammals such as these three elks (5) just outside the campus of Chalmers University of Technology in Gothenburg.

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INTRODUCTION

BACKGROUND AND PROBLEM

Current State of Biodiversity

The World is in crisis and it is our civilization's dependency on natural resources that has led us to this situation. Wars rage in different parts of the World with tension between dominating nations growing – it all takes place in relation to resources (or the lack of them). This centuries-long exploitation of land and nature has led the whole planet on the verge of dramatic changes few dare to imagine and even less can predict. The Living Planet Report 2014 issued by the World Wildlife Foundation (WWF) declares that three of the nine planetary boundaries that keep the Earth in a stable state have been crossed, possibly leading to "abrupt or irreversible environmental changes" (WWF 2014, pp: 13). One of the three is biodiversity loss. The report also states that the population sizes of vertebrate species have declined by 52 percent over the last 40 years. In other words it is a shocking more than a half of all vertebrates lost in just four decades. It seems we're the witnesses of a mass extinction rival to the loss of dinosaurs some 66 million years ago, but haven't fully realized it yet.

But perhaps all is not lost quite yet? The Convention on Biological Diversity that came to force more than two decades ago is leading the way on a global scale with the United Nations Decade on Biodiversity bringing specifically the loss of species richness even further to public awareness. At least the acknowledgment of the problem on the highest political level is going hand in hand with the deteriorating situation. But the question of courage to take actual steps on the national level is a whole other issue. Unfortunately it seems that every country from large to small follows a quick prosperity policy that depletes natural resources.

Nature in Relation to Cities

People living in cities are surrounded by some form of nature almost all the time. But the experience we get in urban areas is a lot different from the nature that can be found outside the urban borders. We can see a lot of unnatural nature in cities, meaning that it is constructed, maintained, manipulated by and at times even dependent on humans. This has resulted in some species thriving with high abundances whereas others are suffering with their numbers declining. The tie between man and nature in urban environments can never be cut. But diverse urban flora and fauna can flourish self-sustainingly without human assistance.

There's a growing need to talk about nature in the cities. As global urbanization continues more and more people lose their connection to where we as a species come from. But it is also important because nature doesn't see the municipal borders we've drawn on plans nor understand the complexity of artificial structures. Species can move from rural to urban sites and vice versa, leading to consequences hard to predict or reverse. On top of this, contemporary land use patterns and agricultural practices in rural areas are not welcoming to species richness. Species are bound together by invisible threads all around us (and we're part of it) and cannot be restricted to designated areas hundreds of kilometers from urban environment. The future looks grim if we continue deconstructing this system developed over millions of years of evolution.

THE AIM AND QUESTIONS

The aim of this thesis is 1) to synthesize current research on urban ecology and find linkages to landscape architecture; and 2) to use this information in order to propose an urban planning and design approach that has a site specific focus on enhancing biodiversity.

The work starts by giving an insight to the research in urban ecology and how this is connected to urban planning and design. It then sets out to apply these findings in relation to the existing situation and the municipal planning program at Frihamnen, Gothenburg. The thesis will look at the scenario likely to happen to urban wildlife at Frihamnen after the construction of a new urban district is realized, and then discusses alternatives to improve the conditions. In detail the work uses a group of specific bird species inhabiting Frihamnen today as an example to demonstrate planning and design solutions set in urban landscape, which enables for these species to remain and prosper in the area after the redevelopment. A thorough theoretical research is necessary because landscape architecture has a direct impact on biodiversity yet the information and analysis on its influences is scarce.

The thesis analyses several questions concerning the relationships between architecture, ecology, people and cities. How do humans impact ecological processes in cities? What impact do these changes have on urban biodiversity? And have species adapted to human impacts? Is there a way to positively affect these processes and how can we do it? What role does a landscape architect have in this equation? The list of questions is long and not all of them have a clear answer.

METHODS

This work is to a great extent based on theoretical research. The collection of possible reference articles slowly began during the start of my master's studies at Chalmers and picked up pace during an internship in the Gothenburg Municipality in the summer of 2013. The research papers discussed in the text have been critically analyzed. Some of the findings are controversial and in such case both viewpoints are put forward. This work also synthesizes a fair proportion of personal insight and previous experience, talks with colleagues, lecturers and other experts from Chalmers, Gothenburg University and the Gothenburg municipality. This applies mainly to the practical discussions concerning vegetation, birds, Gothenburg and urbanization among other topics. In order to improve the readability of the theoretical material photos and illustrations are used.

The existing conditions of the site and its surroundings were analyzed using various methods. The relationship between the greenery at Frihamnen and the rest of Gothenburg was established by mapping the urban green areas using aerial images and on ground sightings. This information was structured using Ingo Kowarik's Four Natures Approach (Kowarik 2013).

A bird atlas of Gothenburg and its neighboring areas (titled in Swedish: Fågelatlas över Göteborg med kranskommuner) was used to analyze the existing species composition of the birdlife at Frihamnen. SLU's digital species portal (in Swedish: Artportalen) gave an overview of the sightings in Frihamnen and along Kvillebäcken. Background data provided by the municipality was used to understand other (ecological) preconditions such as different types of pollution (soil, air, noise etc.), vegetation and impact of neighboring infrastructure among others.

Some data was also collected through field studies. A visual site assessment was done, which included an evaluation of the vegetation, and a general description and the connectivity of the greenery. A more detailed approach of floral evaluation was conducted by a method provided by Gothenburg University. Two test sites on different locations, both with a 2 meter radius, were used to characterize the vegetation and existing habitats of Frihamnen. After learning the characteristics of the site it was possible to establish the shortlist of birds based on the bird atlas, which was eventually used as an exemplary group when discussing planning and design solutions in Frihamnen.

UNDERSTANDING ECOLOGY IN URBAN ENVIRONMENTS

Urban areas are tough environments. Quite often they're warmer, dryer, harder and the chemical composition of soil, air, water is much different there than in the surrounding natural areas. On top of this there are very direct impacts created by noise, light and human actions. Thus it is obvious that most of the ecological processes that once occurred on the site of a present city are no longer there and can't be brought back in the near future. But despite all this, cities are part of ecological cycles and have functioning ecosystems within them. While some species have already vanished from urban areas or are on the course of doing it, others have adapted to human impacts and found new habitats such as some cliff swallows (*Petrochelidon pyrrhonota*) in the USA who've started to inhabit highway bridges, but as a result have also ended up with a shorter wingspan to be able to avoid passing traffic (Brown & Bomberger Brown 2013). It is this sharp, contrasting meeting point of man-made structures and processes with nature that is becoming an important field of study and the focus of this thesis.

Between Architecture and Biology

The last two decades have seen a lot of new disciplines related to landscape, urban environments and ecology emerge. Professionals in the field of architecture are well aware of the terms "ecological urbanism", "ecological planning", "landscape urbanism" etc. The root of this multiplicity of used terms and concepts seems to lie somewhere in the meeting point of nature, humans and built structures. Urban ecology is connected to several disciplines such as landscape architecture, architecture, planning and biology.

Landscape architecture is involved in working with urban ecology from the level of comprehensive planning to the scale of private gardens. Every project with its specific choice of materials has an impact on the existing species composition. Preferring trees to shrubs or choosing a lawn before perennials has a direct effect on the locations ecosystem influencing which species and how many individuals will start using the specific greenery. Understanding ecology in urban environments is complex and the amount of unknown and unpredictable factors is very high. We will look further into these questions in the coming chapters of this thesis.

The contemporary research surrounding ecological processes in urban environments has to a large extent been led by scientists with a background in biology. Biologists have received the formal education to follow, understand and analyze different processes and behavior in nature. This thesis will look into some of these findings and tries to translate them into possible development patterns occurring in cities that have been created by landscape architects, architects, real estate developers, planners, politicians etc.

There's a good range of research articles available on several animal groups – insects, birds, mammals among others – and on vegetation. Since this thesis is investigating a specific site in Gothenburg, it needs corresponding data to match research in order to be able to draw conclusions. From Frihamnen there is good data about birds by Gothenburg Ornithological Society. Therefore birds are selected as a focus group. As a landscape architect I have a solid background with plants enabling me to analyze current conditions and suggest future developments with vegetation.

Birds and Plants

The research on birds is solid and abundant. They are compared to invertebrates or aquatic animals much more visible and easy to detect and follow; compared to mammals they're in general more adapted to human presence (or as they're able to fly, can more easily reduce the impact of that presence). As several birds' species prey on insects, the health of bird population is also to some extent related to insects, indicating their health too (and vice versa). Other important factors are the high attractiveness and popularity of this group among biologists and the large number of hobbyists which makes large scale research easier.

Urban vegetation is also thoroughly studied. It is static, making it easy to detect and sample for further analysis. My background in landscape architecture contributes even further to the use of flora in this thesis.

In general both groups have the capability to reproduce fairly quickly (tens of times during the lifespan of a human), contributing to the detection of changes in behavior, habitat, chemical compositions, physical appearance and numerous other things.

Delimitations

There are several aspects to consider and look into when working with urban landscapes. As the thesis focuses on birds and plants it would be important to study factors such as water (especially due to the proximity of the Göta River), soil, temperature, various types of pollution, land use, social aspects etc. too. Some of these topics have been touched upon in the text, but to a lesser extent. The format of a master's thesis sets its rather strict limits on available work time and eventual volume, enabling to study all the aforementioned factors to the extent required and the personal level of interest and ambition. The thesis puts aside these other factors and focuses on the interaction of birds, vegetation and urban structures to establish a really in-depth level of knowledge.

Ecological Approaches in Urban Planning and Design

Ecologically sustainable attitudes towards urban planning and design have been discussed for some decades now. A research paper by Ferguson and Friday dating back as far as 1983 focused on the use of 'ecological performance standards' in landscape projects and planning, an approach that today is become more widespread thanks to the work of Janine Benyus.

Ecosystem services is a term that rose to attention during the last years and an approach with these services in focus has gained foothold. For example the Department for Environment, Food & Rural Affairs in the UK has adopted a guiding framework for policy and decision makers to value ecosystem services.

There are several municipal initiatives in establishing a sustainable planning approach with Berlin being one of the first cities in the World to introduce its green points system (the Biotope Area Factor) already in the early 1990s. Other cities have followed with examples such as Seattle in the USA or Malmö and Stockholm in Sweden. Ecological compensation methods are also used in different parts of the World (e.g. USA, Australia, Sweden) with the carrying idea behind this notion being that every action impacting nature should be compensated for.

Tools such as the 'biodiversity index' are easy to use and help to establish a general understanding on the ecological conditions of a site.

Ideally every country should have and use such a standard while working on all possible scales – whenever a real-estate developer starts making plans for a new site or someone needs to rebuild a home.

These approaches have not been discussed further in this thesis (although at times the concept might be similar) due to practical reasons, which are mainly limitations in time and volume of the work. On top of this, the thesis focuses more specifically on the aforementioned two taxonomic groups – birds and plants.

INSTRUCTIONS TO THE READER

The discussion is divided into two large parts of roughly equal size.

The first part is theoretical and gives a thorough overview of the challenges surrounding urban nature. Terms such as extinction debt and ecological trap are discussed that are essential, but relatively unknown in the landscape architecture field.

The second part of the thesis takes the research, author's personal inventories and experience, the background information on Frihamnen and estimates the changes to come in Frihamnen through these layers if the municipal planning program is realized. The thesis concludes with a description of an ecologically more diverse solution set in a longer time perspective.

It is important to add as a note to the reader that mainly Latin species names are used in the text, but in order to enhance the usability of the report a full list of species names in English and Swedish is given in Appendix A with the specific glossary on the previous page.

"Biodiversity forms the web of life of which humans are an integral part, and forms the basis for healthy ecosystems that provide a large number of goods and services that sustain our lives physically, psychologically, and spiritually."

(Newman and Jennings 2008)

URBAN HABITATS

FOR WHOM?

This chapter gives an overview on the background of urban biodiversity that is affected by natural preconditions and anthropogenic influences. It also discusses why we as humans should be interested in maintaining species richness in cities.

The fact that over half of the World's population lives in urban areas (Goddard et al. 2009) is not surprising. But the fact that towns and cities cover only a fraction of terrestrial surface (4%) might make us question the need for such a thorough protection of urban nature (Goddard et al. 2009). Nevertheless there are various reasons to do so.

Natural Preconditions

Most of the World's cities even after industrialization have been established on riverfronts, lake or seashores (Kowarik 2011). Water has been essential for trade, movement and basic survival. But shorelines also form complex ecosystems rich with species. It is a telling fact that almost 10% of the total number of animal species recognized globally have been recorded in freshwater, while these rivers, lakes and marshes cover only 0,01% of the total surface of the globe (Decamps 2011). Riparian zones are transition areas between terrestrial and aquatic habitats; therefore, they harbor a rich diversity of vegetation and wildlife. When properly managed, they play a vital role in the protection of aquatic life by preventing sediments and contaminants from entering watercourses. More importantly they also act as a corridor that links various habitats with one another, allowing the movement and dispersal of wildlife and plant species. (ECS & WCC) In conclusion, a large number of species, including humans, have considered shorelines as suitable habitats, leading to the conflict we're in today.

Introduced Species

If we add the introduced species to the precondition of high natural species richness then no wonder that sometimes urban areas have more species than the surrounding natural landscape (Loram et al. 2008). The figures differ depending on the city, but a study in 1998 (Pyšek) showed that on average 40% of the urban flora in 54 European cities is of non-native origin (25% neophytes and 15% archaeophytes). Processes in nature are never simple. First of all there are several uncertainties involved with the introduction of non-native vegetation such as their usage by pollinators. Secondly, the native species living in cities are restricted to rather fragmented habitat patches that might lack connectivity or size to form a functioning system. This is the background of a phenomenon called extinction debt. We'll return to these topics in the later chapters of this theoretical part.

Human Perception

A very important reason to protect urban nature is, as Goddard et al. (2009) puts it: "We're witnessing an extinction of experience." This means that the cities we live in are becoming so species poor that people are more and more disconnected from nature. First of all this is problematic because the ecological impact of cities reaches far beyond its boundaries (even national borders). With biodiversity confined into museums and exhibition rooms, it will be harder and harder to educate children on how this planet actually functions. It is well proven that urban biodiversity has a huge impact on human health and well-being (Kowarik 2011). Altering this can have unpredicted impacts on our species. Studies (e.g., Brown & Bomberger Brown 2013) on urban invertebrates and birds have shown dramatic morphological and physiological changes after several generations caused by the environment they live in.

A Fairly Common European Park (Kungsparken, Gothenburg)

Kungsparken that stretches around the center of Gothenburg has a respectively broad list of tree species represented. Some of them are also quite old as the park itself dates back to mid-19th century. It has a high value as a green corridor and a buffer in an otherwise densely built area. But the ecological capabilities of the park are not used to their full extent as the structure is lacking a shrub layer (mainly due to fear of crime) and the lawns are highly maintained.

Connection to Ecosystem Services

A research paper by Inger et al. (2014) pointed out that over a thirty year period from 1980 to 2009 Europe has seen a dramatic drop in the abundances of the most common bird species while more rare ones have seen their numbers increased thanks to conservation efforts. This is highly alarming as it is these common birds that are the most numerous and have the highest impact on the functioning of ecosystems and the services they provide (Inger et al. 2014).

The importance of biodiversity becomes undoubtedly evident when we look at ecosystem services. Although the connections are sometimes difficult to notice, biodiversity has a vast part in provisioning, regulating, supporting and cultural services. If we take in consideration that the impact of urban areas on ecosystems ranges from local to global and that the majority of global population lives in cities, then the need to uphold urban biodiversity becomes obvious. In order to do it sustainably, functioning ecosystems are necessary. It was almost twenty years ago, when an assessment by the United Nations Environmental Program stated that it is impossible to shield all genes, species and ecosystems from human influence and an approach to minimize impacts on biodiversity should be taken. Ecosystems are about interaction and flexibility, in urban environments these connections are really challenged and the links break. It is necessary to find a balanced approach when dealing with urban nature, at times almost let natural processes take their course.

Enhancing Biodiversity in a City (Tempelhof, Berlin)

The former Tempelhof airfield in the heart of Berlin has been transformed into a public park. Thanks to its size, large areas have been reserved as nesting sites for birds. It is open meadows - exactly what ground nesters such as skylarks need - that are missing in most urban areas. But reserving land for nature has to go hand in hand with educating the people using it.

Skylarks are common all over the World, but changes in land use over the last 50 years have resulted in a drastic decline in numbers in the UK, resulting in RSPB to give it a "Red Status".

THE EXISTING PATTERNS

The following chapter gives an insight to how connecting green areas by vegetation is used as a common method of enhancing nature in cities, with quality and composition of the site pointed out as important factors. The creation of secondary nesting sites is also discussed.

Now that we've briefly looked into the importance of maintaining urban biodiversity, it is time to venture further and see how this is and should be achieved.

Green Connectivity

Biodiversity in nature is a lot about connectivity. This happens in several dimensions – physical connectivity on terrain or water, allowing movement; or connectivity (interaction) between species, allowing e.g. predator-prey relationship and symbiosis. But where do these relationships occur in urban areas and what measures are taken to uphold or restore them? For several decades now numerous cities around the globe have used the comprehensive planning level to maintain and/or create green connections within urban areas and to the rural hinterland. This approach has to a large extent ensured that a more or less natural flow of species still exists even in semi-natural areas. But as these corridors are situated on a limited area of land and are usually relatively narrow, then not all species are able to use it. Some studies even suggest that green corridors make little difference to the diversity of plants and beetles by virtue of their function as corridors (Angold et al. 2006). But the same research paper also notes that instead of being a linear continuous habitat a green corridor functions rather as a chain of habitats. There are small and medium sized mammals that travel through these habitats whereas various plant and invertebrate species are more site specific. The study by Angold et al. also draws attention to the importance of railway land and rivers as corridors.

Quality of the Structure

Another important aspect, when discussing green connectivity, is quality of the space and the projected users. It is hardly enough if a corridor is green on a city map, but lacks parameters suitable for wildlife. Urban greenery has to be appealing for humans, otherwise an important part of its meaning goes missing, but at the same time it shouldn't only serve a recreational function. There's a range of examples where a green area accommodates a good variety of species (but possibly lacking genetic diversity) and is popular among humans.

First of all it is down to combining the needs of existing species (and possible new ones) with thoroughly considered maintenance decisions going hand in hand with raising people's awareness. Secondly, as research on birds by Tomohiro Ichinose has shown that the land-use pattern around such core green areas influences bird communities within the habitats. This means that the proportion of tree cover outwards from the edge of a green area is highly important.

Composition of the Structure

Woods often contain a rich diversity of plants and animals. The more complex a patch of forest is, the greater the variety of species it can support. The same can be

applied to urban parks. It is essential to ensure that urban green areas can provide similar qualities by containing a mix of hardwood and softwood species of various ages and sizes, as well as a diverse under-story of shrubs and plants (ECS & WCC). Trees provide shade, shelter, structure and play value as well as food and nesting sites for wildlife. Old and even dead trees should be retained where possible for they provide valuable nesting and feeding opportunities (SNH). Though this can't be realized everywhere, with the more formal and centrally located parks as the best known exceptions, it does make economic and ecological sense not to mow the lawn according to French aristocrats' ideals everywhere.

Creating Surrogates

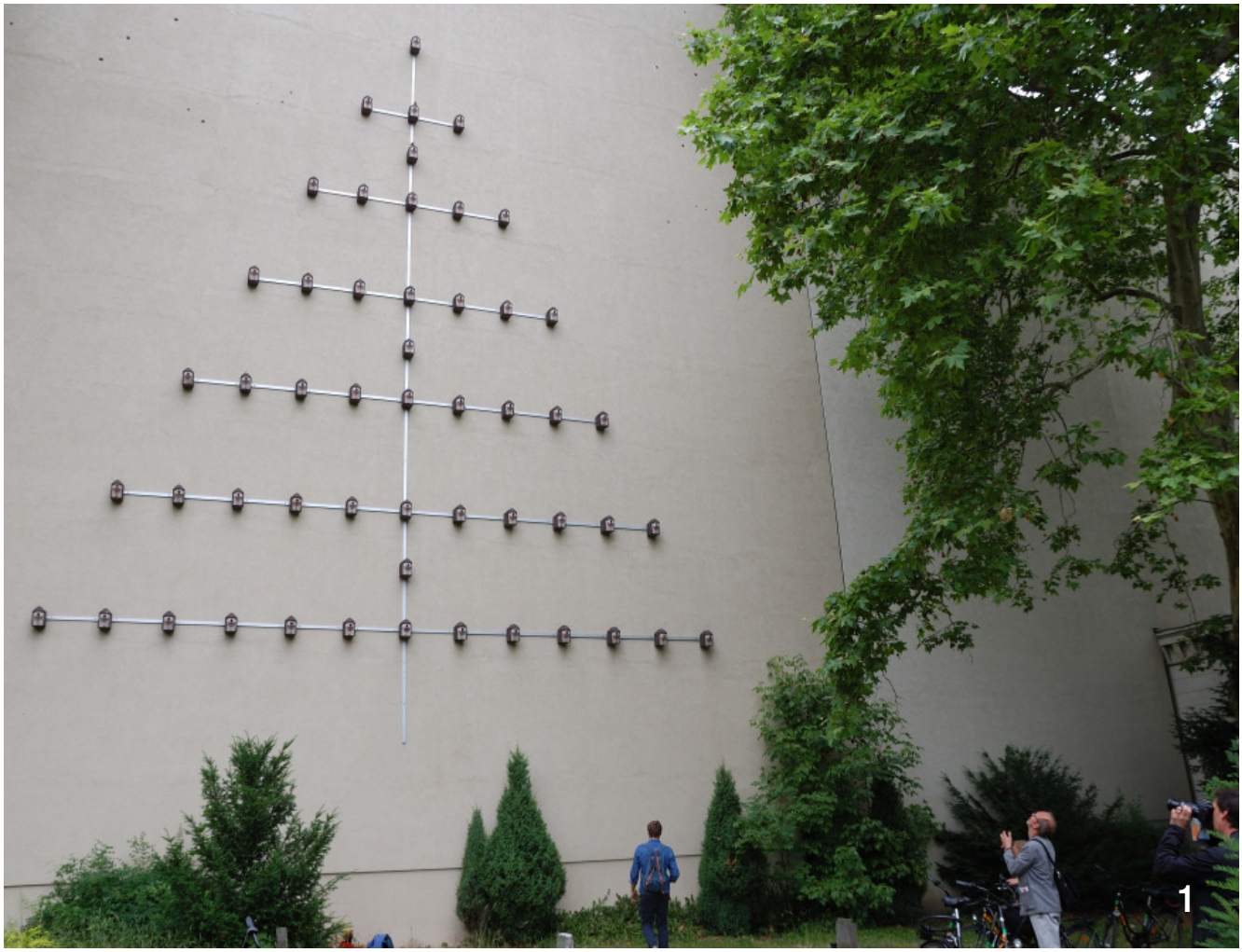
Natural elements ranging from dead trees and streams to a meadow or just a pile of stones can attract a diverse range of birds, mammals, invertebrates, reptiles and insects (hedgehogs, bumblebees, butterflies, bats etc.).

A rather popular contemporary approach to enhance biodiversity is putting up easy-to-make nesting structures if natural nesting areas are lacking on site. This is a good and necessary method to educate and raise awareness of the larger public on urban nature, but building the structures and choosing suitable sites should be done with the help of an expert or based on a specially developed common framework. A nest in a wrong environment can sometimes do more harm than good as it can become an ecological trap - a problem that will be discussed further later on in this thesis.

In general, conserving existing habitat is far more beneficial than simply adding nesting structures because wildlife may become dependent on them for their survival. These structures should be used as a temporary solution when habitats are in the process of being improved or enhanced. (ECS & WCC)

Fragmentation and Pollination

Pollination is an invaluably important ecosystem service. Although wind, bird and self-pollination are also rather common, insects are the largest group of pollinators (USDA) and the yield of most plants is improved where insect pollination occurs (Fuller et al. 2010). During the last decade we've learned that a parasite, probably related to the large use of pesticides in agriculture, has drastically reduced the numbers of several groups of bees. Urban conditions are not among the easiest either, making it sometimes even more difficult for pollinators to find a suitable habitat. Now researchers (Fuller et al. 2010, Cheptou and Avendaño, 2006) are suggesting that more fragmented and dissected habitat patches lead to the decline of urban pollinator populations as it harder for them to find suitable plants with pollen. A study by Cheptou and Avendaño (2006) showed that as the number of flowers on a patch increased, so did the number of pollinators. The more diverse range of plants, the more diverse range of pollinators.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Designing for Biodiversity

Photos on the left (1-3) are of a wall and it's surroundings in a cemetery in Berlin.
On the right and below (4-5), a courtyard in the newly built Kvillebäcken residential area near the center of Gothenburg is shown.

Whose interests do these nesting boxes serve? In the case of Berlin on the left one can easily state that it's the birds. But with the example on the right it surely can't be the birds with no suitable vegetation to uphold the community supposed to live in these nests - boxes at sites like this are likely to do more harm than good.

DETAIL

THE CHANGE OF SPECIES COMPOSITION AND DIVERSITY IN URBAN AREAS

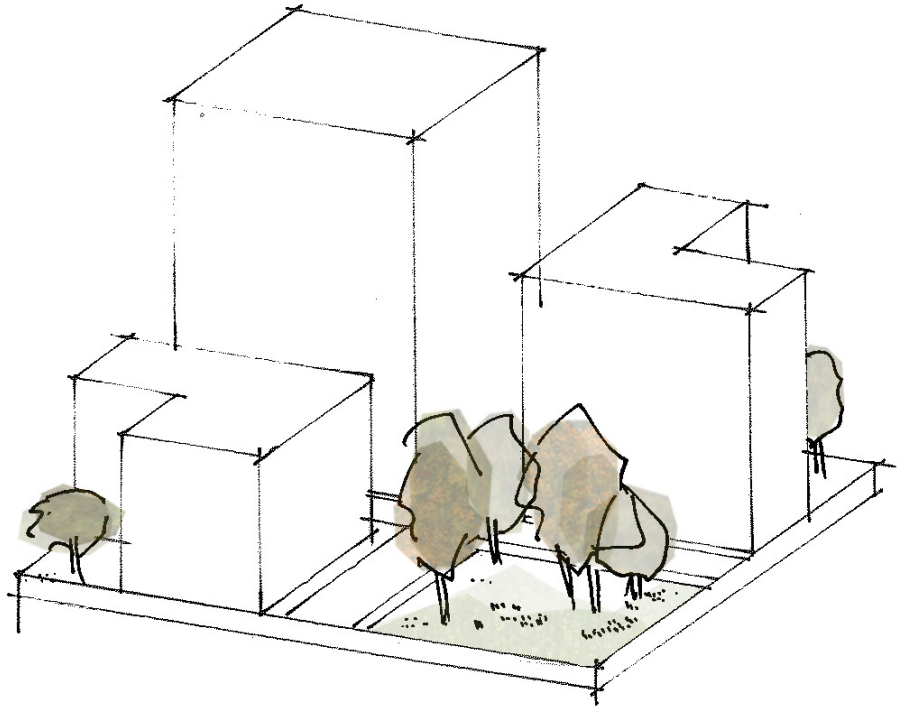
Research on the biological richness of cities has to date been somewhat controversial. Some studies have stated that cities are rich with species (Loram et al. 2008), others that they're poorer in terms of biodiversity (Goddard et al. 2009). First of all this does depend a lot on the urban area in question, but as we've found out in earlier chapters then (1) cities are likely to have a high number of species thanks to the ecological preconditions and (2) cities can have a high number of non-native species.

But the diversity of vegetation that goes hand in hand with other taxonomic groups varies a lot even within a city.

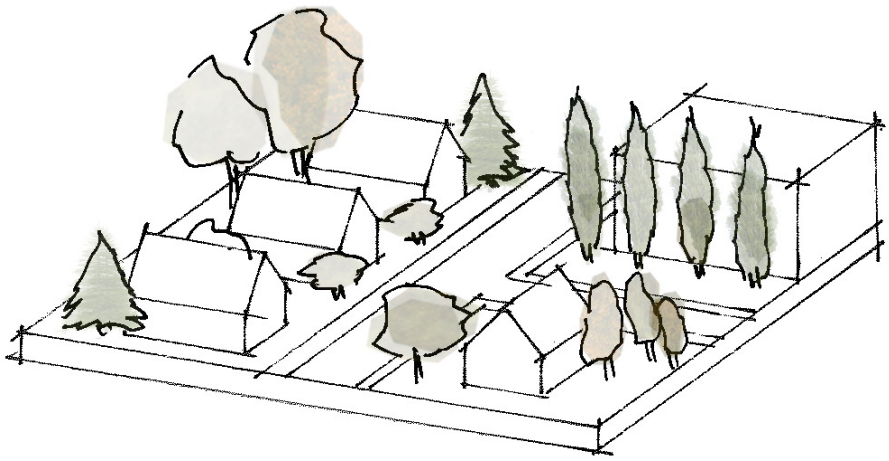
The **center** has low diversity as it is often densely built and lacks green areas. Though one can find very old trees here, but replacing them is an almost impossible task.

The **middle** part, quite often residential areas, is species rich with a high number of non-native species, a good proportion of natives also remaining and average building density.

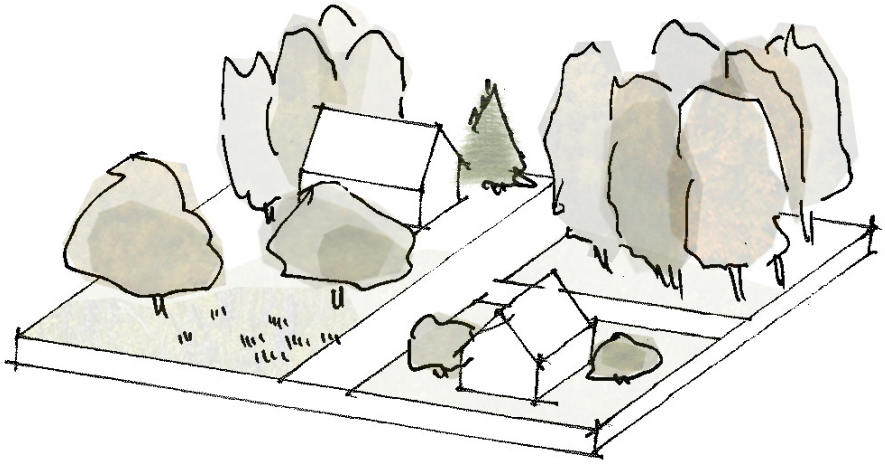
The **outskirts** of an urban area are usually relatively diverse, have a low number of non-native species and low building density.



THE CENTER OF A CITY



THE MIDDLE ZONE



THE OUTSKIRTS OF A CITY

THE USE OF INTRODUCED SPECIES

In this chapter the use of introduced plant species and the potential risks surrounding it are discussed. The possibility of mixing different tree species on urban streets is brought up in the later parts of the text.

Though the use of foreign plant species is almost as old as human civilization, it reached a new level of extent in the 20th century. Initially this happened mainly due to medical and culinary use, but as centuries passed and the World got more connected, more and more plants have both intentionally and unintentionally found new habitats on other continents. But can this be considered a problem? Though there are unfortunate examples of invasiveness by foreign species, the debate among ecologists is still active.

Durability of Introduced Plants

The extensive use of non-native plants in urban environments can make a lot of sense. We put aside their ornamental value as aesthetics is both neither the easiest nor most objective criterion, and just look at the biological traits.

Cities are harsh environments if you're a plant and in most parts of the World there's a very restricted range of vegetation suitable for dryer, warmer, dustier and more nitrogen-filled habitats than the existing natural ones. At the same time in other parts of the World some plants in similar climate have adjusted to slightly different conditions over thousands of years of evolution, making them therefore more durable and suitable to urban conditions, giving way to their extensive use. The logic of this equation is rather simple. Some ecologists (e.g., Davis 2011) have gone great lengths to prove that the management of introduced species is very much based on emotive and not rational reasons.

Involved Risks

Experience backed by research is showing that such an approach towards non-native plants bares risks. After decades or in some cases centuries, non-native species have started to form specific new plant compositions making it possible to start drawing conclusions of their effects. Now several studies have pointed out that (1) bird and butterfly diversity is higher among native planting (Burghardt et al. 2009, French et al. 2005) and (2) that non-native plants are little utilized by native pollinating insects (Corbet et al. 2001). These results are hardly surprising if with consider the fact that at least 90% of all phytophagous insects are specialists of one or a few plant lineages (Bernays & Graham 1988). If there are no insects eating the plants, there's nothing to eat for birds, amphibians, mammals and other groups either. On top of this, Douglas Tallamy (2004) has pointed at two more very adequate reasons why we can suspect that non-native plants affect phytophagous insects negatively. First, as mentioned earlier, most of the non-native plants have been chosen for their high durability and resistance towards insects. Secondly, the success on these non-natives can be credited to their escape from their natural enemy.

Design with Introduced Plants

Despite the emerging evidence on the negative impact of non-natives calling for a more cautious approach when using them, the existence of foreign species in urban areas can't and perhaps shouldn't be completely ruled out. Despite their anthropogenic introduction non-natives are becoming an important part of these novel ecosystems forming in cities. There is logic in inhibiting their expansion in natural and rural sites, but such actions might make very little sense in cities, where there might be very few other alternatives available. A more explorative approach to urban greenery could be considered when native solutions fail. Perhaps maintaining and not restricting the growth of foreign species, while limiting new plantings to mainly natives, could be an alternative to consider.

DETAIL

THE IMPACT OF INVASIVE NON-NATIVE SPECIES ON NATURAL HABITAT

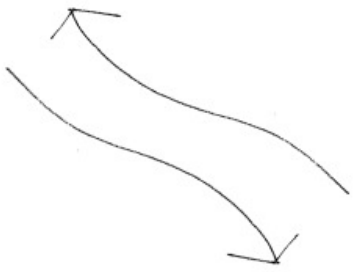
A natural habitat is balanced with specialist and generalist bird species (e.g., *Setophaga striata* and *Cardinalis cardinalis*). Generalists eat insects, seeds, berries etc. whereas specialists in this example mainly insects.

Non-native invasive species spread into landscape (e.g. Lonicera maackii)

NATURAL HABITAT

ALTERED HABITAT

But as a non-native invasive shrub (e.g., *Lonicera maackii*) changes the composition of vegetation, creating a denser forest understory and possibly reducing the number of insects as they are not accustomed to eating this shrub, so changes the composition of birds.



Generalists who eat a large variety of food arrive and specialists who eat e.g. insects depart

Variations with Street Trees

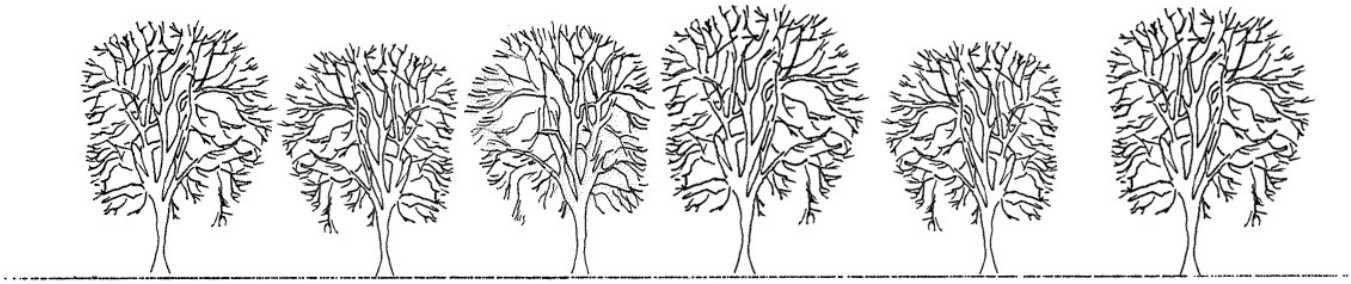
Opting for a certain native plant doesn't necessary guarantee diverse and resistant urban greenery. Too often are new plantings restricted to the same popular species, creating a set of problems. Planting according to trends doesn't make economic sense and these homogenic landscapes are much more susceptible to ecological disturbances. Diversity can and should be created in various forms and levels.

During the last years a variety of pests and diseases, some of which appear to be linked to climate change, have started attacking common street trees in the UK (besides *Ulmus glabra* also *Quercus sp, Aesculus hippocastanum*). In continental Europe one of the most wide spread trees – *Platanus* – has been attacked by a fungus, meaning that if the disease took hold, it could spread rapidly from street to street. (Shamash 2011) Long avenues of single species may look lovely, but they are more prone to infection. Instead, a variety of trees with a similar appearance could be preferred (e.g., *Fagus sylvatica* and *Carpinus betulus*). A mix of trees will be essential if streets are to avoid the sort of damage that the Dutch Elm disease has caused and here one perhaps shouldn't prefer only native species, because diversity and stronger pollution resistance is necessary in an urban environment that at times native species can't provide (Shamash 2011).

On a newly developed site planting trees of different growing speed should be considered, because this way the actual size and effect of trees can be achieved already during the life time of the first residents. For instance some species of *Populus*, *Salix, Acer* or *Larix* could be combined with those of *Quercus, Tilia, Fagus* or *Picea*. A good example of such an approach can be seen in the center of Helsingborg, Sweden, where a street next to the H99 residential area has been planted with several different street tree species. The image perceived during the summer months is simply nice and green, but the autumn colors vary greatly from light brown to dark red. If our streets are filled with buildings from various eras with different shapes, sizes and colors, then why do the trees have to look exactly the same?

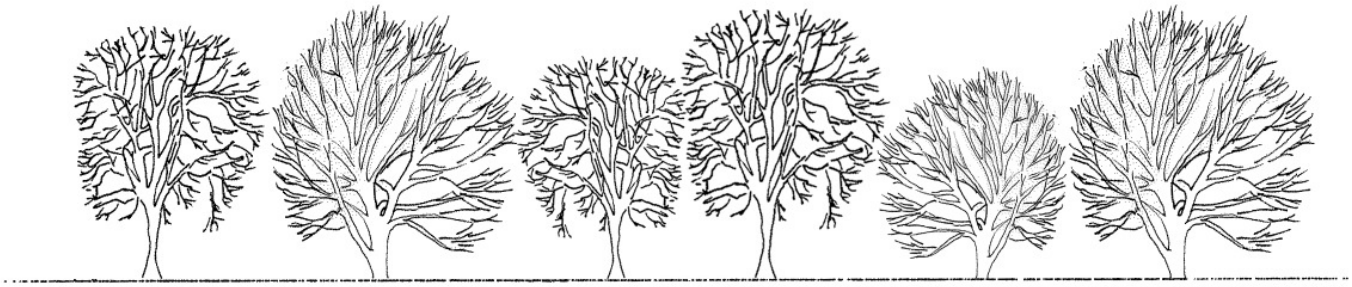
DETAIL

URBAN TREES - FROM MONOCULTURE TO DIVERSITY



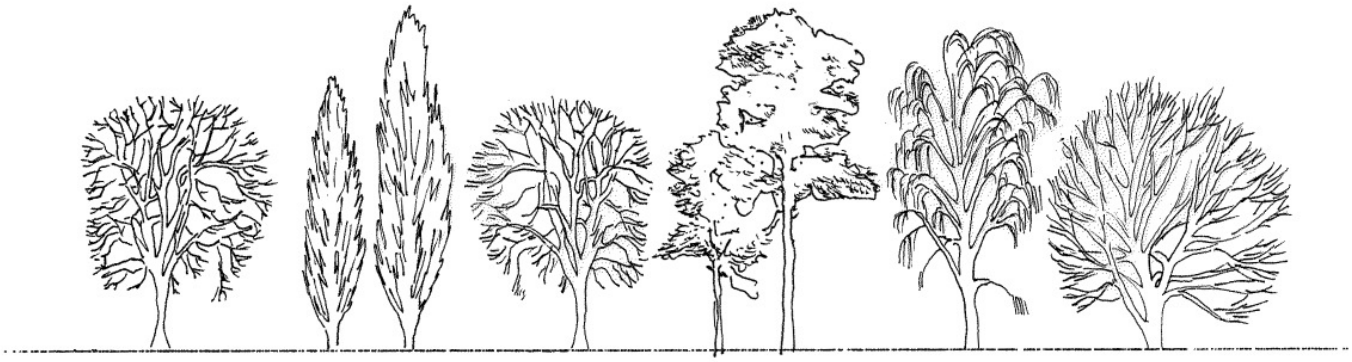
Tilia sp. *Tilia sp.* *Tilia sp.* *Tilia sp.* *Tilia sp.* *Tilia sp.*

It is highly common that urban trees planted alongside a street in Europe are usually of the same species, making them much more vulnerable towards pests and diseases.



Tilia sp. *Salix sp.* *Tilia sp.* *Tilia sp.* *Salix sp.* *Salix sp.*

By mixing for example two species one can create a similar visual impact to the untrained eye, which at the same time is more resistant.



Tilia sp. *Populus sp.* *Tilia sp.* *Pinus sp.* *Betula sp.* *Salix sp.*

Mixing even a higher number of species can lead into a far more diverse and sustainable urban greenery.

EXTINCTION DEBT

Insight to 'extinction debt' as a possible cause for higher biodiversity is given. The presence of urban trees, especially old ones, is discussed and visualized in relation to this.

For years there's been talk on how urban areas are even richer in species than their natural equivalents. This can hardly be considered a surprise if we think of all the introduced plant species in private gardens and public areas as discussed in the previous chapter. But the research emerging in the last few years is showing that there's more to what numbers are indicating at the moment.

There's a term that ecologists refer to as extinction debt, which means that the negative impact of human activities on current biodiversity will not become fully realized until several decades into the future (Dullinger et al. 2012). Stefan Dullinger and colleagues have looked at the historical and contemporary socioeconomic actions in 22 European countries and compared this data with current medium-to-high extinction risk species. It turned out that proportions of species in various taxonomic groups facing extinction today suffer from actions from the early or mid-20th century. There's similar data (Seto et al. 2012, Hahs et al. 2009) coming from other parts of the World too. This really changes how we should look at urban nature – just because a certain species is growing or living in a park at the moment, it doesn't mean that it might be there in 30 years. Dullinger et al. note that range adaptations of native species to changing climates considerably lag behind the velocity of climate change and that remnant populations currently occupy sites that are no longer suitable for them in the long run.

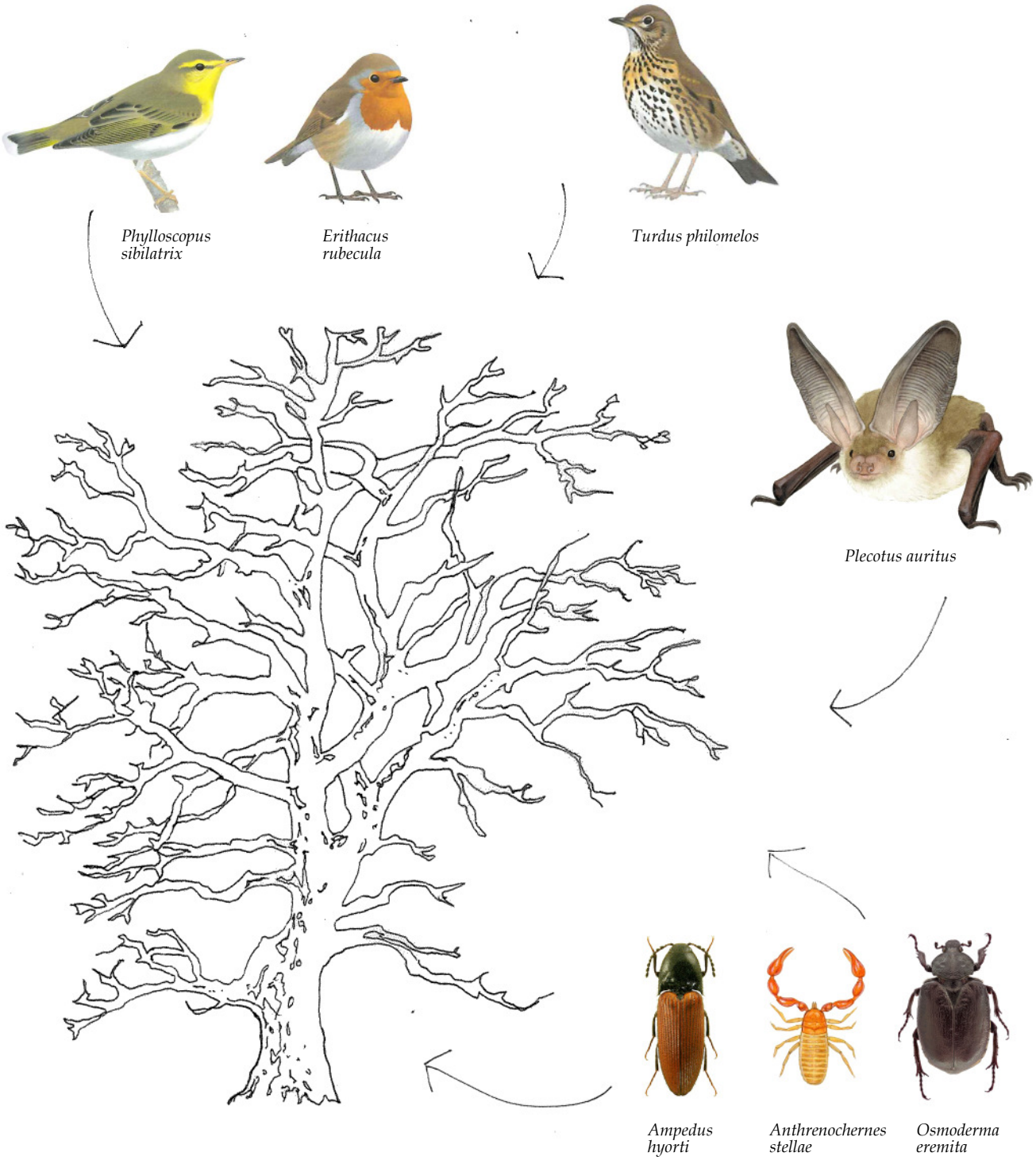
Extinction debt forces us to really rethink the actions taken to mitigate the impacts on vulnerable species, because the thread between cause and effect might not be so clear if the time interval in question is several decades or in some cases a whole century.

The Presence of Trees

A study (Fuller et al. 2010) about street trees conducted in Sheffield, UK illustrates one side of this growing problem quite eloquently. It turned out, unsurprisingly, that tree richness increased with distances from city center, along with associated increase in tree size. Although some very mature trees existed (3-4 m in girth), 50% of the individuals had a girth of less than 0,5 meters. This is a clear result of continuous replacement of mature urban trees with younger and smaller ones due to easier management, less risk of insurance claims and root intrusion. (Fuller et al. 2010) If we consider that the life expectancy of a newly planted urban tree is between 10-20 years, then the risk of degradation in urban ecosystems is high. Old trees – also dead ones – are invaluable towers of biodiversity. Various birds, small mammals and insects inhabit in the trunk, between dense branches or layers of thick bark even if the surrounding landscape consists of mainly mowed lawns and paved streets. To the right an example is given of how an old tree functions as a habitat.

EXAMPLE

A SINGLE OLD TREE CAN BE A HABITAT



A single old oak tree (*Quercus robur*) can be a home for more than a thousand species. It is mainly lichens, mosses and insects that make up this list, but they're as important as any other species in making our planet function despite lacking the visibility (read: popularity) of birds or mammals.

ECOLOGICAL TRAPS

The process of how urban environments can turn into 'ecological traps' and how to predict such a situation in advance is explained in the coming chapter.

Species usually have to use indirect cues when assessing habitat quality. This means that it is possible for humans to alter habitats in a way that causes a discrepancy between the cues and the true quality of different habitats. This phenomenon is called an 'ecological trap'. (Kokko and Sutherland 2001, p. 537) It occurs when animals abandon superior habitats to settle in poorer ones (Battin 2004) without recognizing it themselves.

It can be hard to predict when such a trap is created as the impact becomes visible after a longer period of time and observations, and quite often the connections within the trap are not so straightforward and direct. An example of such an event is given on the page to the right, where a city center provides a suitable habitat for cooper's hawks, but also leads to high mortality of young birds due to a parasite infection.

Characteristics of a Trap

Battin (2004) has pointed out several landscape and organism characteristics that increase the likelihood of ecological traps. In relation to landscapes he has named:

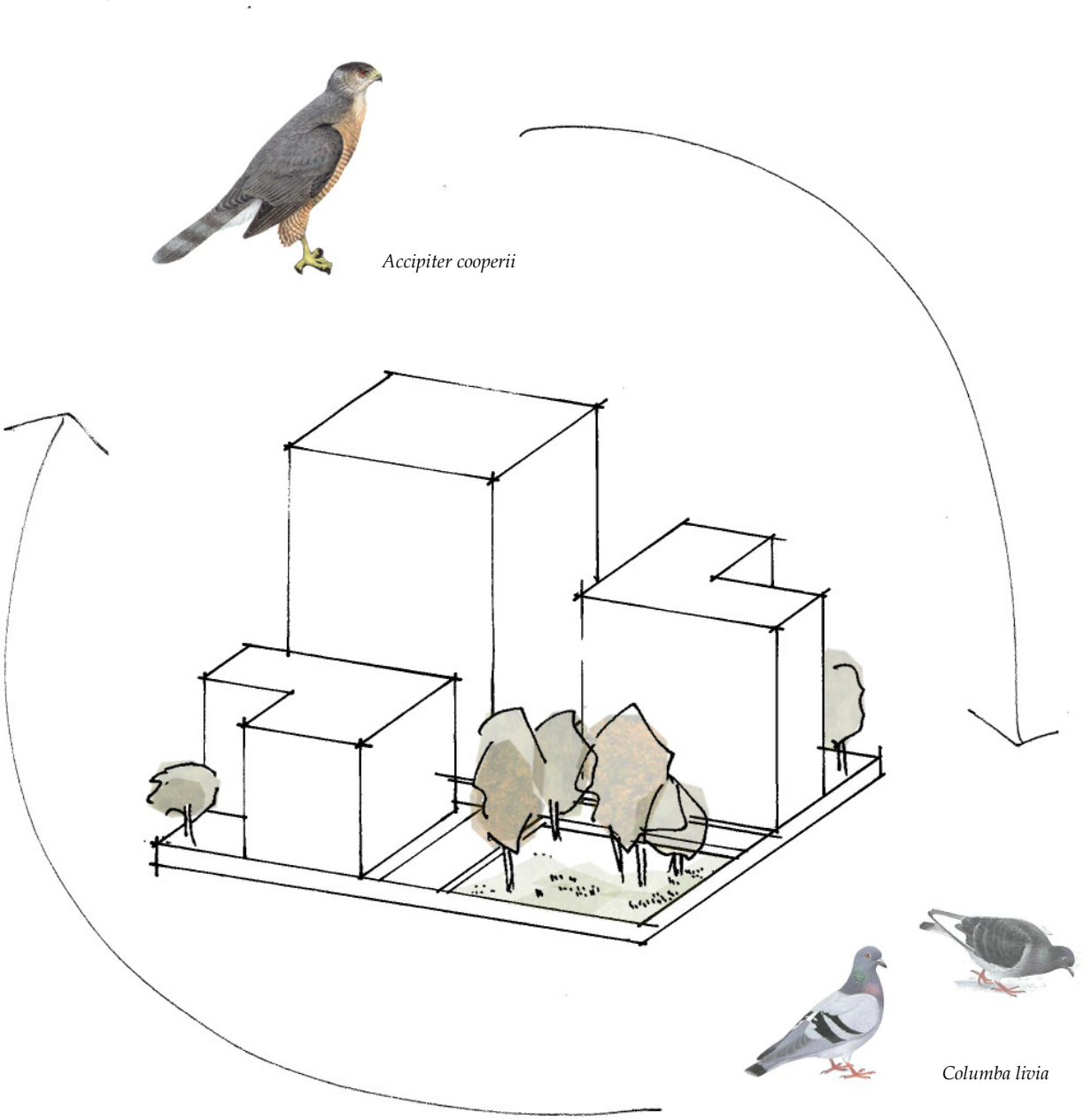
- High rate of non-native species invasion (native species have no evolutionary experience with them);
- Rapid pace of landscape change (most likely because of anthropogenic alteration);
- And high ratio of trap to source habitat (there are too many bad choices available).

In general one can state that the less time organisms have to adapt to a changing environment – through either adaptation or learning – the more likely they are to make habitat-selection mistakes (Battin 2004).

Battin (2004) also adds that such traps are a transitory phenomenon because populations will either (1) learn and adapt through evolution, (2) outlast it or (3) become extinct. The problem is that we as humans create more and more such conditions at a rapid speed and some populations are not able to adjust to this fast enough and go extinct.

EXAMPLE

HIGH MORTALITY OF YOUNG HAWKS CREATES AN ECOLOGICAL TRAP



The case of cooper's hawks (*Accipiter cooperii*) getting infected by *Trichomonas gallinae* as they prey on urban doves and pigeons in Tuscon, USA, is a well-documented (Battin 2004) example of an ecological trap. In nature the members of the *Columbidae* family make up about 4% of the hawks' diet, whereas in urban areas it is 50%. With the availability of easily hunted food and the high rise buildings providing suitable nesting sites, these hawks have adapted to the urban environment. But because of the higher infection rate of *Trichomonas gallinae* that the doves and pigeon carry, the mortality of young cooper's hawks in urban areas is 51% whereas in nature it is only 9%.

CORE AND BUFFER

The chapter discusses the value of street greenery as a buffer to urban parks. This approach possibly increases the species richness in the core green areas. A set of principles in order to create an effective buffer is also listed. In the end a more detailed description on the preferences of birds is given.

The ecological importance of an urban park depends not only on its size but also surroundings. Several species need a sufficient buffer zone to protect them from light, noise and other human caused impacts. Even if the park is large in size, but lacks suitable vegetation, it might have less ecological value than it actually has potential for. The situation is worsened by the lack of greenery around the park itself. But a bigger buffer zone enables the core to grow, resulting in a positive effect on the species richness and the viability of populations within the park.

How to work with greenery in an existing urban structure is a question of its own. In the case of Frihamnen the creation of the buffer can and should be included already from the first stages of the planning process. It can be constructed with the help of various green elements such as rows of trees, hedgerows, raingardens, vertical vegetation, roof gardens or pocket parks among others. The main beneficiaries of this type of urban greenery in terms of fauna are birds as they're most mobile and best adapted to urban structures, but this applies to various invertebrates too. A combination of different alternatives should be used in order to provide a diverse environment suitable for several species. But a lush, vegetated street has high aesthetic values and is appreciated by humans too.

Size and Connectivity

A buffer also has its limits as it can't be stretched endlessly. The width of the buffer that fauna need is clearly dependent on the preferences of the species. A study in Japan (Ichinose 2005) has shown that the ratio of woodland within 500 m of urban parks was the most important environmental factor for birds' species. In order to introduce forest birds into an urban area, the proportion of woodland near core habitat has to be increased. A thorough study in France (Pellissier et al. 2012) partially also discusses the proximity of green areas and birds' preferences. The results of this study are discussed separately at the end of this chapter.

Most of the green areas in cities are planned for human use and nature has to adapt to what is provided. In terms of people there are studies that address the issue of minimum distances to parks and natural areas of different scale with 300 m to a small green area as being the common number referred to. This distance applies also to the future Frihamnen with the size of the local parks at a minimum 0,2 ha.

Comparison of Two Urban Structures

The image on the left shows a park between urban blocks. It stands isolated with only a few bird species being able to live on such a habitat.
The image on the right shows a park between the same urban blocks, but this one is connected by various types of street greenery and has a denser, more diversely vegetated center. The core area is therefore large, being able to support more bird species and higher abundances.

Creating a Buffer

Some principles can be developed based on the previous discussion of creating a wider buffer zone around core parkland as a basis for enhancing connectivity and richness of green structure.

- Most of the proposed buffer greenery should be close to the ground level (growing in the ground). This makes the vegetation more resistant and possibly long-lasting. Aforementioned trees, hedges, shrubs, raingardens, climbers etc. are suitable. This approach also enriches the public space as street vegetation creates a better microclimate, reduces the amount of dust and noise.

- The use of green roofs and walls should be considered depending on the characteristics of the site and region. It is necessary to know how these structures will impact the surrounding fauna (e.g., the relationship between ground nesting birds and green roofs).

- Less maintenance, more natural meadows and shrubbery to create ecologically higher valued and connected areas.

- Even narrow vegetated front yards and small pocket parks have a high social, aesthetic and ecological benefit.

- In extremely limited conditions container vegetation can be considered. This too can be diverse and educational with farming and gardening as possible methods.

In more central and built up locations with low green qualities a network of small vegetated oases can be created. With this approach the vegetation is reintroduced step by step. Though these pockets might be physically on different heights such as up on the roofs, walls and down on the ground level and therefore disconnected, they might eventually start functioning as a part of a larger system.

Preferences of Urban Structure of Birds

A short recap on the condition and preferences of different bird groups in urban environments is given.

Insectivorous species are considered adapted to urban environments, but their abundance is strongly related to the proportion of shrubs, with the impact of shrub layer being stronger in areas with homogeneous building heights between 18 to 30 meters (Pellissier et al. 2012, Evans et al. 2011).

Granivorous and omnivorous species are considered generally well-adapted to urban environment (Lim and Sodhi 2004). But Pellissier et al. (2012) have also shown that the abundance of granivorous species was even higher in areas where homogeneous medium-height buildings (18-30 m) and high proportion of shrubs were close to vegetated areas. Omnivorous species on the other hand preferred heterogeneity in medium-height built areas.

The abundance of **shrub nesters** that are considered sensitive to urbanization (Lim and Sodhi 2004) was somewhat unsurprisingly increased with the increasing shrub cover (Pellissier et al. 2012).

Ground nesters are very vulnerable to urbanization mainly due to high predation rates (Thaxter et al. 2010) with their numbers being very low in deeply urbanized areas.

Tree nesters are considered well-adapted to urban conditions and their abundance is further enhanced by good tree cover, large areas with bare soil, and building heterogeneity in medium-height built areas (which they probably experience as nesting surrogates) (Pellissier et al. 2012).

Roof nesters on the other hand don't enjoy large amounts of bare soil, but require a well-varying vegetation cover such as an urban park, wasteland or an unmaintained cemetery nearby nesting sites (Pellissier et al. 2012).

Urban Wilderness in an Aesthetic Packaging

Phalen Wetlands Amenity Park in St. Paul, USA has been developed according Joan Nassauer's principles of giving a natural area a more decorative border.

Here an overview is given on how people perceive urban nature. The general preferences of people are listed as well as Joan Nassauer's suggestions in combining aesthetics to urban wilderness. Understanding of urban nature and spontaneous vegetation in relation to personal security is also discussed.

Amidst the talk on biodiversity one can't forget the species that has created these urban environments – the humans. A city with functioning ecology is a city of knowledge and education, where people are aware of the reasons why access to some areas might be occasionally limited or why sometimes the aesthetic appearance of the landscape might not be the most appealing to the eye. As Newman and Jennings (2008) phrase it, on cultural level, nurturing biodiversity is about rebuilding real connections between city dwellers and the living world so as to foster attitudes of respect and care. They continue that this may be achieved by encouraging cultural practices and stories that sustain connections, and by creating the opportunity for daily interaction with the more-than-human world through parks, city farms, green architecture and infrastructure. In short, it is about spreading knowledge through direct and indirect measures.

Perception of Urban Nature

How does the majority of us relate to the landscape around us and the species richness within? How do the non-experts see it and what draws their attention? Within natural landscapes it is water, topographic variation and vegetation that are held in high regard, whereas built features and degraded landscapes are associated with low preference and poor scenic evaluations (Low et al. 2005). Study by Fuller et al. (2007) points out that people understand and appreciate areas with high biodiversity. Though such a suggestion can be addressed with some reservation as areas like ruderal wastelands and swampy wetlands, which are not very often regarded with high aesthetic value, are notoriously rich with species. Nevertheless, it can be stated on public urban green areas.

In environmental psychology the 'habitat selection theory' suggests that people seem to have an instinctive liking for trees in landscape, especially savanna-type landscape. The preference for savannas is even further strengthened by the 'prospect refuge theory' which suggests that humans prefer large trees with low-hanging branches as they're easy to climb and therefore provide shelter. But there are also researchers who quite understandably believe that the liking for such open landscapes punctuated by large trees is an outcome of cultural historical developments (just think of the landscape parks and paintings produced since the 17th century).

Nassauer's Approach

So how should one work with this conflict of people liking scenic, well-maintained views, while high biodiversity is found in the aesthetically lower valued areas? Scientist Joan Nassauer has put forward a suggestion that as long as a green area seems to be maintained or at least is showing signs of it, then people embrace it. As Nassauer herself says: the landscape shows 'cues to care'. She suggests that these natural and diverse areas could be put into 'orderly frames' – by doing so, the valuable and natural core has a higher chance of surviving as, thanks to the 'border', it is somewhat hidden.

‘Cues to Care’

Joan Nassauer’s points for a successful ecological landscape project accepted by the general public for its design solutions offer an approach on a detailed level.

- Built structures improve visual quality as landscape shouldn’t look like it is neglected.
- Open water is desirable as long as it looks good and doesn’t smell.
- Picturesque, sharp edges have a high appeal (think of a golf course).
- 1:1 ratio of mown grass to native planting has a high acceptance by the public.
- Large patches of native planting (at least the size of an average football field, approximately 80X50 meters) are viewed more favorably.
- Butterflies and other wildlife are valued.
- Flowering plants are more accepted not depending on their origin.

General Preferences

In addition there’s relatively strong proof on the following (somewhat controversial) human preferences:

- People like treed landscapes without a dense understory (Low et al. 2005),
- Forests with open areas within (Low et al. 2005),
- Landscapes with clear spatial definition (Low et al. 2005),
- Landscapes with focal points (Low et al. 2005 and Nassauer 2004),
- But also areas with high biodiversity (Fuller et al. 2007),
- Birdsong (Heyman and Gunnarsson 2011) (but a lot of songbirds prefer a habitat with a dense understory, creating a paradox).

Putting Nature into an Orderly Frame

Urban wilderness can be maintained and have even an aesthetic value as the picture on the left (1) shows. A relict railway track has been turned into a landscape element in Park am Gleisdreieck in Berlin, creating a unique jungle-like atmosphere in the heart of a city. The meadows at Tempelhof, Berlin (2) are bordered by a neatly cut lawn strip giving the land wider use. On the third photo maintenance reveals the plot border on Falkenbergsgatan, Gothenburg, but at same time also creates a nice contrasting landscape feature - a true example of design by accident.

Understanding Urban Wilderness

It is important to remember that the new urban wilderness is different from the original wilderness of the past. Though it consists of a variety of species and has a specific structure, it is secondary wilderness, so one shouldn't expect the return of large mammals. If we take urban woodlands as an example, then despite their natural look, they require maintenance too, though not as much as traditional urban park landscape. (Henne 2005)

Urban forests such as at Ramberget next to Frihamnen don't consist of entirely natural species that try to mimic wild nature, it is rather a mixture of natives and aliens therefore it is more of a "surrogate nature". Nevertheless, on perhaps a slightly smaller scale natural process occur there, making it valuable in an urban environment.

In general, the relationship between urban woodland and the people using it is a complex one. For example it is proven that for a more diverse birdlife the understory of a forest should remain dense, but it is quite often cleared according to human interests on personal security and aesthetic beauty (Heyman and Gunnarsson 2011). To add even more complexity to the issue, some birds prey on various insects such as mosquitoes. Therefore we can say that the lack of shrubbery (which most people seem to prefer), results in the lack of birds, which results in more mosquitoes (which most people don't prefer). To put it shortly, with less shrubs we end with less birds and more mosquitoes.

Crime and Urban Greenery

As mentioned in the previous paragraph, a frequent argument for higher maintenance in urban green areas is personal safety. The shrub layer is most often seen as a potential risk because it blocks eyesight and supposedly creates a location for hiding. But it is not only green areas itself that impact crime rates; the surrounding built and social structures have an even greater role.

A study (Wolfe & Mennis 2012) in the USA has revealed that maintained greenery encourages social interaction and

Preferences of Animals vs Preferences of Humans

Two images of pine forest with the top one (1) more natural, wild and probably upholding more mammals and birds. The lower one (2) is for a higher recreational value kept free of dense understory, but it could possibly also have a higher number of plant species.

community supervision of public spaces, as well the calming effect that vegetated landscapes may impart, thus reducing psychological precursors to violent acts. It turned out that the presence of grass, trees and shrubs is associated with lower crime rates in Philadelphia (USA), particularly for robberies and assaults.

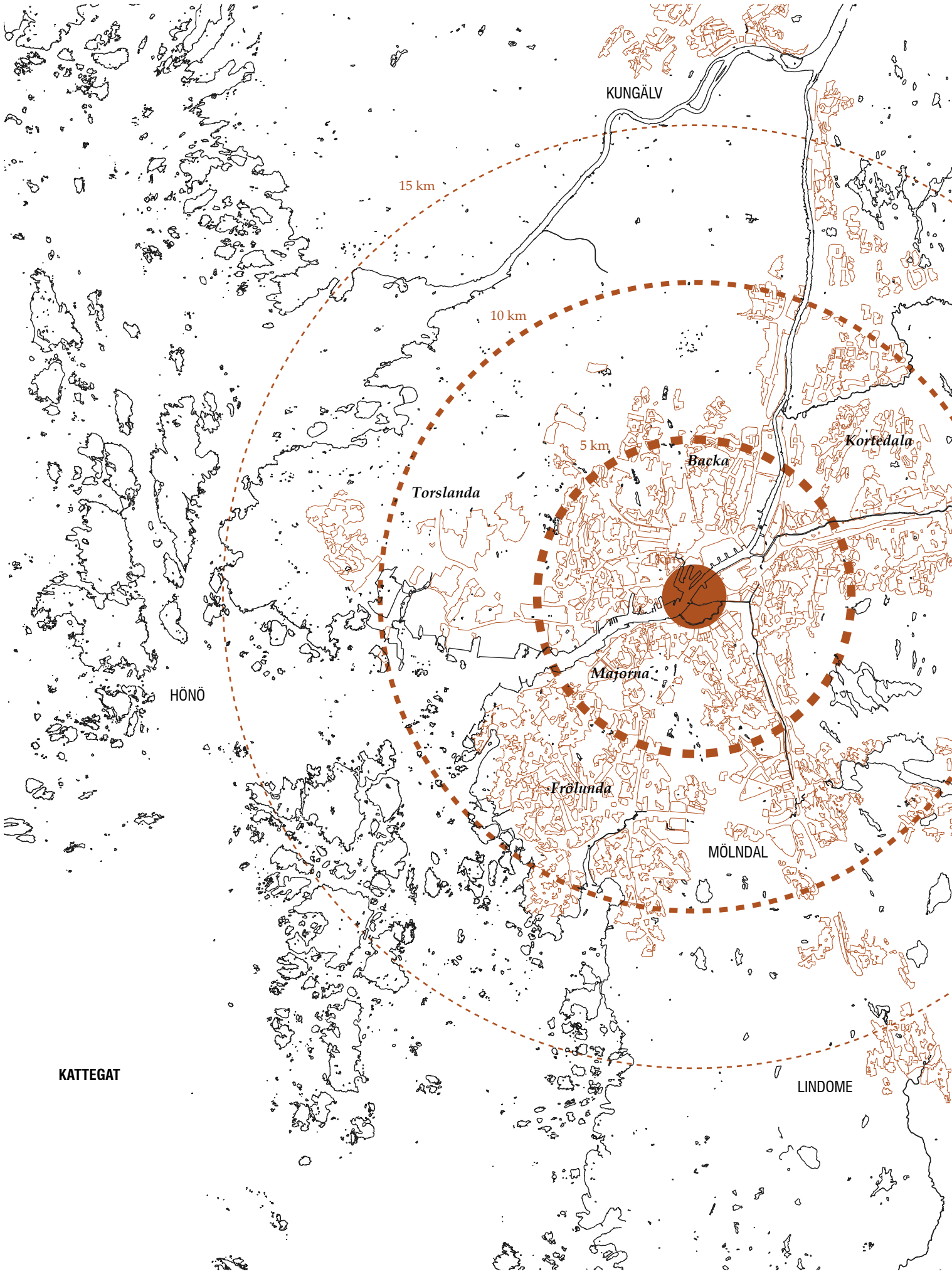
There's an equally interesting study by researchers with the University of Vermont and the U.S. Forest Service. They examined crime-mapping data and high-resolution tree canopy images for the Baltimore area and found that a 10% increase in tree cover was associated with a 12% decrease in crime. (Quan 2012)

Therefore rather than decreasing vegetation as a crime deterrent, these findings provide evidence that cities should be exploring increasing the use of green spaces.

Spontaneous Vegetation

A type of vegetation that can't be overlooked is the derelict and brown field sites, and the amount of ecosystem services they provide.

It has been proven (Robinson and Lundholm 2012) that spontaneous urban vegetation contributes equivalently or greater to certain urban climate regulation processes and habitat provisioning compared with other urban habitat types (parks, gardens etc). The presence of spontaneous vegetation within the urban landscape should be seen as a compliment and enhancement of the urban quality of life. (Robinson and Lundholm 2012) This takes us back to the thought of perhaps not needing to maintain all urban areas in a similar manner. Clear signage, paving, cut edges and borders can neatly frame more natural and "wild" without compromising human security nor aesthetics.


KUNGÄLV
15 km
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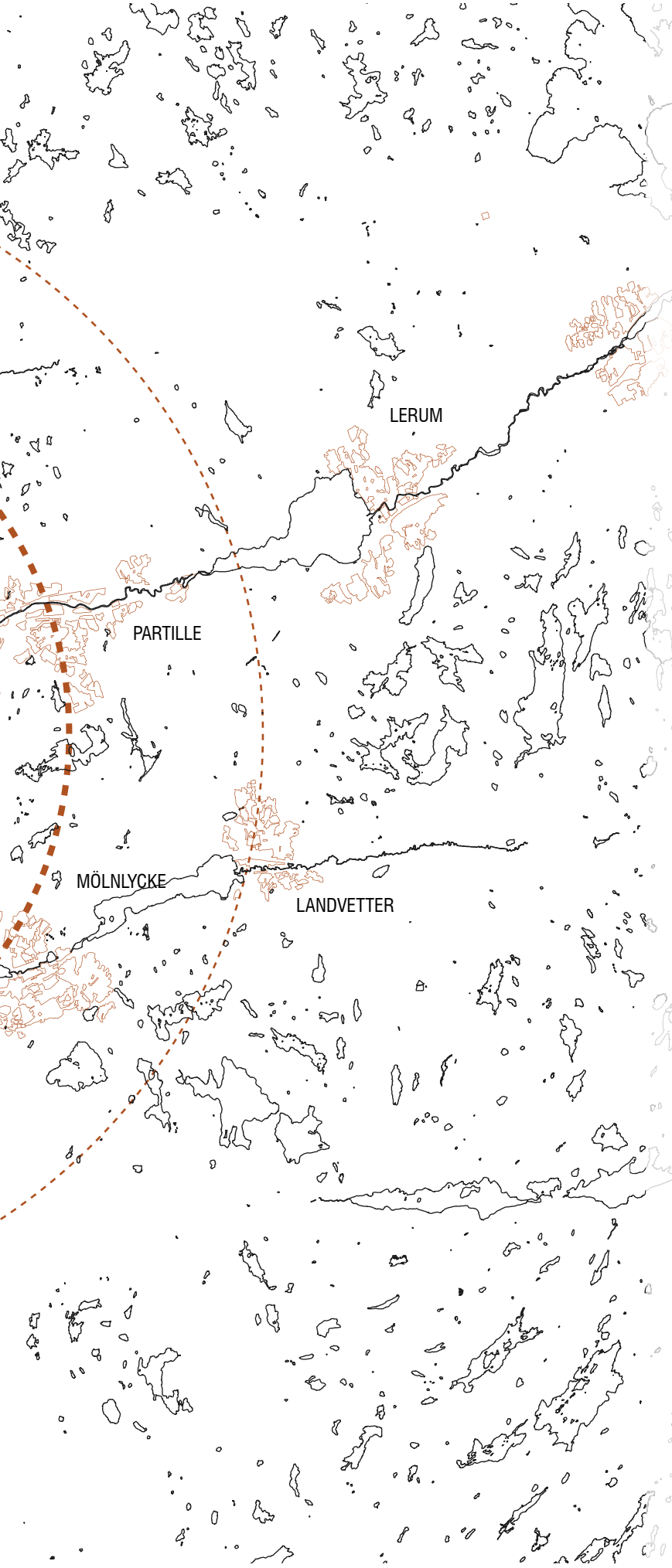


GOTHENBURG REGION

BACKGROUND

The municipality of Gothenburg is situated in the southwestern part of the Scandinavian Peninsula, at the mouth of the Göta River, on the shore of the Kattegat. The closeness of sea has resulted in the climate being slightly milder than for example further south inland. In terms of natural vegetation it lies on the border of deciduous and coniferous forests (Sahlin 2009) and according to the Köppen-Geiger climate classification it is situated in the humid continental climate zone. But the vegetation changes greatly also because of the geological variation of the Gothenburg-region, varying between bedrock, deep layers of clay and moraine. The flora and fauna of the region has for now, despite urbanization, remained relatively diverse thanks to the varying landscape providing a broad range of habitats. (Trafikverket 2011) As mentioned earlier, the vegetation varies between deciduous trees and conifers. But most of the broadleaf trees are situated closer to the coast and other deciduous trees such as from the families of *Betula*, *Alnus* and *Salix* populate areas further inland and river, stream and lake shores. (Trafikverket 2011)

SITE AND THE SURROUNDINGS

GREEN STRUCTURE

In order to best describe the existing structure of urban greenery in the center of Gothenburg Ingo Kowarik's Four Natures Approach (Kowarik 2013) was used to characterize the different types of urban nature in the areas surrounding Frihamnen.

Character of the Surrounding Nature According to Kowarik's Approach

Nature of the first kind encompasses **remnants of pristine ecosystems** such as old-growth forests or wetlands that often exist at the urban fringe or have been incorporated in the urban matrix (Kowarik 2013). There are several such examples in Gothenburg e.g. Ramberget, Änggårdsbergen, Slottsskogen. On the plan they're visualized as the dark green patches.

Nature of the second kind represents **rural cultural landscapes** that result from the transformation of pristine landscapes by human land uses such as agriculture. Fields, hedges, and grasslands are prominent examples that are often to be found in the urban periphery (Kowarik 2013). Such areas are not common in the center of Gothenburg, but one can find examples of nature of the second kind further out on Hisingen Island.

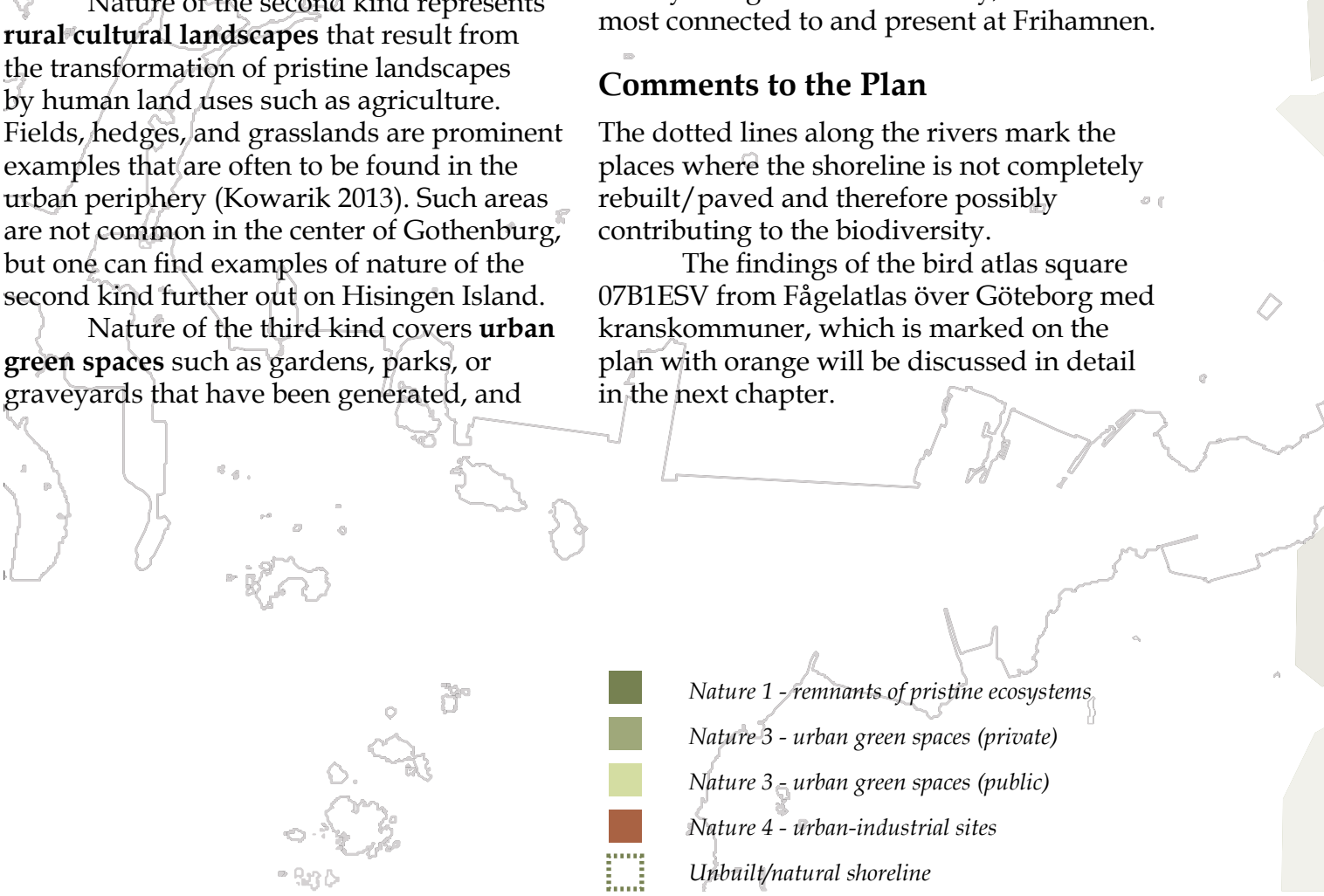
Nature of the third kind covers **urban green spaces** such as gardens, parks, or graveyards that have been generated, and are maintained, by deliberate horticultural interventions, either by transforming existing habitats or establishing new green spaces after habitat destruction (Kowarik 2013). This is for example all the areas with private gardens, and large public parks. On the drawing to the right this group has been divided into two colors of respectively medium green and light green for stronger structural clarity.

Nature of the fourth kind, emerges spontaneously as a novel urban green space on vacant lots or other **urban-industrial sites** despite severe habitat transformations. It may be shaped accidentally by human agency but may also develop towards wild urban woodlands (Kowarik 2013). These are the pastel orange patches that are situated mainly along roads and railway, and that are most connected to and present at Frihamnen.

Comments to the Plan

The dotted lines along the rivers mark the places where the shoreline is not completely rebuilt/paved and therefore possibly contributing to the biodiversity.

The findings of the bird atlas square 07B1ESV from Fågelatlas över Göteborg med kranskommuner, which is marked on the plan with orange will be discussed in detail in the next chapter.




N
Hisings-
parken
BACKA
KVILLEBÄCKEN
RINGÖN
LUNDBY
FRIHAMNEN
GÖTA RIVER
Ramberget
BIRD ATLAS SQUARE 07B1ESV
LINDHOLMEN
CENTRUM
Slottsskogen
EKEBÄCK
Änggårdsbergen
TOLTORPSDALEN

Frihamnen Today

The old harbor has seen extensive industrial use over the last century, leaving the landscape full of signs of human presence. But the relatively quiet last decades have in some locations helped to create an attractive semi-natural shoreline (1) with great views over the city center. A view to the north from Kvillepiren (2) shows the proximity of Kvillebäcken residential area, but also demonstrates the tough (and in the context of Gothenburg also unique) conditions for urban nature.

FRIHAMNEN HARBOR

BACKGROUND

The following chapter gives an overview on the background information on Frihamnen. Problems surrounding different types of pollution arising from former use and existing traffic are discussed, as well as concerns building close to water.

The area of Frihamnen is situated in the center of Gothenburg on Hisingen Island. It is a former harbor and industrial site that has little active use left. In total it covers about 45 ha together with the three piers – Frihamnen, Norra Frihamnen and Kvillepiren – and the water between them. The area has been completely reshaped by human actions during the last 150 years or so and practically nothing is left of the original floodplain most likely dominated by *Phragmites australis* vegetation. Dredging and filling has completely reshaped the shore and left large areas paved and built, and to some extent contaminated. (Sweco, 2013)

Therefore, considering the previous information, whatever developments lay ahead in Frihamnen, the approach of ecosystem restoration seems unrealistic and unnecessary in this context.

Ecological Conditions

Transforming a former industrial site into a residential area is never easy, but developing it into a completely new urban neighborhood in the heart of a city is obviously several times more complex. This applies to Frihamnen too. Because of the historical use, surrounding activities and infrastructural landscape, the area is faced with a broad range of health and environment related issues. This work acknowledges them, but doesn't work on the scale to actually solve them in detail. Considering their extent and focus, working with them could be a topic for another master's thesis. Nevertheless, an overview based on Sweco's work Fördjupad avgränsning, Frihamnen-Ringön 2013-11-15 of the more pressing issues is given.

The overview is divided into six subcategories with nature being discussed in a separate chapter.

Traffic

There are several national interests involved in terms of goods traffic. A part of Frihamnen is occasionally still in use, the Göta River is an active transport corridor and from the north Frihamnen is border by a railway leading up to the container terminal next to the Gothenburg archipelago. (Sweco 2013)

Noise, light and air pollution

The extensive infrastructural landscape is a huge source of noise. Since it includes both road and rail traffic (with ships having a minor part here), then it covers the whole 24-hour cycle. The nearby Götaälv Bridge and Lundbyleden road have on the average about 30,000 vehicles/24 h and the railroad 70 trains/24 h with both of these figures expected to grow. (Sweco 2013) The noise and light pollution created by both of them and its possible impact (on birds) is an issue that needs to be taken in consideration.

Another direct impact of the traffic (a problem in any central location) is air pollution, with the release of NO_2 and the amount of dust particles in the air being the biggest issue. The ability of vegetation to tie up these particles has been noted in several papers whereas information on NO_2 is still somewhat controversial. But vegetation along roads tends to have higher nitrogen content in the foliage and such plants go through physiological changes that also impact the insects eating the plants. (Jones & Leather 2012)

Transport

The transport of dangerous goods on the aforementioned roads and river is something that will have an impact on the urban

pattern created in the early stages of the development. The railroad has the biggest impact, which requires a 30 meter wide building-free zone next to it (there's also a possibility that the tracks will be dug lower in the more distant future, which will most likely take away the need for the zone). (Sweco 2013) Depending on the eventual width of the actual rail corridor and the amount of chemicals used to keep it clear of vegetation, it could remain as an interesting habitat.

Soil Pollution

The existing soil and riverbed contamination in the Frihamnen area isn't considered excessively high, but it does require attention (Sweco 2013). Phytoremediation could be a method to cleanse the soil in future green areas and on other sites during the long construction process. The cleansing of the river mud is much more complicated and covering them with a 1 meter thick layer of sand to stop erosion has been suggested by Sweco. The whole Kvillepiren area, which is seen as the most contaminated area, will eventually be filled up (Sweco 2013).

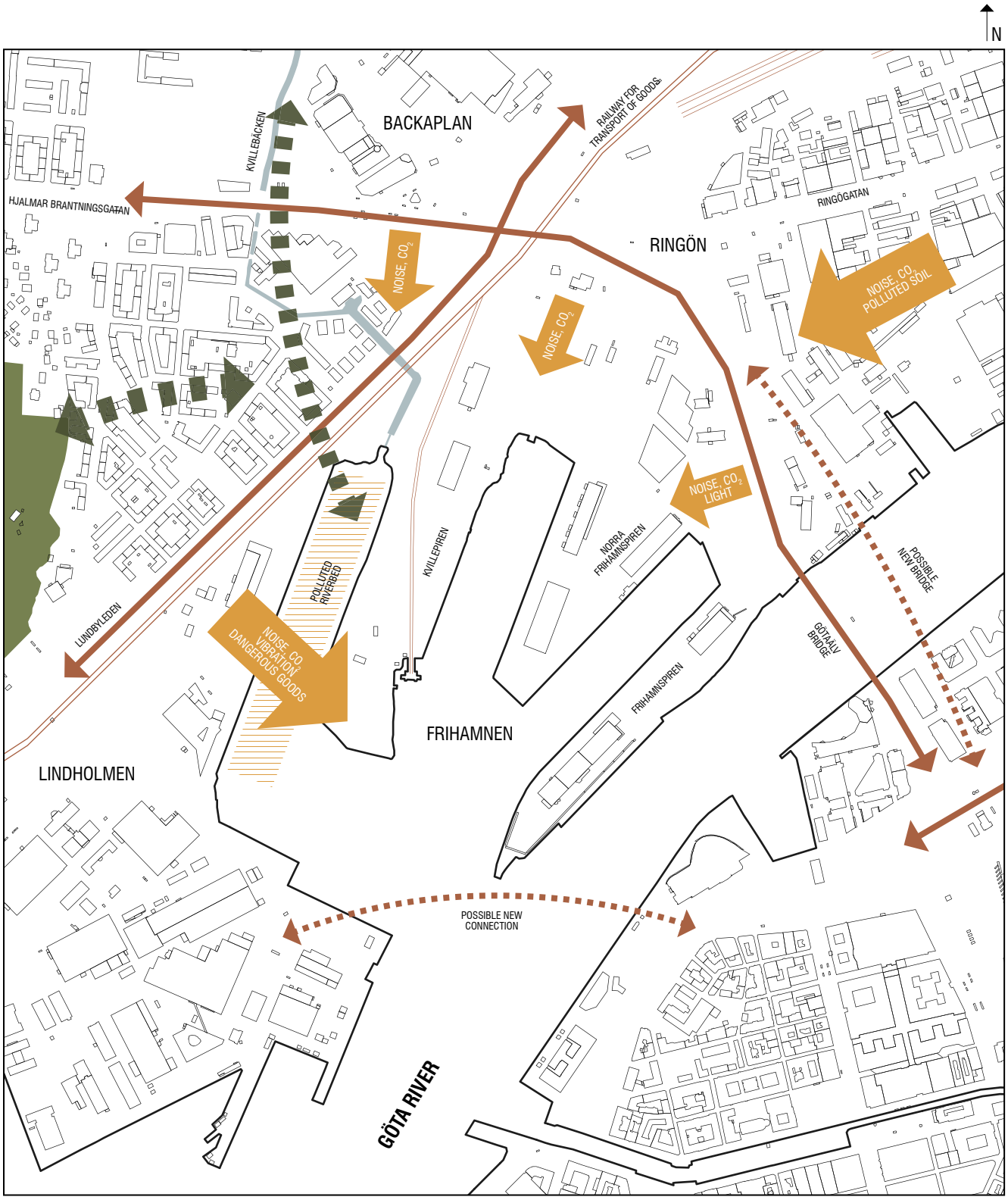
Working with the Riverfront

Creating the mentioned landfill will solve some of the geotechnical problems that the Kvillepiren pier has, but on the other hand it will have a huge impact on the most natural part of the whole harbor. The western side and the southernmost point of Kvillepiren has for some decades been able to develop in a natural way as it has been unused and cut off from access (Sweco 2013) (possibly because of the poor geotechnical situation).

An official inventory of this area is lacking, but based on studies of similar ruderal areas around Europe, one can assume that it is a relatively diverse green oasis in the heart of the city. Although the Jubileum Park has been planned on this location, it will take a very delicate approach in the surrounding areas in order not to disturb the existing composition of species. Though, one of the most important sources of diversity, direct connection to water, will nevertheless be destroyed because of the landfill. This is even more unfortunate considering that most of Gothenburg's urban riverfront is anyway a high quay or a paved slope or is in the process of becoming either one of these two (such as the mouth of Säve River), which inhibits the creation of a rich and unique shoreline habitat. The more connected habitats are, the stronger they are.

Sea Level Rise

The rising sea level is an important issue in a city lying in a river valley next to the sea. In terms of Frihamnen, there are several possible scenarios to tackle this problem. It is likely that a mixture of raising the ground level from +1.4 to +3.5 meters and a system of gates and pumps closing off the excess water will be used.



FACTORS IMPACTING THE SITE | 1:1000

NATURE IN FRIHAMNEN

Next the natural preconditions of Frihamnen are described. As stated earlier the focus is on vegetation and birds. The composition of both of these groups is to a large extent characteristic to open, ruderal sites with connection to water also an identifiable aspect.

The landscape at Frihamnen is typical to a ruderal site. Large areas are paved or covered with gravel, construction waste has been used as landfill, metal scrap lies behind buildings and along fences – in general signs of human activity can be seen everywhere, which is hardly a surprise considering the harbor's history. But the harbor is also (or at least is showing such possibility) of being a river floodplain habitat. Both of these suggestions are also supported by the analysis done by Sweco as a whole range of anthropogenic impacts are mentioned in the work as well as concern for high floods. These suggestions are also reflected in the existing vegetation.

Vegetation

A simple survey was done by the author in August 2014 to get an understanding of the species composition there. On two different test sites (both areas with a radius of 2 meters) on Frihamnen pier (photos 1-2 to the right) 39 vascular plant species were identified altogether. Considering that one of the sites was located on the seemingly (visually) unvegetated part of the harbor, this can be taken as a quite a large number. The first site, situated next to the water, had highly characteristic pioneer species (e.g., *Solidago canadensis, Salix sp*) with species related to the closeness of water also represented (e.g., *Phragmites australis, Salix sp*).

The second site, located in the middle of the pier, had even a higher number of species with several grasses and succulents also represented (e.g., *Festuca sp, Sedum sp*).

The Swedish plant portal also states that *Potamogeton trichoides*, a highly threatened and therefore red listed freshwater perennial, can be found in the Kvillebäcken Stream. Though mainly suffering from habitat loss, this plant has demonstrated the capability to re-establish itself in newly created suitable habitats (Sweco 2013).

Historically the area has quite likely been similar to the floodplain meadows further upstream – yearly flooded in spring and to some extent also in autumn, with a high water table and dominated by *Phragmites australis*.

Diversity of Vegetation

The waterfront at Kvillepiren (1) is lush with fast spreading pioneer species such as Aegopodium podagraria, Convolvulus arvensis, Epilobium angustifolium and Solidago canadensis among others. The more drier and rockier central areas (2) have a different composition with more grasses and succulent species represented such as Festuca sp, Poa sp and Sedum sp, but also Salix sp, Fragaria sp, Arctium sp and Taraxacum sp.

NATURAL PRECONDITIONS | 1:1000

- *Nature 1 - remnants of pristine ecosystems*
- *Nature 3 - urban green spaces (private)*
- *Nature 3 - urban green spaces (public)*
- *Nature 4 - urban-industrial sites*
- *Nature 4 - urban-industrial sites (high biomass)*
- *Unbuilt/natural shoreline*

Birdlife at Frihamnen

The analysis of the existing birdlife at Frihamnen and in the surroundings is mainly based on the sightings listed in the book Fågelatlas över Göteborg med kranskommuner. This atlas has divided the Gothenburg-region into a grid of 2,5x2,5 km squares and the sightings are divided into three categories – confirmed, likely and possible. The atlas square 07B1ESV that Frihamnen is located in (see drawing on page 45) obviously covers an area larger than the harbor itself, but conclusions on the richness of the site can be drawn by comparing the list of birds and their possible habitats in the viewed square. The inventoried area has Frihamnen lying in the southwestern corner, but it also includes Kvillebäcken area to the northwest, Tingstad to the northeast and reaches all the way over Ringön down to the central train station in the southeast.

In total, 65 bird species were identified in the square according to the atlas. A shortlist of 11 bird species (the full list is presented on the next page) likely to inhabit Frihamnen was drawn up based on their habitat preferences and the characteristics of the atlas square. Obviously this list doesn't represent the whole spectrum of birds living in Frihamnen, as seagulls, doves and other very common urban birds inhabit the site too and will most likely continue to do so in even higher numbers after the construction is completed. These 11 species were chosen to work with as they prefer either ruderal sites or the closeness of natural shoreline, and belong mainly to either ground or shrub nesting groups and are therefore likely to see dramatic changes to their habitat in Frihamnen.

The list as well as this method was discussed with an experienced birdwatcher who also took part of the original inventory itself. As the development of the (former) industrial sites in the center of Gothenburg continues, so will the number of most of the aforementioned species gradually decrease.

Gallinula chloropus | *common moorhen* | *rörhöna* 1

Haematopus ostralegus | *oystercatcher* | *strandskata* 2

Charadrius dubius
little ringed plover | *mindre strandpipare* 3

Actitis hypoleucos | *common sandpiper* | *drillsnäppa* 4

Phoenicurus ochruros | *black redstart* | *svart rödstjärt* 5

Phoenicurus phoenicurus
common redstart | *rödstjärt* 6

The Birds in Focus

The shortlisted birds from Frihamnen with the change of abundance of their confirmed sightings (worse to better) since the previous atlas inventory in 1973-1984 and a rough estimation of their situation nowadays (poor to good):

Gallinula chloropus (1) – same – good
Haematopus ostralegus (2) – same – good
Charadrius dubius (3) – slightly better – poor
Actitis hypoleucos (4) – worse – average
Phoenicurus ochruros (5) – worse – very poor
Phoenicurus phoenicurus (6) – same – good
Oenanthe oenanthe (7) – worse – average
Acrocephalus palustris (8) – same – average
Acrocephalus scirpaceus (9) – same – average
Sylvia communis (10) – slightly better – good
Emberiza schoeniclus (11) – same – good

Photos 1-4, 7 and 10-11 courtesy of Erik Edvardsson. Photos 5-6 and 8-9 from Wikimedia Commons.


Oenanthe oenanthe | northern wheatear | stenskvätta **7**


Acrocephalus palustris
marsh warbler | kärrsångare **8**


Acrocephalus scirpaceus | reed warbler | rörsångare **9**


Sylvia communis
common whitethroat | törnsångare **10**


Emberiza schoeniclus
common reed bunting | sävsparv **11**

THE MUNICIPAL PROGRAM

The municipal planning program is discussed next. An overview of the green and built structure with the realization of the plans is given.

Although the development of Frihamnen and parts of Ringön is still in its early stages, conclusions can be drawn from the program. The municipal planning office is according to the program (visualized on the plan to the right) looking to create a new urban district with ca 9,000 apartments for 18,000 inhabitants and 15,000 workplaces. It is seen as a linkage between the existing center south of Göta River and rapidly developing Kvillebäcken and Backaplan areas. (Stadsbyggnadskontoret 2014)

Green Structure

In general the program states that the new district will be "green and sustainable" with cyclists and pedestrians prioritized. In terms of the green structure the Jubileumsparken (ca 10 ha in size) with several local parks (minimum 0,2 ha per park) are proposed. Vegetated streets with trees and raingardens are meant to connect green areas with each other and the surroundings. (Stadsbyggnadskontoret 2014) The mouth of the Kvillebäcken Stream is changed by 90 degrees from SW to SE. The shoreline is proposed as a continuous quay with stairs, slopes and wooden decks leading down to the water level.

Built Structure

The building heights of the new quarters will vary between an estimated 11 to 44 meters. The lower housing blocks will be situated in the southwestern part, where 3-5 floor buildings (ca 11-17 meters) have been envisioned. The rebuilt street Hjalmar Brantningsgatan will see its sides densified by buildings between 6-14 floors (ca 20-44 meters) and the quarters surrounding them are planned 6-8 floors high (ca 20-26 meters). (Stadsbyggnadskontoret 2014)

Construction Stages

The construction of the whole area is divided into maximum 5 stages with the eventual completion date set as far as year 2040. The Frihamnen area will be developed in stages 1, 3 and 5 with Kvillepiren and Norra Frihamnspiren built first. Frihamnspiren, closest to the Göta River, is planned to be built third and the area stretching along the railway, including parts of the Jubileumsparken, constructed last. (Stadsbyggnadskontoret 2014)

Timeframe

The timeframe suggested by the municipal planning office sees that by 2021 the first stage with 1,000 apartments and 1,000 workplaces, and the Jubileumsparken (at least parts of it) are finished. The construction of the second stage is dependent on the progress made with the new Götaälv Bridge, expected to be finished in 2020. (Stadsbyggnadskontoret 2014)

Comments to the Plan

The map to the right also offers a visual scale comparison between the developed area and parts of the Gothenburg old town and the Nordstan shopping center.

THE MUNICIPAL PROGRAM | 1:1000

3-5 floor buildings

6-8 floor buildings

6-14 floor building

Proposed public green areas

Major new /altered connections

The Future of Frihamnen?

The visionary picture provided in the planning program by the Gothenburg municipality shows high building density with building heights gradually rising towards Hjalmar Brantningsgatan in the northeast.

ASSESSING FRIHAMNEN

INTRODUCTION

In the final part of this thesis scenarios of Frihamnen are discussed in relation to biodiversity.

A prognosis on the future of the existing habitats with the residing species is given after the realization of the municipal program. At the end of the chapter not only the means of mitigation are shown, but also a step forward from the current situation – the goal is not to just minimize the impact on biodiversity, but make the urban area even richer and more diverse. The possible development of the green structure is also put into a longer timeframe.

"BUSINESS-AS-USUAL"

This chapter evaluates the impact of the municipal planning program on a more detailed level. It discusses the new habitats that will be created and the affect on existing plant and bird species. Time is also pointed out as a crucial aspect in the development of new habitats.

Impact on Existing Habitats

The overview of the impacts starts on the habitat level. The areas identified with higher species richness and deemed valuable in the previous chapter are mainly situated on development stages 1 and 5, which will see the construction of 3-5 floor buildings and the Jubileumsparken. It is rather obvious that the habitats under the construction sites will be filled up and built on. The ruderal habitats on Kvillepiren might at first glance seem to go through some sort of transformation, but reading further in the planning program reveals that the ground level will be raised in order to tackle increasing flood risks caused by climate change. In addition to this the filling of the Lundbyvassen harbor pool will destroy the shoreline vegetation around Kvillepiren and leads to the relocation of the mouth of the Kvillebäcken Stream.

One can therefore assume that during the implementation of the program all of the existing land habitats will be destroyed or disturbed to the extent that the continuation of the populations is intersected.

Creation of New Habitats

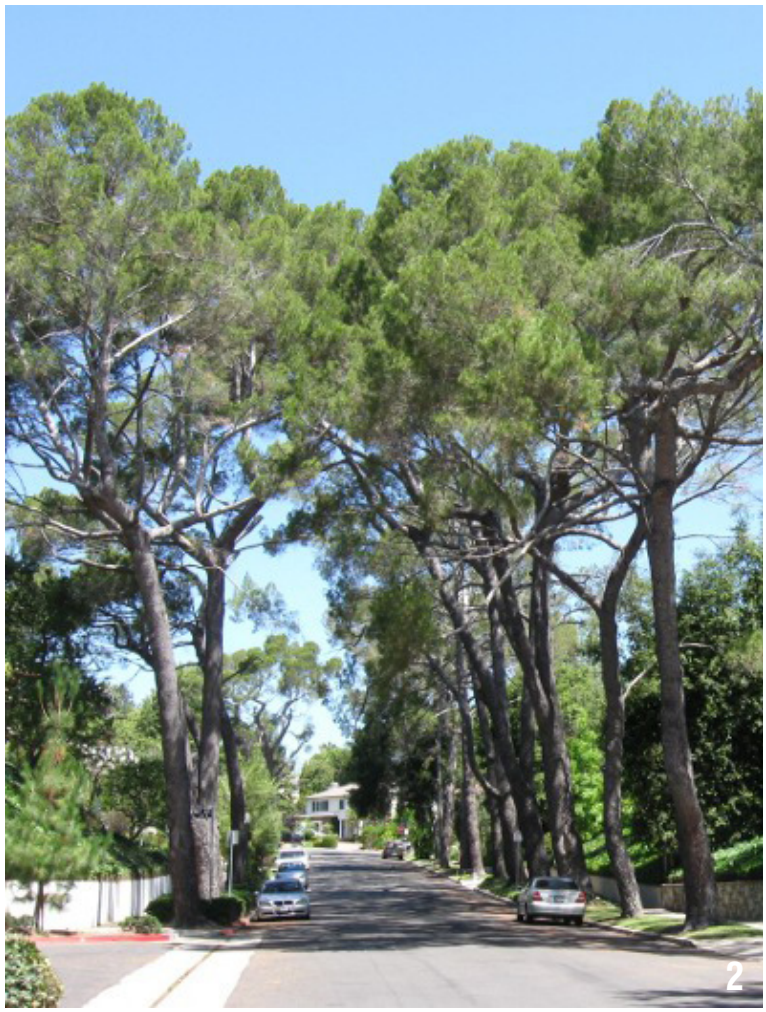
As the planning program sees the creation of new parks and street greenery, so will new habitats also be created. The characteristics of these new thoroughly urban habitats will be determined by the composition and structure of the parks as well as the vegetation surrounding them. Some speculations on this are made in the coming paragraphs. What can be said based on the information in the program is that the large Jubileumsparken will most likely not be able to provide a surrogate habitat to the 11 shortlisted bird species.

There are two main reasons for this – the number of the new buildings with their projected users and the raised waterfront. Although the Jubileumsparken will cover approximately 10 ha, it has an estimated 15,000 new inhabitants in the near vicinity and several thousand existing ones in nearby Brämaregården. The intense use, likely visits by domestic animals, frequent maintenance and general aesthetic principles of an urban park result in a more "tame" composition with species of ducks, warblers, sea-gulls and doves as everyday users.

The second aspect – a quay promenade on the waterfront – takes away the possibility of the creation of a natural shoreline. Wetlands dense with *Phragmites australis* provide shelter to e.g., *Gallinula chloropus, Acrocephalus palustris, Acrocephalus scirpaceus, Sylvia communis* and *Emperiza schoeniclus*. The likelihood of such a shoreline is though reasonably high at the mouth of the Kvillebäcken Stream, but the extent of it will most likely be restricted due to aesthetic reasons as the stream is located close to the residential area. Smaller size and the proximity of humans diminishes the possibility of it being used as a nesting site by birds.

Different Types of Waterfronts

A natural shoreline can also be an accessible one as this example (1) from Stockholm shows. A recent survey from the USA revealed that waterfronts are the most popular open space across the country with nearly half of the study group naming it as their favorite - and that even in landlocked communities (Katsma, 2014). The Rosenlund Canal in Gothenburg (2), though seemingly natural, doesn't fulfill its potential in terms of the ecosystem, because of the stone slabs that pave the shoreline and inhibit the creation of a diverse border zone habitat.



Evergreens as Street Trees

Two examples of using conifers as street trees from two completely different locations.

The photo above (1) shows a suburb in Viljandi, Estonia that has a rare street with two rows of Douglas firs (Pseudotsuga menziesii) planted alongside it. Now fully grown, they create a unique ambiance throughout the year. The picture to the right (2) is from Los Angeles, USA and shows a street bordered by Aleppo pines (Pinus halepensis).

But planting specimens of the same species and same age always bares a risk of ending up with a completely unvegetated streetscape.

Impact on Existing Vegetation

The existing ruderal vegetation will be replaced because of the reasons listed in the previous paragraph. It is hard to predict the new composition as the competition for the design of the Jubileumsparken is estimated to take place in 2015 and the following design phase even further away, but some predictions can be made based on prevailing trends and general principles. The biggest challenge both aesthetically and ecologically will be creating an attractive green area in an almost bare landscape.

New Vegetation

But what can be stated about the new vegetation without being too speculative? First of all the focus of it will most likely be to add recreational value to humans. This means tree cover and extensive grass areas with high maintenance. Multifunctional open grasslands and sports grounds are an integral part of urban recreation, but don't add much to the ecosystem. The likelihood of extensive areas with low maintenance meadows is relatively slim due to the high number of users projected. This pattern is visible in other large parks in Gothenburg such as Slottsskogen and Kungsparken.

Some of the more commonly planted trees in urban environments are species from the families *Prunus, Sorbus* and *Tilia*, which provide opportunities for feeding and pollinating. But they also enhance the homogeneity of urban nature as they are very extensively used. The same applies to the shrubs and perennials. E-mail correspondence by the author (2014) revealed that most of the species noted as "best-selling" by two plant schools located in the southern parts of Sweden are non-native, but despite this they add some value because of their fruits. In general their contribution to the ecosystem can be questioned according to the reasons stated in the first part of this thesis (e.g., the relationship between insects and non-native species).

Raingardens

The composition of the proposed raingardens is likely to be quite different from the parks, but as practice has shown a fair amount of non-native species is used in such green areas too. Though, it is important to state that the idea of creating rain gardens in the center of the city is a forward-thinking and highly welcomed approach.

Birdlife

The loss of ruderal habitat and the urbanization of the harbor will lead to changes in the composition of birds. Most of the previously shortlisted 11 species (see pages 58-59) will disappear unless counter measures will be taken. Some conclusions can also be drawn based on the building density and structure.

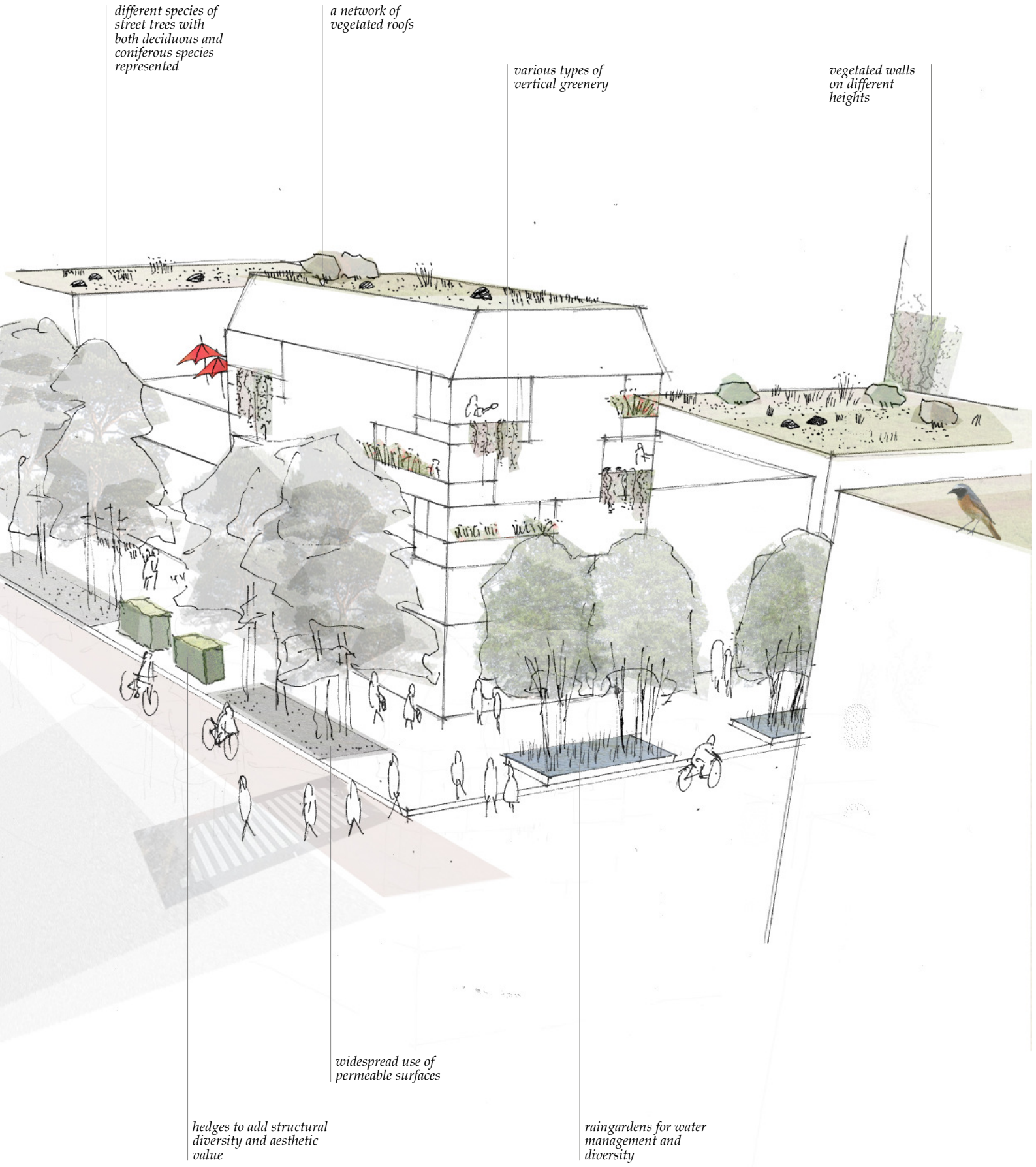
A district of relatively homogeneous height is being created in the Frihamnen area as seen on the early 3D visualizations. As Pellissier et al. (2012) found out, there are bird guilds that have their abundances influenced by building proportion and heterogeneity. Both tree nester and omnivorous species abundance (but not the species richness) is enhanced in heterogenic structures such as the more central areas along Hjalmar Brantningsgatan. But the latter needs a good proportion of trees in the vicinity in order to have a higher level of species richness too; otherwise the outcome will be dense flocks of jackdaws or doves circling the skyline as seen nowadays in Gothenburg.

In order to increase the abundance of insectivorous, granivorous and roof nester species the proximity and configuration of green spaces becomes important. Connected and closely situated parks increase the amount of these three guilds and in the case of insectivorous and granivorous birds high proportion of shrubs raises their numbers even further. This obviously applies to shrub nesters too. But the situation of ground nesters that roughly half of the shortlisted Frihamnen species were, can't be enhanced according to Pellissier et al. with neither the configuration of built structure or green spaces.

In general, the species richness of birds could be influenced from increased area or from increased habitat diversity within the larger parks (Oliver et al. 2011 pp: 218). This suggests that a large area can support a more diverse mix of habitats that can accommodate a wider range of birds' species.

Time

One of the most important aspects in hindering the creation of a biologically diverse green area is time. The first residents of Frihamnen will experience the parks as almost a "silent spring" type of a scenario. It will take years, in some cases even decades until the vegetation can be sufficiently populated by insects, birds or mammals. Clearly an approach covering both the short and the long term future is needed in the creation of green areas. Despite trees such as *Betula pendula* or *Acer platanoides* being fast-growing, it will still take a couple of decades until they're an active part of an ecosystem. As it was shown in the first part of the thesis, according to Pellissier et al. (2012) large open green areas with little shrub and tree cover are uninviting to all of the bird guilds. Measures of mitigation and a green area designed with succession in mind are discussed in the later chapters of this thesis.


different species of street trees with both deciduous and coniferous species represented
a network of vegetated roofs
various types of vertical greenery
vegetated walls on different heights
widespread use of permeable surfaces
hedges to add structural diversity and aesthetic value
raingardens for water management and diversity

CREATING FRIHAMNEN

INTRODUCTION

The loss of existing habitats and therefore the likely loss of most of the focus birds' species seems a reality in Frihamnen. It is equally probable that the species richness of vegetation per hectare will decrease with the creation of new public parks as ruderal habitats are in general considered more diverse than stretching lawns with high maintenance. What measures can be taken in order to tackle the impacts of the urban development and not only uphold, but increase biodiversity in the study area? Some suggestions can be given on how to create richer urban nature. The need to work ubiquitously with habitat creation applies to both plants and birds. The site, surroundings and the composition of species has to function together not only in space but also in time. It is important to acknowledge and accept that as the green areas in Frihamnen age, so will the composition change. This is a natural process and should be seen as a benefit for it can provide a richer wildlife to various generations of residents.

The focus of this chapter will be on (1) listing the measures to create a diverse birdlife, (2) increasing the biodiversity of the vegetation in a sustainable and long-lasting way and (3) programming compositional changes of the site on a longer timescale.

WORKING WITH EXISTING SPECIES

Some solutions are pointed out next to improve the habitat conditions for several of the shortlisted birds' species. Green roof design is discussed in order to provide an alternative ruderal habitat. The concerns surrounding the relocation of the Kvillebäcken Stream are also brought up.

Birdlife

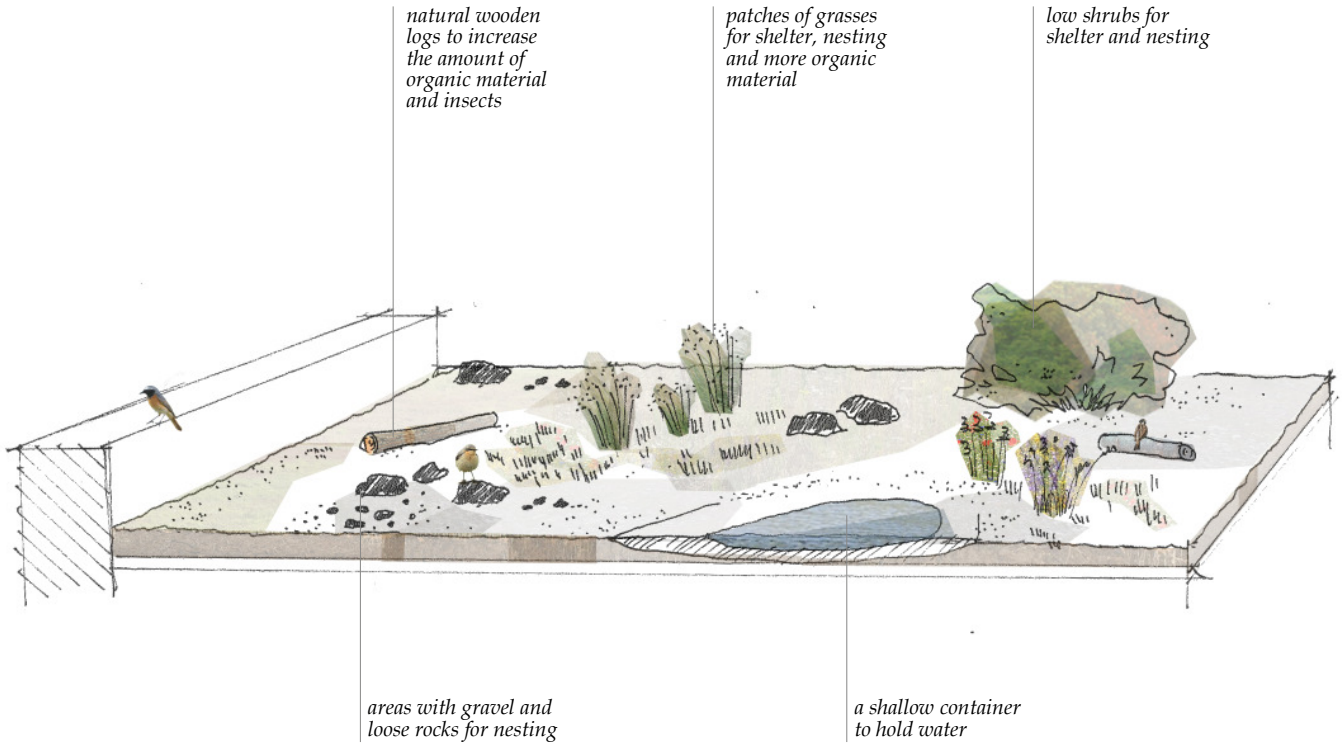
The analysis of the proposal based on the overview of research in the theoretical part showed that the likelihood of disappearance of shrub and ground nesting bird species in Frihamnen is very high. This casts doubt on the future of most of the shortlisted birds in the study area. Several direct and indirect anthropogenic impacts (i.e. their specific habitats will be destroyed, predation by domestic animals) caused by the development will mean that these birds cannot inhabit this area any longer.

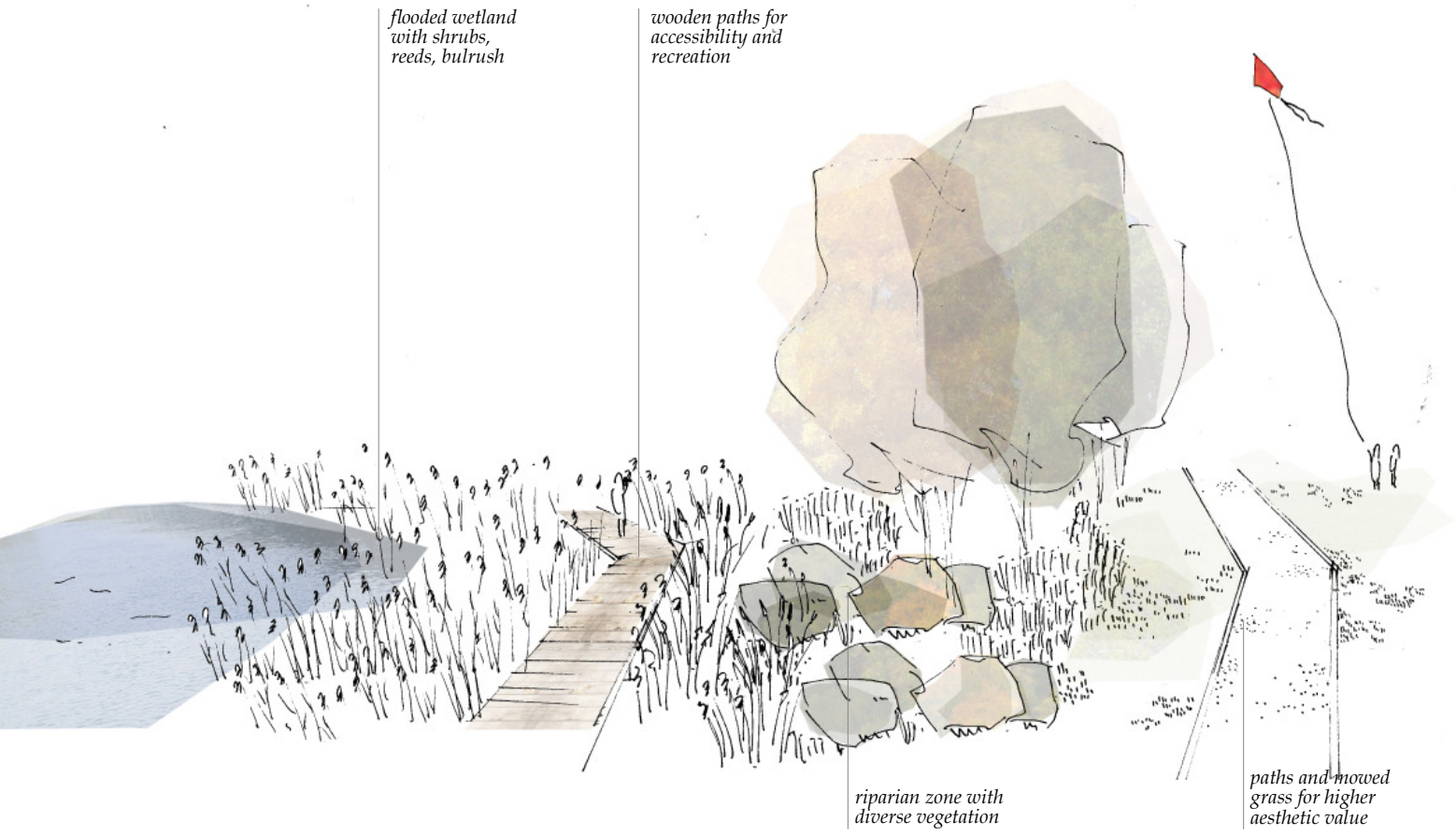
But considering the preferences of these birds, a secondary habitat could be created to some of them on the flat roofs of the lower buildings by the waterfront. Preliminary studies (Baumann 2006) in Switzerland are showing this possibility with ground nesting *Charadrius dubius* and *Vanellus vanellus*. Though risks are involved as the mortality of young birds was extremely high in this study. This problem could be explained by the fact that none of the roofs were actually designed as a habitat – birds just started using them – and they couldn't provide sufficient food and water to the young birds. The "problem" with ground nesting species is that they're precocial, meaning that the parents leave the young birds within two days after hatching (this is why they can't survive in urban areas as the predation rates for these young birds incapable of flight are obviously extremely high). In order to survive, the vegetation on the roof needs to offer insects, spiders and other small invertebrates to eat. Unfortunately the most common *Sedum* roofs use a substrate with a low level of organic material in it, resulting in very little biomass and possibly few insects. Also the *Sedum* plants used are often very low-growing and provide no shelter from aerial predators.

Reducing the Risks

These risks can be minimized by design solutions. A more diverse roof surface is needed with both vegetated and non-vegetated areas (Baumann 2006). The substrate layer needs to be occasionally thicker (but not necessarily more than 20 cm) in order to support patches of grasses and smaller shrubs of *Salix sp* and *Pinus sp*. A low, easy-to-access water holding container should be added (such products can be designed but are also available on the Swedish market), and non-vegetated patches of clay or volcanic rock based substrate are also important with occasional piles of loose rocks and stomps of dead wood. It is important to create a diverse habitat so the birds can determine the most suitable nesting site, and that the hatched birds have an environment where they can actually survive in. Considering the natural preferences of the shortlisted ground nesters then these habitat roofs should be located next to the water in order to mimic the natural situation as closely as possible. A fair amount of open green space with low vegetation could also be seen as a benefit (an additional feeding site), which could be provided in the Jubileumsparken.

The total surface area is also an important factor, but it is hard to give a minimum size as the quality of the site can change these parameters. To give an indication then the smallest study site in Switzerland was 2,000 sq meters in size,


natural wooden logs to increase the amount of organic material and insects
patches of grasses for shelter, nesting and more organic material
low shrubs for shelter and nesting
areas with gravel and loose rocks for nesting
a shallow container to hold water


flooded wetland with shrubs, reeds, bulrush
wooden paths for accessibility and recreation
riparian zone with diverse vegetation
paths and mowed grass for higher aesthetic value

but was planted with low-growing *Sedum* and moss species. Since the planning process at Frihamnen is in its early stages then sufficient roof surface can be allocated for habitats. Even the preserved harbor buildings provide such a possibility with their flat roofs.

Insects on Green Roofs

In general, having a good representation of invertebrates on a *Sedum* roof shouldn't be a problem as studies such as the one by Kadas (2006) have shown that they can be found in good numbers even in one of the most urbanized areas of the World that is London. It is hard to say why the roofs in Switzerland didn't have sufficient amount of invertebrates leading to high mortality of young birds. Just to speculate, then one reason could be that the natural areas around the study sites in Switzerland provided enough habitats for the insects, whereas in London they were concentrated to the only habitats available, the green roofs.

It is hard to predict such processes, but it is continuous testing, monitoring the situation, and making adjustments if necessary that will eventually lead to finding the right solution to a specific site. The risks are high, and not only economical, as a secondary habitat such as the discussed green roof could end up being an ecological trap.

Shrub Nesters

If the ground nesters (and some of the shrub nesters too) could benefit from vegetated roofs, then most shrub nesters require a good mixture of reeds, bushes or low-growing trees. Species such as *Gallinula chloropus, Acrocephalus palustris, Acrocephalus scirpaceus, Sylvia communis* and *Emberiza schoeniclus* would find suitable nesting sites in reeds and dense low-growing coastal shrubs. *Phoenicurus phoenicurus* and *Phoenicurus ochurros* are quite adaptable to living in specifically built nesting boxes, rainwater pipes and cavities of old buildings.

Some more detailed examples of creating the middle-layer are given in the next chapter.

The Kvillebäcken Stream

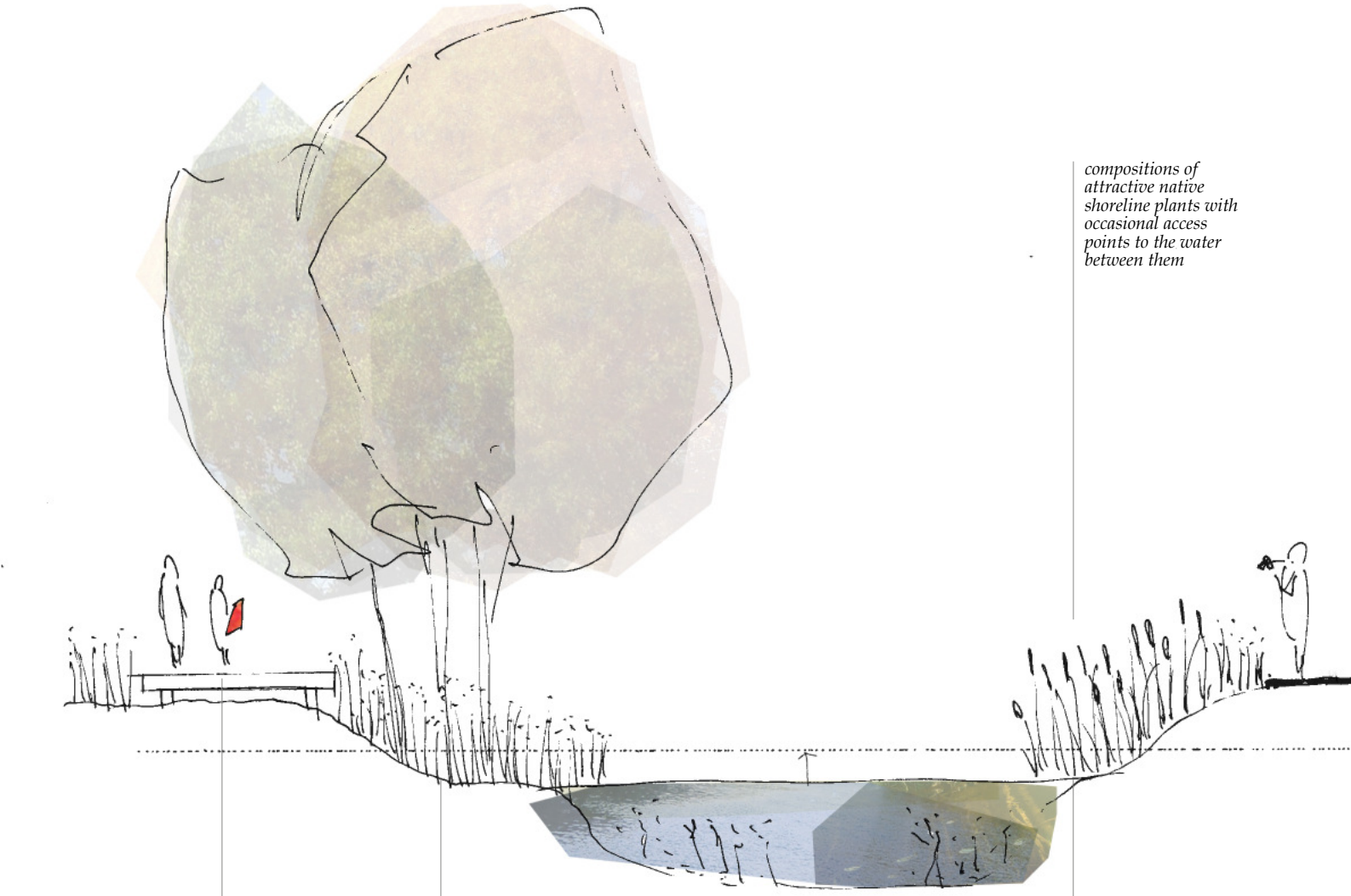
The wildlife of the Kvillebäcken Stream is briefly discussed as the impact of the planned district can be quite high there when compared to for example the whole Göta River.

The biggest disturbance will be caused by moving the mouth of the stream to the other side of the Kvillepiren from SW to SE. There are several problematic issues involved with the reaction of the existing wildlife and nature being first, and the (re-) created composition of the new location with its succession being second. Although the report by Sweco points out that the red listed *Potamogeton trichoides* found in the stream is known to be adaptable, then the flora and fauna of Kvillebäcken and its surrounding areas upstream is much more diverse. According to SLU's species portal several other red listed species have been noted in the area next to the stream – plants such as *Coronopus squamatus, Setaria viridis, Gypsophila muralis* and *Potamogeton acutifolius,* fungus *Fistulina hepatica,* butterfly *Satyrium w-album,* and beetle *Gnorimus nobilis* – with a high probability of amphibians and fish also using the stream.

Unpredictable Changes to the Stream

Though the direct impact of changes might not be so evident, then water networks function as biodiversity hotlines and disruptions in one place can result in change at another. Replanting and redesigning a waterbody always carries risks with new vegetation possibly carrying diseases, insects and other hard-to-see factors that can disrupt the existing composition.

But the meaning of this short discussion is not to criticize or be overly negative, it is just to address issues that are important and should be considered when planning such a move. One can hope that the change planned will in fact improve the existing visibly poor condition of the Kvillebäcken Stream or at least draws wider attention to the problems there.



compositions of attractive native shoreline plants with occasional access points to the water between them

a slightly elevated path to enable use at all seasons and the continuation of the shoreline vegetation

diverse shoreline vegetation with a well-established tree layer (possibly Alnus glutinosa, Populus tremula, Betula pendula etc.)

a broad river bank to accommodate seasonal water level change and create a species rich tidal habitat

WORKING WITH THE NEW STRUCTURE

In this chapter several suggestions are given on how to increase the species richness and abundance of birds through green structure. Different elements of urban greenery are pointed out with special attention given to the middle (shrub) layer that often is limited in cities.

Impact of the Built Structure on Birdlife

As discussed in previous chapters then the height, density and heterogeneity of the new district will have a direct impact on the composition of birds' species. Besides the changes to the more vulnerable existing species, the new district will also by default become a relatively large new habitat for other birds that are more adapted to urban settings. These are mainly the generalists and omnivores that are frequently seen in most European cities.

But some changes to the built structure, both horizontal and vertical, accompanied by well-planned guidelines to the green structure, can improve the conditions in such a manner that a healthier and richer urban environment will be created.

Constructing for Species Richness

Studies (e.g., Pellissier et al. 2012, Ichinose 2005) have indicated that proximity, higher connectedness and diverse configuration of green areas have a positive effect on birds' species abundance (and possibly to richness too). Pellissier et al. have presented a rather detailed overview on the preferences of different bird guilds. In order to increase the abundance of insectivorous, granivorous and roof nester species the proximity and configuration of green spaces becomes important. Connected and closely situated parks increase the amount of these three guilds and in the case of insectivorous and granivorous birds, high proportion of shrubs raises their numbers even further. This applies to shrub nesters too. These detailed findings are visualized on the coming pages.

Street Greenery

The positive attitude towards street greenery, as also seen to some extent in the municipal planning program, works in favor of biodiversity. The streets can become both linking corridors between larger green areas and buffer zones around parks that extend the habitats of several birds. The benefits for humans living and working in the district are also clear.

But the configuration and composition of street greenery is of high importance. Instead of opting for commonly used trees such as species from families *Tilia* or *Prunus*, a more pest, fungi, disease resistant composition could be created. Combining species such as *Alnus glutinosa, Sorbus intermedia/aucuparia, Pinus sylvestris, Fraxinus excelsior* and even *Betula pendula* can add year round diversity with foliage, blossoms, berries and seeds. They also provide a wider range of nesting and feeding opportunities.

Raingardens

The initial sketches in the planning program give an encouraging indication that the use of raingardens is considered. The creation of such urban wetlands is highly promising for vegetation, insects and birds alike. It could also serve as a great example of the environmental diversity around us to the people living there. But as hard as it may be, the extensive use of non-native plants should be avoided for reasons mentioned in the earlier parts of this thesis. And it shouldn't really be a problem as temporally flooded wetlands and riverbeds, densely vegetated with plants, are more than common in Scandinavia. Though the natural setting of such plants is different of an urban one, it is patience and willingness to test that is required to establish the right composition. The use of foreign species can't and really shouldn't be completely ruled out either.

Aesthetics

Urban greenery is created for the enjoyment of people too and generally accepted aesthetics are important. This brings us back to Joan Nassauer's studies on wilderness and human perception of it. Neither the street greenery nor the parks can look overly wild as it is rather likely that a public outcry for better maintenance will follow. But a middle ground between man and urban nature can be achieved following Nassauer's suggestion. Urban wilderness is a question of design, communication and education.

Configuration of Green Areas

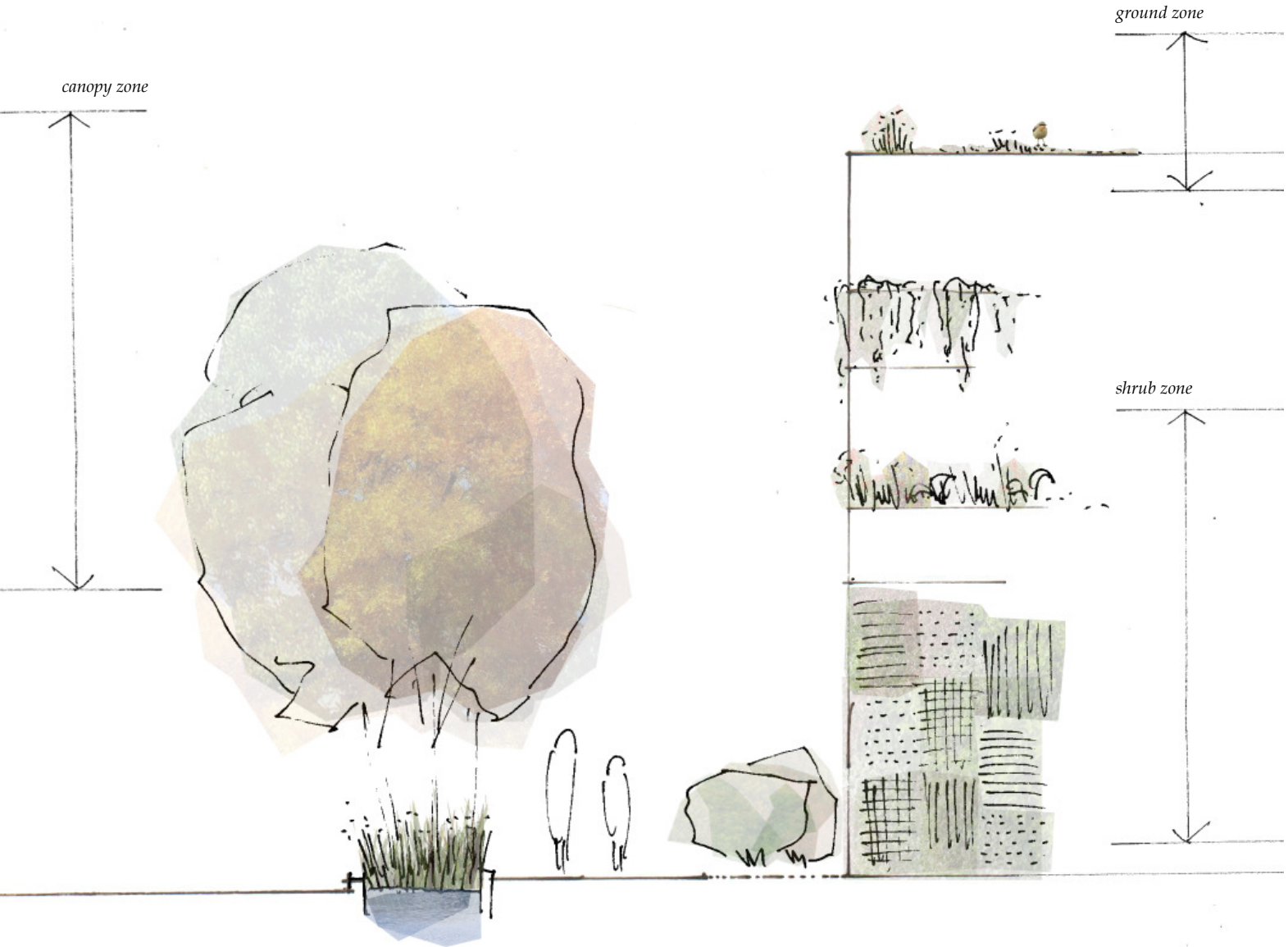
Another aspect of urban vegetation is configuration – is it just mowed grass and trees or is there good balance between grass, shrub and tree layers. Configuration of vegetation can impact birdlife quite directly. It is common that urban parks have a well-established tree layer with extensive lawns underneath it, which favors only the best urban adapters. But designing (or allowing) a middle layer with shrubs works favorably for most birds (ground nesters are a more complicated exception, but solutions to them were discussed earlier). The reason behind the generally low proportion of shrubs in urban areas is aesthetics and personal security.

Studies (e.g., Ribe 1989 and references therein) have indicated that humans tend to prefer a landscape with low understory, providing good visibility. Whether this is because of the 'savannah hypothesis' or that we've taught ourselves to like such landscapes during the last centuries is up for debate. But combining a shrub layer into parks and streets is to a large extent a design question. Providing seasonal changes, combining low and high-growing shrubs, altering maintenance, using facade greenery and working site-specifically are as simple as it may seem some of the possible ways to work with the middle layer.

Next some general examples of such an approach are given to demonstrate the possibilities.

Diverse Structure of Vegetation

Different urban green components can become parts of habitats for various bird guilds. Starting from the top, there's usually the lowest, the ground nesters, who have found a new nesting site on the roof of a building. Birds that are used to living in tree canopies are in the middle. The conditions of shrub nesters can be enhanced through the use of facade vegetation (green walls, climbers, vegetated balconies etc.) and front gardens. A rich shrub layer possibly including the aforementioned facades increases the abundances of most bird guilds.



Introducing a Middle Layer of Vegetation to Urban Areas

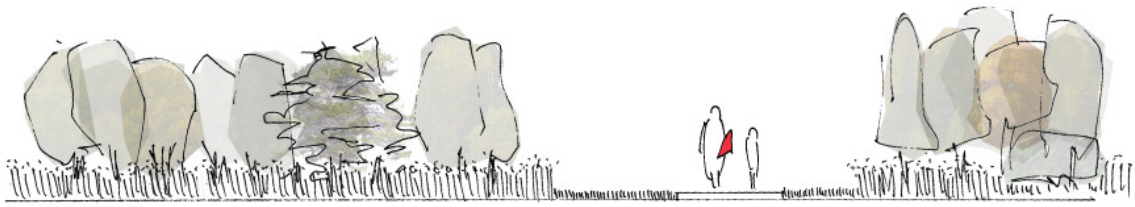
The **use of evergreens** adds seasonal diversity to the landscape and provides secure nesting sites. This shouldn't only be limited to the use of low-growing species such as *Taxus baccata, Pinus mugo* or others from these respective families. Large trees such as the most common *Picea abies* have a canopy reaching almost all the way to the ground, providing suitable shelter.

The **shape and size of shrubs** varies a great deal and in places where risks on personal safety should be considered, a combination of low shrubs and bushes of tree-like form can be used. One example could be mixing the varieties of *Potentilla fruticosa* with higher specimens of *Crataegus* and *Viburnum*.

Hedges are a compact and in general aesthetically enjoyable way of working with urban shrubs. Passerines usually flock hedges as their dense foliage reaching all the way to the ground provides excellent shelter. Altering height and thickness, and using species such as *Crataegus flabellata* or *Ribes alpinum* provide good nesting and feeding opportunities.

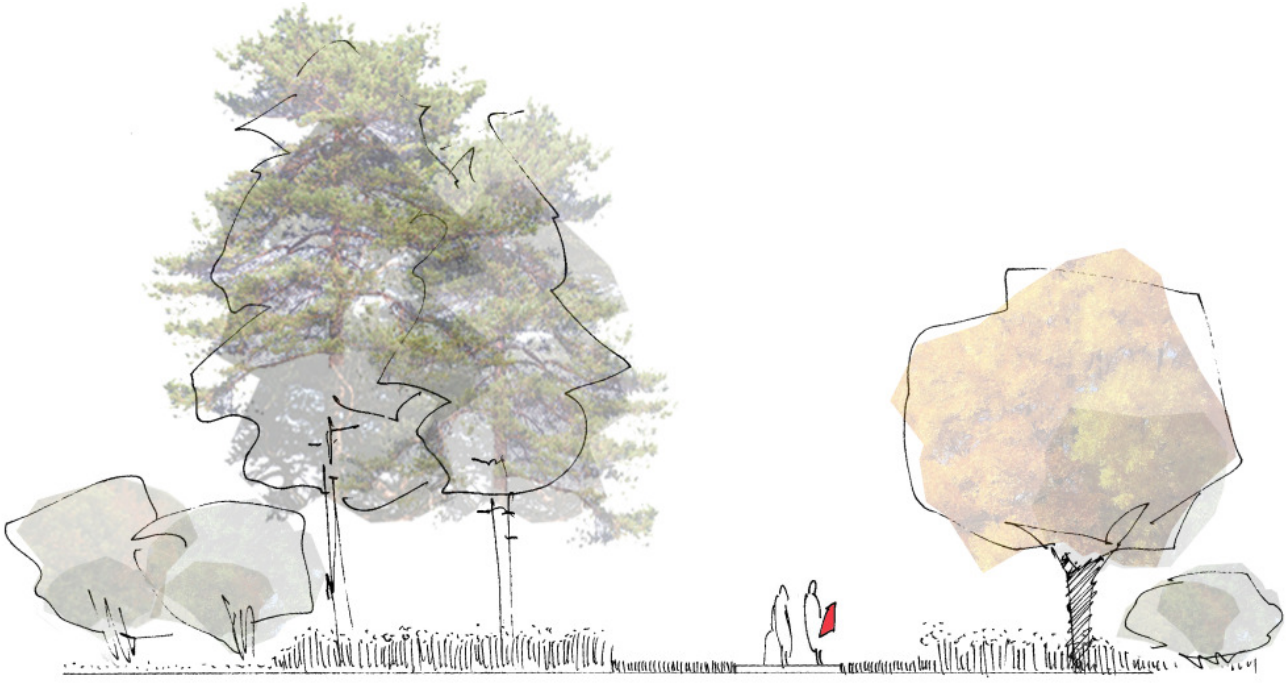
The use of **facade vegetation** is becoming more and more important as the discussion on urban densification continues. The use of climbers or a specially designed green wall alone rarely provides a habitat large enough for a community of birds to live in. But it can be a valuable part of a larger network if connected to green structure. Such walls carry a high aesthetic value, reduce noise and the amount of small particles in the air, but in order to provide suitable conditions for birds, the greenery needs thickness and good structure. Sometimes even an old dried-up climber still attached to a wall can accommodate several nests whereas a specially engineered green wall goes unused.

There are no simple answers or default designs when working with nature. All of the aforementioned solutions were given as an illustrating example and will not work under certain conditions. A successful solution not only takes care of the aesthetics, but works closely with the natural preconditions too.



***Phase 1** - mainly perennials, young trees and shrubs; dominated by fast growing softwoods and pioneer species (e.g. Alnus sp, Betula sp, Populus sp, Salix sp).*

***Phase 2** - the understory starts to open up and the composition changes; some softwoods are maturing and hardwood species are soon catching up.*



***Phase 3** - fast growing trees are removed (with some dead trunks left standing to increase biodiversity) and the long-living species dominate the wooded meadow type of landscape.*

WORKING WITH TIME AND SPACE

INTRODUCTION

All of the aforementioned examples and solutions at Frihamnen have to be put into the correct timeframe. When rebuilding a completely new district with no existing vegetation or habitats spared, a strategy is needed in order to have at least some ecological qualities already from the first years of establishment. It takes several decades for most tree species to reach adulthood and start carrying a broader ecological and aesthetic value, and it can take equally long for small mammals, birds, insects and other invertebrates to start living there and function as a system.

It is rather difficult to make an exact prognosis of the future as the amount of variables and the likelihood of stochastic events (e.g., the presence of humans or changing climate) are very high and it increases several-fold the further into the future one looks. Even more so the built structure of Frihamnen is not decided yet with the detailed planning to begin in some areas in 2015 or 2016. Nevertheless the program does offer enough material to make speculations on the impact to the wildlife. The estimated heights, urban structure, locations and sizes of parks and street greenery are all pieces of valuable information possible to use for such a prognosis.

Next a timescale is discussed on how the urban nature at Frihamnen would change if this 'design by succession' would be applied there.

Plant Succession in a Public Park

On the left, succession of vegetation is demonstrated with a park landscape fragment. As decades pass and the vegetation grows the bird species (and other taxonomic groups too) using the park change.
But the affect on humans is equally strong as for example visibility from and within the park, direct access to nature, and sunlight-shade conditions change.

PHASE 1 - THE FIRST DECADES

In this chapter a description of the habitats and their composition during the first two decades after the start of construction is given. Suggestions are made on how to increase species richness and structural diversity through vegetation for the benefit of both people and nature.

The Parks

It would be best if the first shrubs and trees would be planted immediately after the approximate locations of the parks are officially decided. This would almost directly create a sanctuary to the fauna there. Most of these parks could at first be dense and low-maintained patches of shrubs and young trees as the area is under construction and parks wouldn't have any human users. Once the building process reaches these areas and designing of the parks is concluded, these green patches can be trimmed and thinned to make them aesthetically more acceptable to most users. Although not all of the species would be able to remain, but at least some type of a composition would be in place and densely grown young trees would provide height and structure already from the first year after an official opening of the park.

A slight exception would be the Jubileumsparken as it is part of a district built first, it is relatively large in size and it has a long shoreline making it possible to create a mosaic of habitats there. The park could be divided into zones with sufficient space for floodplains, wooded areas and open meadows.

The Shoreline

The riverfront could be more diverse than envisioned at the moment with not only a walkable quay and small harbor but also natural sections dominated by *Phragmites australis*, *Typha latifolia* and patches of *Alnus sp* or *Betula sp*. These parts could be equally accessible thanks to wooden decks to residents and visitors alike. A somewhat similar example in Sweden would be sections of the shoreline at Hammarby Sjöstad in Stockholm. But at Frihamnen the floodplains could have more width making them a possible habitat for birdlife, especially some of the shortlisted species such as *Gallinula chloropus, Acrocephalus palustris, Acrocephalus scirpaceus, Sylvia communis* and *Emberiza schoeniclus*. Higher ground would see the addition of *Salix, Pinus and Alnus* to diversify the composition.

Patches of Fast-Growing Trees

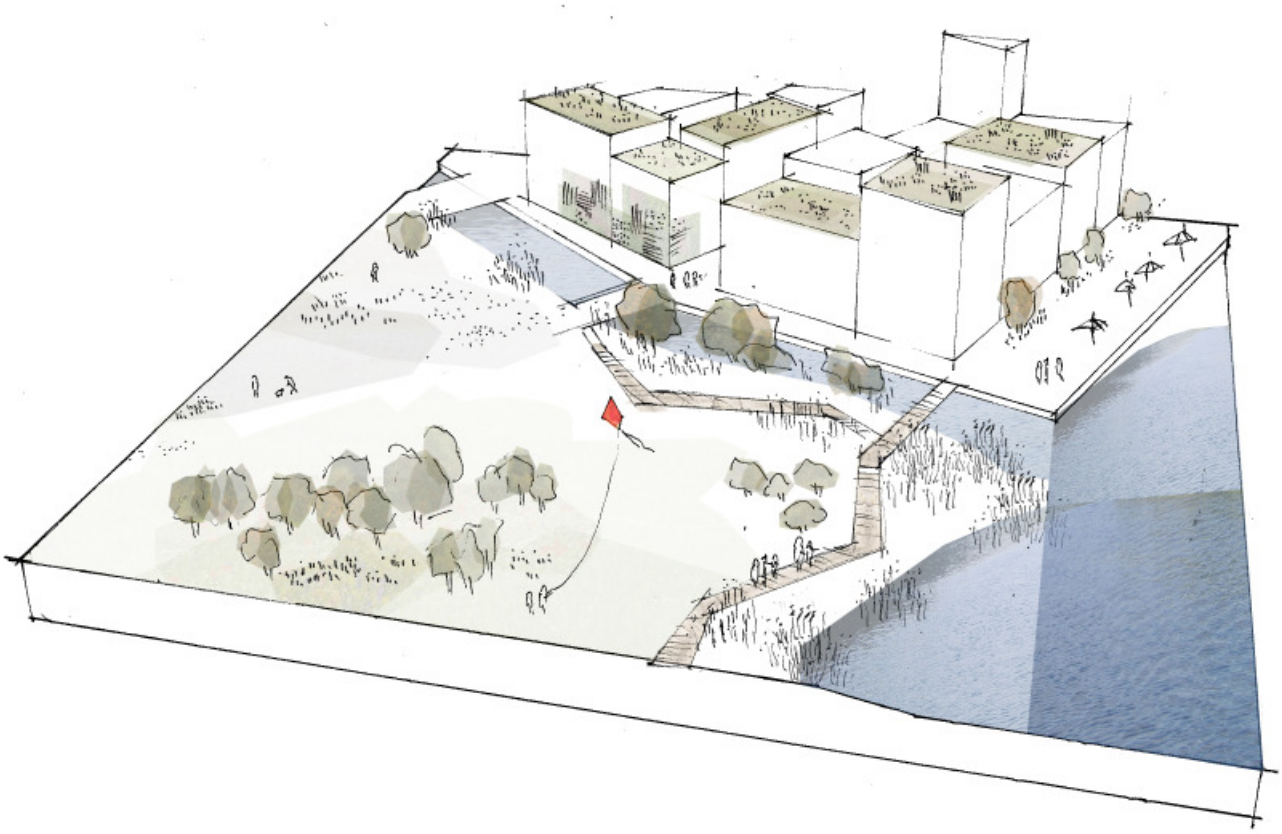
The wooded areas are a mix of fast growing species, evergreens and valuable broadleaf trees. The first decades after the creation of the park could be dominated by groups of fast growing and water tolerant species such as *Alnus glutinosa, Alnus incana, Betula pendula, Betula pubescens, Populus tremula*. Densely planted groups of these specimens quickly form sufficient biomass to not only provide shelter for fauna but also break wind and add diversity to humans. In addition *Alnus glutinosa* and *Betula pendula* could live up to 150-200 years old, meaning that they would be part of the park landscape for several generations.

Populus tremula would provide aesthetic qualities with its leaves already shaking in the slightest breeze and the contrasting yellow autumn foliage. A background of evergreen *Pinus sylvestris* specimens would emphasize it even greater, a combination also often seen in nature.

Planting for the Next Generation

Further away from the shore broadleaf trees become more dominant with a healthy mix of *Acer platanoides, Quercus sp, Fagus sylvatica, Carpinus betulus, Fraxinus excelsior* and *Tilia sp* as some suitable examples. These species provide plenty of nectar to pollinators, seeds for birds and small mammals, but also decorative and diverse foliage throughout the year.

The use of *Ulmus glabra* and *Ulmus laevis* could also be tested. Although this family has been tormented by the Dutch Elm disease during the last forty years, it is definitely worth a try if a more diverse



vegetation could spare the specimens. If the trees do die after some decades, then they serve an educational value on the consequences of monoculture planting and the dead tree trunks become a habitat to various invertebrates.

A Diverse Landscape

Open landscape is a necessity if the park is to be actively used by the residents. It has aesthetic qualities as it adds structural diversity, emphasizes vegetation (such as trees and shrubs) and can guide views within/from/to the park. But it mainly carries a practical function for it is usually the wide lawns where people enjoy their sunny weekend out in the park.

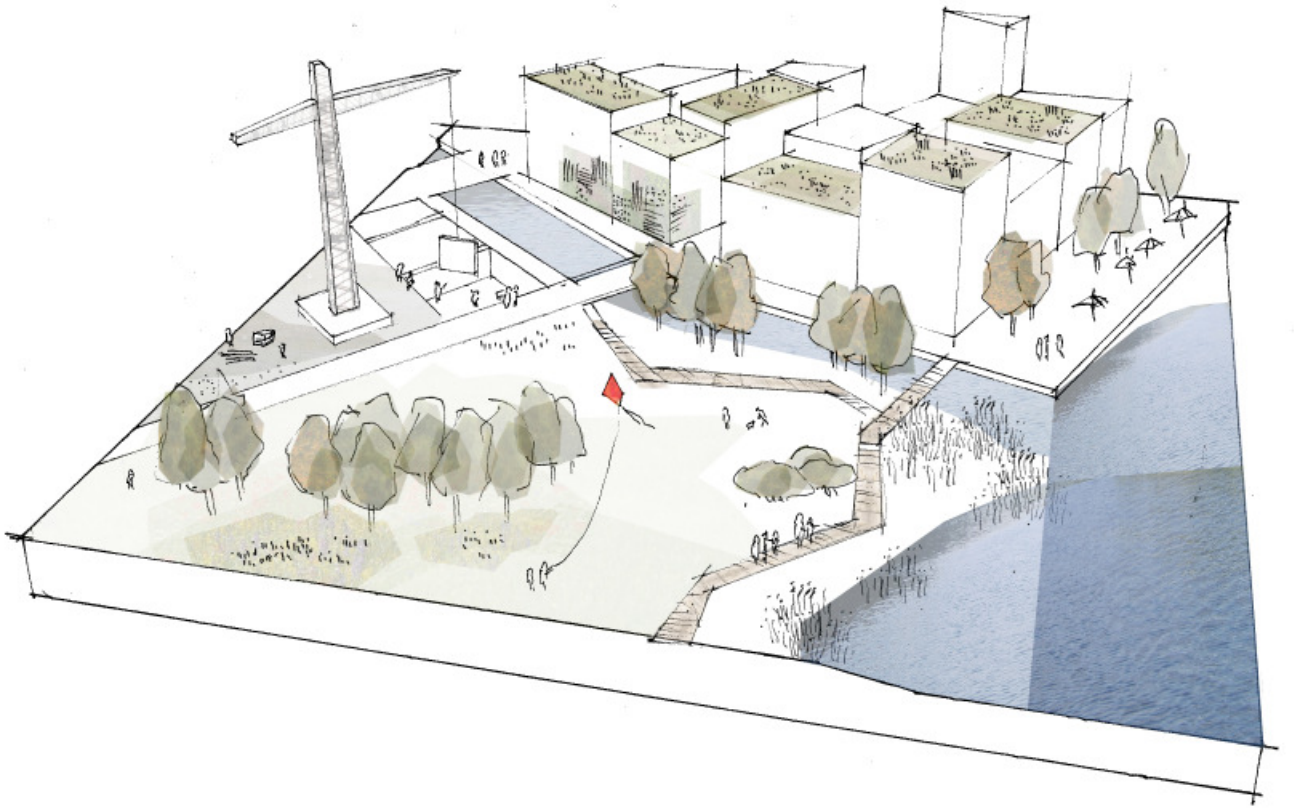
The openness will be experienced as much broader (perhaps even as empty) during the first decades because all of the vegetation is still very young. Therefore diversity and details should be added by different materials and maintenance. Reeds and low growing shrubs don't block views on the large scale, but create more intimate space on the smaller scale. Patches of meadows or areas of gravel surfacing add intricate details. The ecological benefit of these variations goes without saying.

Birdlife

The bird species most likely to enjoy the conditions of the first decades in the Jubileumsparken with the assumption that the suggestions of this chapter are realized would be some members of the shrub and ground nester guilds. But this is likely to change as the vegetation grows and the area becomes more popular, because of this the roofs were earlier discussed as a possible secondary habitat.

Connections

The creation of a functioning ecological connection to Ramberget can be discussed in the later stages of succession as the bird species living there are mainly adapted to forest environments. The nesting and feeding possibilities provided by the young trees at Frihamnen most likely will not fulfill their needs. But taking the shortlisted species as an example then these young and slightly wild patches of vegetation could be suitable for *Phoenicurus phoenicurus, Sylvia communis, Acrocephalus palustris, Acrocephalus scirpaceus* and *Emberiza schoeniclus*. It applies to the local parks among the construction sites too.



PHASE 2 - HALF A CENTURY OF WILDLIFE

Here the compositional changes of the urban wildlife at Frihamnen taking place after the first decades are discussed. It is an area in transition that functions as an archipelago of green patches.

Vegetation

By this stage construction of the whole Frihamnen area with parts of its neighboring Ringön should be finished. Assuming that some of the parks were planted already during the first stage then the fast growing tree species should be in full height by now. During this stage some specimens of *Populus tremula, Alnus incana, Salix sp* are removed to enhance the growing conditions of broadleaf trees that are likely to live much longer.

The shrub layer should also be rich and dense, with combinations of *Viburnum sp, Crataegus sp, Corylus avellana* among others providing a good range of feeding and nesting opportunities.

Birdlife

It is difficult to give an exact prognosis on how the composition of birds will look like in these local parks as there are several variables involved that need a more advanced analysis.

Firstly, even if the parks are planted rather shortly after the locations are established they will remain isolated in a very inhospitable environment as the

construction around them probably lasts for two decades.

On top of this the connectivity to other parks and the green buffer that the street vegetation provides around them won't mature until several years after the whole district is built. It most likely won't be possible to establish the raingardens or any other type of street greenery before the construction is completed as the vegetation is likely to get in the way of construction.

Some of the aforementioned shortlisted species who could have inhabited these patches are likely to disappear as the configuration of the parks changes from low-growing wilderness to a maintained forest. The local parks will immediately start acting as valuable green oases to the residents too as the courtyards of their homes are at that point still quite open and with very little vegetation – a situation that only a few species find favorable.

Large Green Areas

At this stage the vegetation at the Jubileumsparken is starting to take shape. The shoreline habitat with water-tolerant shrubs, grasses and reeds is becoming a hub for most of the shortlisted birds and likely to many others too.

In terms of abundance an equilibrium is reached. Though the size and persistent closeness to humans won't make it possible to have the area as a real hot-spot of birdlife, then the uniqueness of such a site in the center of a city makes it a rare exception and an interesting study area for ecologists, carrying a high educational value for the general public.

The birdlife is likely to become much more diverse in other areas of the Jubileumsparken too, as the specimens of *Populus, Alnus and Salix* mature and start providing suitable habitat conditions for tree and roof nesters. But the homogeneity of the building heights in the nearby residential blocks and at Brämaregården probably restricts the abundance.

Connectivity

It could be possible that by the end of this stage a link between Ramberget and the Jubileumsparken is finally created. The vegetation between (and within) the two areas should be mature enough for even some of the forest specialized species (e.g., *Dendrocopos major, Picus viridis*) that don't tend to fly long distances to be able to move from one green area to another.

PHASE 3 - EQUILIBRIUM IN A CENTURY

The further into the future, the harder it is to make predictions. Nevertheless this chapter gives a glimpse on how after a century Frihamnen's green structure starts functioning as a system within itself and with the green areas around it.

The Birth of a System

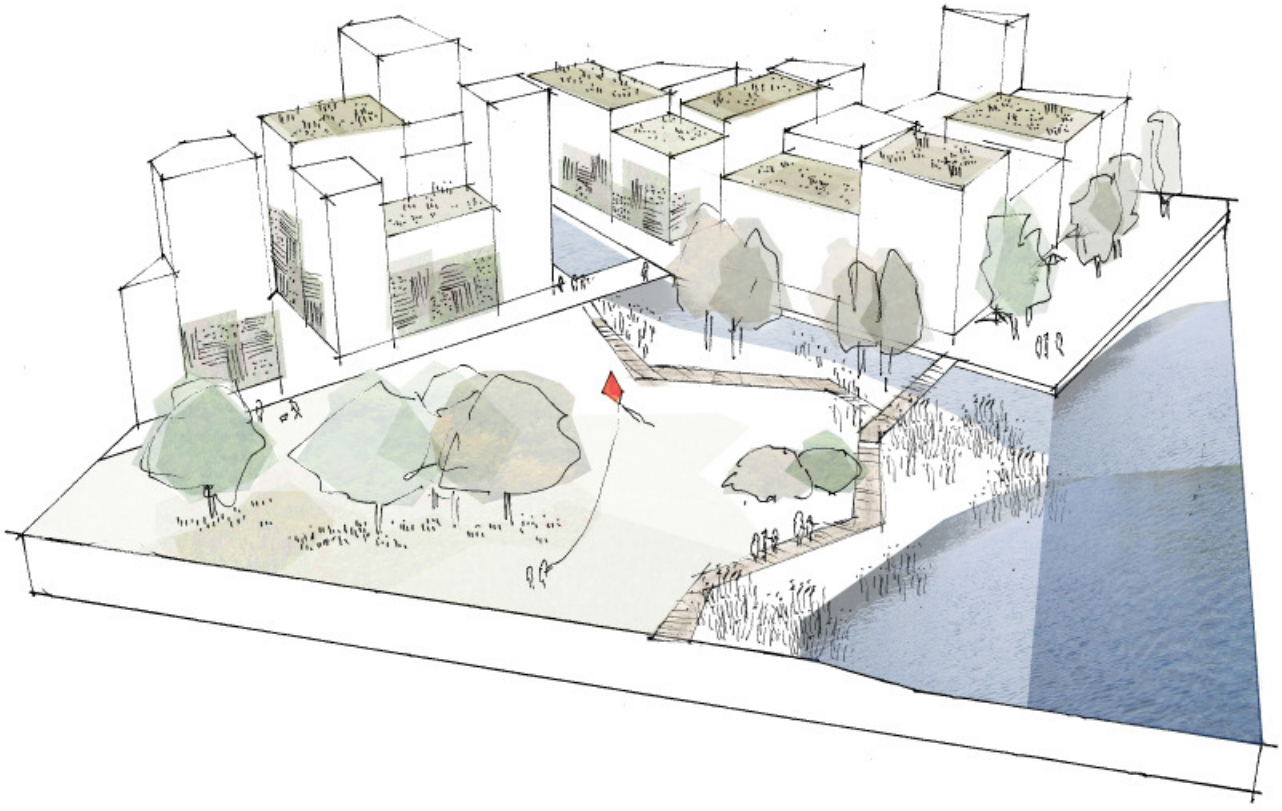
This stage will see the whole district start to function as a system. Large green areas such as the Ramberget and the Jubileumsparken are connected with the local parks by the street greenery, the latter being represented in the forms of raingardens, rows of trees and shrubs, clipped hedges, hardy perennials, vertical greenery and roof gardens to name a few.

Parks form the core areas of urban wildlife and the surrounding streets their buffer. Such a structure is not only valuable to the fauna but also to humans, as the quality of the urban space in terms of noise, air pollution, wind conditions, closeness of greenery and aesthetics in general is much higher.

Vegetation

The local parks and the Jubileumsparken have a diverse range of vegetation with a good proportion of shrubs and trees of various ages.

Most of the initially planted fast growing species have perished by now, but some of the old trunks are still standing (in locations where they are not likely to



cause any damage to humans or property if they'd fall over) providing a habitat to hundreds of insects, but also several birds and small mammals. The broadleaf trees and evergreens have fully grown and provide a patchwork of high quality urban wilderness. Patches of young softwood trees with the occasional hardwoods are planted here and there to secure diversity for the coming century.

The courtyards of the residential buildings and offices are smaller in size and likely to have much higher maintenance levels. It is probable that these areas are vegetated by more decorative but also edible plants with latter providing a valuable food source to granivorous species. The likely increased shrub density in these areas will also benefit the abundances of insectivores and granivores with shrub and tree nesters.

Birdlife

By now some conclusions have been drawn on the suitability of the green roofs as a secondary habitat to ground nesters. Testing, failing, learning and adapting have hopefully led to more information on how these species behave in cities, how does the urban wildlife around them react, and what conditions do they require in order to survive and thrive.

It is likely that with the maturing vegetation the balance between forest habitat species and open habitat birds has shifted to the favor of the first group. Diversity remains if the parks are not seen as a static piece of architecture, but as an endlessly changing complex system.

ENDNOTES

STRATEGIES

The question "how to proceed?" often arises after new essential information is put to the table. This thesis has provided several pages of discussion on how to approach the urban wildlife at Frihamnen and what solutions can be used in order to enhance biodiversity with the existing species as the core. Based on this discussion and findings a short list of more precise strategies is given next.

1.) Start by creating a diverse shoreline and parks with diverse structures.

A riverfront that is mixed with natural areas and quays, and parks with diverse greenery ensure that the district will have more varied users. This applies at the same time for people with different interests and species with their different needs.

2.) Start planting now.

Vegetation needs years, even decades to grow and mature. With initial, more general plans already in place it is reasonable to start creating the green structure as soon as possible.

3.) Vary building heights in some districts.

As already seen to some extent in the municipal program, the building heights at Frihamnen should be varied in some locations. This ensures a broader range of birds (and therefore other wildlife) can use the district as a habitat.

4.) Work with different levels of greenery.

It is not just trees and grass that are needed to create diverse greenery. Shrubs, hedges, meadows, perennials among others are just as important components.

5.) Diverse street vegetation to support diverse built structure.

Street trees of various species, raingardens, facade vegetation, front gardens with hedges and shrubs are just some of the methods available to strengthen connections between urban green areas. It creates both a green network within Frihamnen and also links it to areas around it.

6.) Roofs as special habitats for birds.

Due to the existing preconditions of Frihamnen it is a site naturally inviting for ground and some species of shrub nesting birds. Specially designed roofs can act as a surrogate habitat for these species after the district is built.

7.) Use all types of water as an asset (including Kvillebäcken).

The importance of Göta River is obvious and the use of raingardens highly welcomed. But taking note of Kvillebäcken Stream is equally important as it provides a different habitat, increases connectivity and enables a flow of different species through the district.

8.) Involve specialists not only to plan and design, but also to observe and document.

If enhancing biodiversity is taken as one of the carrying ideas for the creation of the district then documenting the changes in the species composition from the current situation to several decades onward can provide invaluable information on the behavior and preferences of species in urban areas.

9.) Achieving high urban biodiversity takes time, patience and systematic work.

Species richness that includes more than just vegetation is something than can't be created overnight. It takes years for greenery to become part of natural processes.

CONCLUSIONS AND DISCUSSION

We know that nature is a highly complex system developed over hundreds of millions of years of evolution, but it is until the recent decades that we've realized the extent, speed and depth of human induced negative changes that urban environments (but also rural) have on ecological balance. With the problem of steadily rising global urbanization on the background, it is clear that the need to address questions surrounding urban biodiversity is acute. Therefore it is necessary for urban planners, designers, architects and other professionals to reevaluate the existing business-as-usual work methods according to the emerging information.

Contemporary research in ecology has provided a broad range of data on the preferences and behavior of birds and vegetation in urban environments. The amount of new information grows steadily as studying urban ecology has become more popular among biologists. But transferring this knowledge to practitioners – in this case landscape architects – has proven to be a much slower process.

With such thoughts as a starting point, this thesis has sought to translate academic research into landscape architecture with practical examples, tools and strategies that are essential for ubiquitous and interdisciplinary methods of working with nature in cities. Though, one can never forget that there are no easy, uniform answers when it comes to working with an urban site in an ecologically comprehensive way. The core should always form from the existing conditions of a specific area such as habitats, represented species, possibilities and site history. But with all this research about a wide range of species available, the term 'site specific' needs to be further zoomed in to. It's not enough to work with urban greenery, whether it is natural or maintained, in a generalized way. This approach suits species adapted to cities anyway and pushes rarer specialist further away from survival, resulting in the loss of biodiversity and unbalancing respective ecosystems. There's a need to understand all the different parts of an ecosystem not only the human perspective, understand its connectivity on site and beyond its boundaries, and design with more than people and aesthetical values in focus.

By synthesizing academic research with data on local conditions, this paper has provided possible visions on the future of Frihamnen. As stated in the introduction, the emphasis of the work lies on urban wildlife and due to the obvious limitations on the length of the thesis and time available, it does not look at other factors such as social or economic, which are equally important to create a lively and vibrant urban district. In specific this work concentrates on two large biological classes – birds and vascular plants – and shows how a lush, diverse urban landscape can be created by zooming in to specific species. Although such an approach of focusing on certain biological groups

has its obvious delimitations, the work has shown that the envisioned landscape at Frihamnen not only supports the populations of the birds or plants in focus, but also locks in other biological classes such as invertebrates, mammals or mushrooms, and creates and environment that holds up all the different aspects of sustainable development. Until today the most common practice has been concentrating on people and our preferences, which as we now know has its own very clear delimitations in terms of biodiversity. Building the work around the birds' perspective is a way of tilting the scales closer to balance. In conclusion, this work has placed the layers of the existing situation, the planned changes and the research on top of each other, and has used the outcome to visualize the positive changes to biodiversity at Frihamnen.

Besides the obvious need for a stronger focus on wildlife when working with urban landscapes, this thesis points at the necessity for more collaboration between academics and practitioners, and between various disciplines such as architecture and biology, but also environmental psychology and others. There is unfortunately an impermeable wall of bureaucracy, principles and tradition that restrict the flow of academic research into the hands of practitioners. Research on urban biology is filtered forward through occasional articles in the daily press or seminars for practitioners. But with such an approach there's always the risk that an arbitrary selection is made from the original information by the person delivering it to the wider public. It also results in the time lapse between findings in research and their application in practice being further enhanced. One way around this problem would be to encourage more interdisciplinary design teams, where biologists, landscape architects, architects, spatial planners all have an equal role. By understanding and incorporating other professions we can create better design that includes the interests and needs of all the urban inhabitants in addition to humans.

Nature is versatile and tough, but the pressure and stress created by humans through urban environments is often too extreme. Adapting to life in cities demands swift changes and quick evolution from wildlife that at times might not be possible. The moment when the level of stress catches up with the capability to adapt, is when species start going extinct. We need to remember that with the loss of biodiversity we gradually lose invaluable pieces of the ecosystem that eventually might lead to our own extinction.

SUMMARY

Nature is all around us in the cities, but in urban environments it unfortunately can be unnatural. It is constructed, maintained and manipulated by humans and there are populations who even depend on us for their survival. This has resulted in some species thriving with high abundances whereas others are suffering with their numbers declining.

The report is divided into two large parts of equal size. The first part is mainly based on research articles and gives a thorough overview of the challenges surrounding urban nature. The second part works with the Frihamnen harbor area in the center of Gothenburg. It takes the research, personal inventories and experience of the author, the background information on the harbor and gives an estimation of the changes through the prism of ecology if the municipal planning program is realized.

The thesis looks at the biological and social importance of urban species richness. First, most of the World's cities even after industrialization have been established on riverfronts, lake or seashores that are often rich with species. Secondly, it is more and more important to keep people connected to nature in our urbanizing World. Lastly, biodiversity is directly connected to several ecosystem services and humans simply cannot afford to lose it.

Some studies have indicated that urban areas could be even species richer than the rural equivalents. But nature isn't equally distributed throughout the cities nor can some of it actually be called 'nature'. Non-native species form on average an incredible 40% of the flora in European cities, but these plants sometimes hold little value for the ecosystem. Researchers have found evidence that urban species richness is likely to decrease as it can take decades for some of the native species to go extinct. Another aspect is that cities might constantly attract species away from their native habitats, creating a rich environment here, but upsetting the natural ecosystem there in the hinterland.

Urban greenery needs to be of sufficient size in order to thrive and this can be achieved with better connectivity. The cores of green areas can be expanded if the buffer of vegetation on the surrounding streets is of good structure and scale. But the vegetation needs to be diverse and have some wilder patches too as clipped lawns and pruned trees are not sufficient for a diverse birdlife.

The study area of the thesis is situated in the center of Gothenburg – more precisely in Frihamnen. Today the area is in little use and a fascinating ruderal habitat has developed there. As it often is with former industrial sites, also Frihamnen has problems with pollution from previous activities and existing infrastructure around it. Despite this it has become a habitat for some not so common urban birds' species.

The municipal program proposes the construction of a new district with building heights between 11-44 meters and 18,000 new residents. A large park with several smaller ones is also planned. But if the design and construction of this district is carried out following today's work methods and principles, then it is unlikely that some of these more uncommon species will prevail there. The use of popular vegetation leads to a continuation of contemporary urban structures that support the abundances of certain species but not the general diversity.

Alternatives to mitigate the impact of the new district are proposed. An idea is put forward to create a roof top habitat for the ground nesting birds. Shrub nesters that sometimes find urban environments difficult to live in would benefit from increased bush vegetation, front gardens, green facades and hedgerows. Sections of broad natural shoreline would increase the wildlife remarkably and be a suitable habitat for various birds. The Kvillebäcken Stream is seen as a valuable connection to the natural areas upstream. In general, vegetation of different size, characteristics and requirements – but mainly native – planted in raingardens, roof tops, walls, sidewalks and obviously parks, is seen as a way to create a green, rich city.

When building a completely new district on an open landscape time becomes a key factor while considering suitable vegetation. A strategy is needed to create both an attractive habitat for wildlife and an aesthetically appealing public space for humans. This leads to specific requirements for the used vegetation and its maintenance. With time the spatial configuration of the parks changes greatly and with that the list of species living there too.

As conclusion, this work placed the information layers of the existing situation, the planned changes and the research on top of each other, making it possible to visualize the coming changes in Frihamnen and propose an alternative approach to not only mitigate the damage, but create an urban district ecologically richer and more complex than the existing situation.

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Photo 1 from Google Maps Streetview function.
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APPENDIX A

LIST OF SPECIES NAMES

Plants

Acer sp | Maples | Lönnar
Acer platanoides | Norway maple | Skogslönn
Aegopodium podagraria | Ground elder | Kirskål
Aesculus hippocastanum | Horse-chestnut | Hästkastanj
Alnus sp | Alders | Alsläktet
Alnus glutinosa | Common alder | Klibbal
Alnus incana | Grey alder | Gråal
Arctium sp | Burdock | Kardborresläktet
Betula pendula | Silver birch | Vårtbjörk
Betula pubescens | Downy birch | Glasbjörk
Carpinus betulus | Common hornbeam | Avenbok
Convolvulus arvensis | Field bindweed | Åkervinda
Coronopus squamatus | Swine-cress | Kråkkrassing
Corylus avellana | Common hazel | Hassel
Crataegus sp | Hawthorns | Hagtornssläktet
Epilobium angustifolium | Fireweed | Mjölke
Fagus sylvatica | Common beech | Bok
Festuca sp | Fescue | Svingelsläktet
Fragaria sp | Strawberries | Smultronsläktet
Fraxinus excelsior | European ash | Ask
Gypsophila muralis | A species of baby's-breath | Grusnejlika
Larix sp | Larches | Lärkar
Lonicera maackii | Amur honeysuckle | Koreatry
Phragmites australis | Common reed | Bladvass
Picea sp | Spruces | Granar
Pinus halepensis | Aleppo pine | Aleppotall
Pinus sylvestris | Scots pine | Tall
Poa sp | Poa genus grasses | Gröesläktet
Populus sp | Poplars | Poppelsläktet
Populus tremula | Common aspen | Asp
Potamogeton trichoides | Hairlike pondweed | Knölnate
Potamogeton acutifolius | Sharp-leaved pondweed | Spetsnate
Prunus sp | Here cherry trees | Prunusar
Pseudotsuga menziesii | Douglas fir | Douglasgran
Quercus sp | Oaks | Eksläktet
Quercus robur | English oak | Skogsek
Salix sp | Willows | Videsläktet
Sedum sp | Stonecrops | Fetknoppssläktet
Setaria viridis | Green foxtail | Kavelhirs
Solidago canadensis | Canadian goldenrod | Kanadensiskt gullris
Sorbus sp | Sorbus genus (here mountain-ash and rowan) | Rönnsläktet
Sorbus aucuparia | Rowan | Rönn
Sorbus intermedia | Swedish whitebeam | Oxel
Taraxacum sp | Dandelions | Maskrossläktet

Tilia sp | Lime trees | Lindsläktet
Typha latifolia | Bulrush | Bredkaveldun
Ulmus glabra | Scots elm | Skogsalm
Ulmus laevis | European white elm | Vresalm
Viburnum sp | Viburnum genus | Olvonsläktet

Birds

Accipiter cooperii | Cooper's hawk | Cooperhök
Acrocephalus palustris | Marsh warbler | Kärrsångare
Acrocephalus scirpaceus | Reed warbler | Rörsångare
Actitis hypoleucos | Common sandpiper | Drillsnäppa
Alauda arvensis | Eurasian skylark | Sånglärka
Cardinalis cardinalis | Northern cardinal | Röd kardinal
Charadrius dubius | Little ringed plover | Mindre strandpipare
Columbidae sp | Pigeons and doves | Duvor
Columba livia | Rock dove | Klippduva
Dendrocopos major | Great spotted woodpecker | Större hackspett
Emberiza schoeniclus | Common reed bunting | Sävsparv
Erithacus rubecula | European robin | Rödhake
Gallinula chloropus | Common moorhen | Rörhöna
Haematopus ostralegus | Oystercatcher | Strandskata
Oenanthe oenanthe | Northern wheatear | Stenskvätta
Petrochelidon pyrrhonota | American cliff swallow | Stensvala
Phoenicurus ochruros | Black redstart | Svart rödstjärt
Phoenicurus phoenicurus | Common redstart | Rödstjärt
Phylloscopus sibilatrix | Wood warbler | Grönsångare
Picus viridis | European green woodpecker | Gröngöling
Setophaga striata | Blackpoll warbler
Sylvia communis | Common whitethroat | Törnsångare
Turdus philomelos | Song thrush | Taltrast
Vanellus vanellus | Northern lapwing | Tofsvipa

Insects

Ampedus hyorti
Gnorimus nobilis | Noble chafer | Ädelguldbagge
Osmoderma eremita | Hermit beetle | Läderbaggen
Satyrium w-album | White-letter hairstreak | Almsnabbvinge

Arachnids

Anthrenochernes stellae | Stella's chernes | Hålträdsklokrypare

Mammals

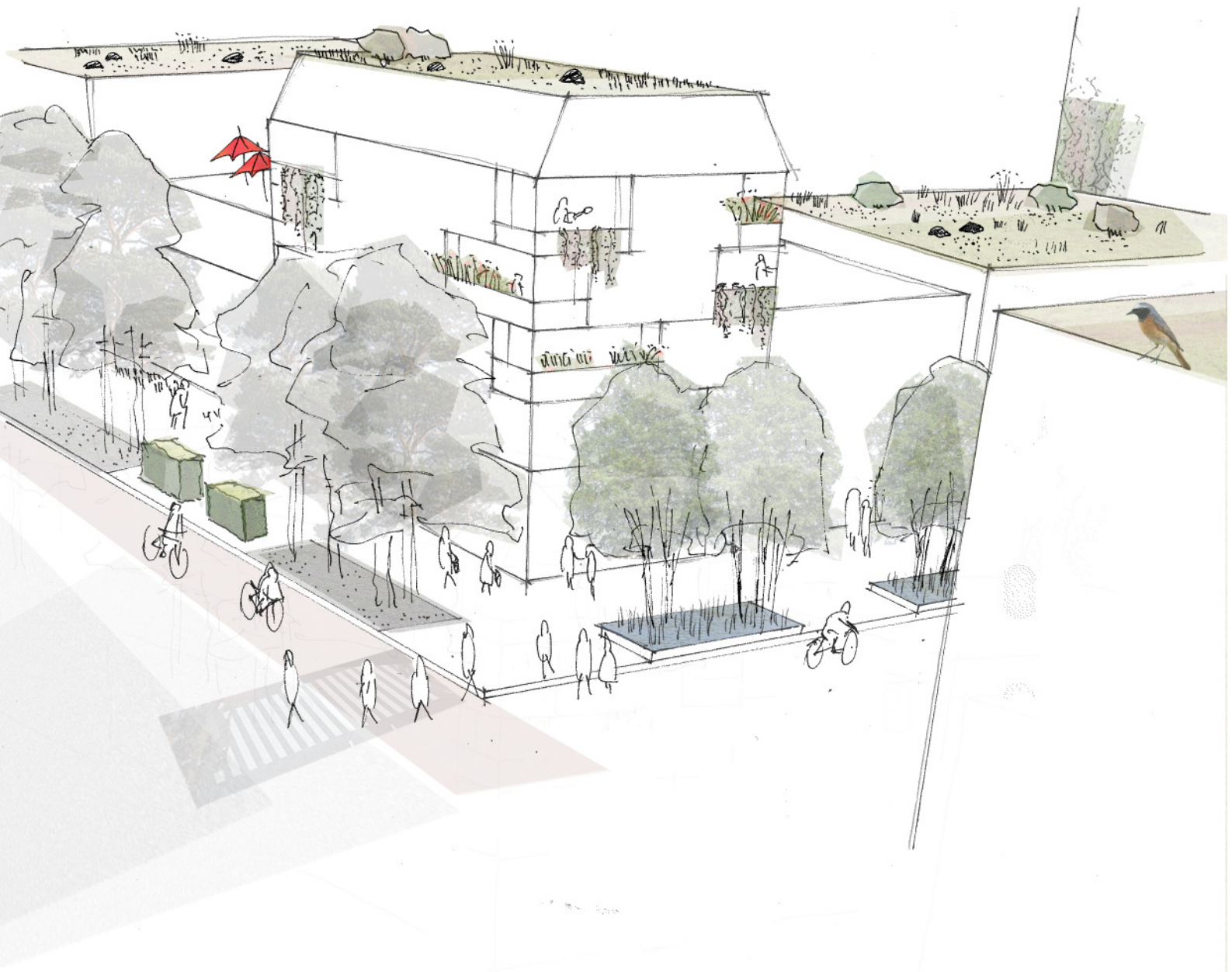
Plecotus auritus | Brown long-eared bat | Långörad fladdermus

Mushrooms

Fistulina hepatica | Beefsteak fungus | Oxtungssvamp

Parasites

Trichomonas gallinae



This is a master thesis at Chalmers Architecture.

The work gives an insight to the research in urban ecology and then sets out to apply these findings in relation to the existing situation and the municipal planning program in Frihamnen, Gothenburg. The thesis will look at the scenario likely to happen to the urban wildlife in Frihamnen and discusses alternatives to improve the conditions.

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Exploring Urban Habitats
The Case of Frihamnen

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