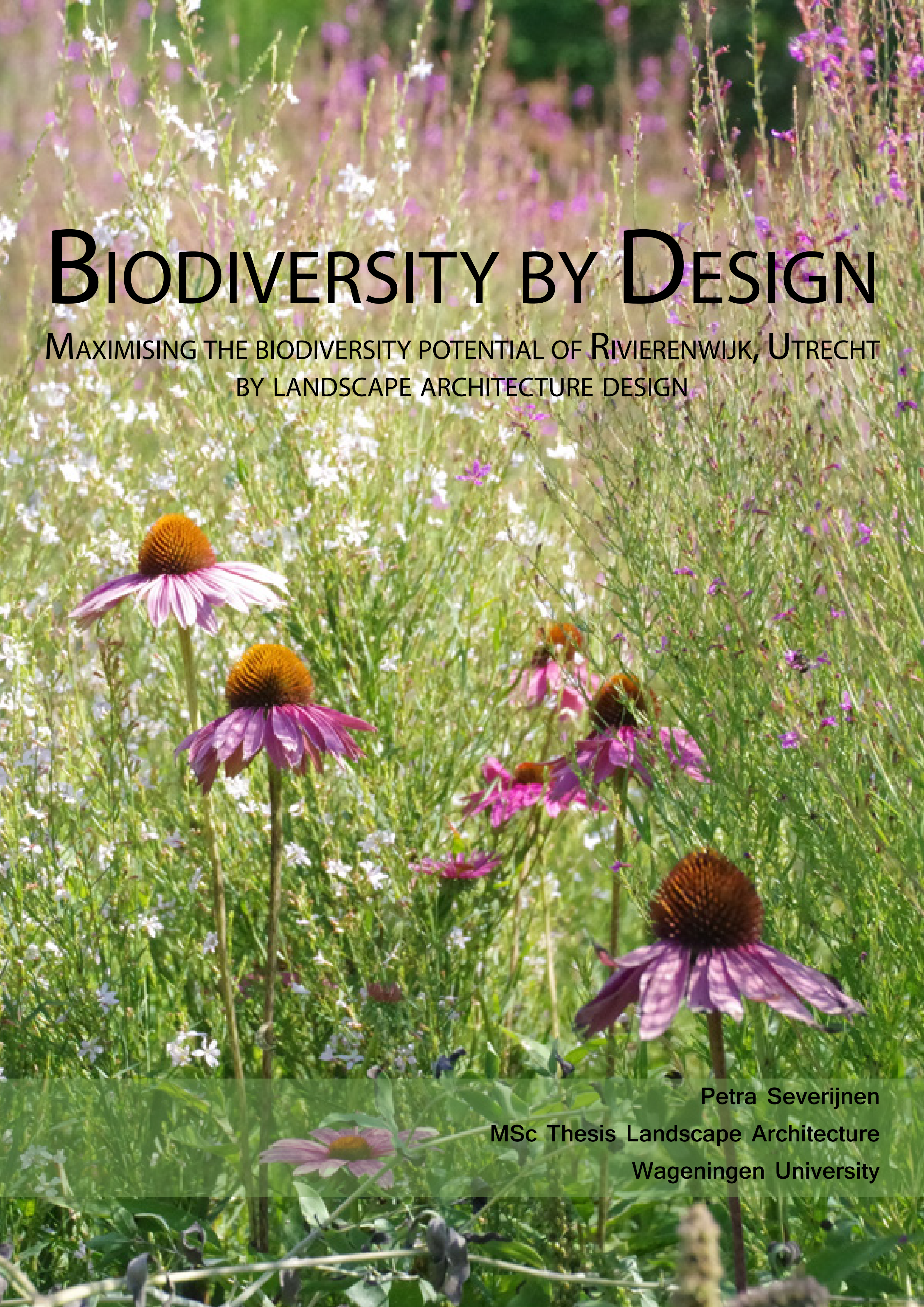
Biodiversity by Design

Maximising the biodiversity potential of Rivierenwijk, Utrecht by landscape architecture design



Petra Severijnen
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Wageningen University

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Petra Carline Severijnen
Registration number: 940603759030
MSc thesis Landscape Architecture, Wageningen University

Chair group Landscape Architecture
Phone: +31 317 484 056
E-mail: office.lar@wur.nl

Postal address
postbus 47
6700 AA Wageningen
The Netherlands

Visiting address
Gaia (building number 101)
Droevendaalsesteeg 3
6708 PB, Wageningen
The Netherlands

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Examiner
Prof. Dr. Ir. A (Adri) van den Brink
Wageningen University, Landscape Architecture group

Supervisor & examiner
Dr. Ir. R (Rudi) van Etteger
Wageningen University, Landscape Architecture group

Second supervisor
Dr. J (Juul) Limpens
Wageningen University, Plant Ecology and Nature Conservation group

“First, drink deeply from the natural history of the species you want to help. Study their reproductive cycles, their diets, and their behavior. Abstract the essence of their needs from what you observe. Then apply it without worrying whether your redesign of the human landscape will resemble a wilderness. It won’t, so feel free to be outrageously creative.”

Michael L. Rosenzweig, 2003

Preface

As most of my fellow students know, I have always been colouring outside the lines. This thesis has been no different. As such, I now present a comprehensive research on designing for biodiversity and a biodiverse design that pushes the boundaries of what is commonly acceptable in our current urban environment.

This thesis was sparked by my personal fascination for ecology and biodiversity in combination with landscape architecture. This fascination sprouted from my never-ending curiosity about all things nature that eventually led me to become a landscape architecture student. It was only during my study that I slowly discovered that ecology was often overlooked in landscape architecture education and practice. Which seemed like a strange disconnect to me, as I believe that ecology can be seen as the base for our discipline, in the way that nature, and thereby ecology, provides us to a large extent with the building blocks of our designs.

Altogether, this triggered me to familiarise myself with ecological design approaches, such as Sim van der Ryn and Stuart Cowan's 'Ecological Design', Timothy Beatley's 'Biophilic Cities' and Randolph Hester's 'Design for Ecological Democracy'. Though I was especially fascinated by the latter, it became apparent to me that these so-called ecological design approaches were more directed at establishing pleasant green environments for people than they were about integrating natural ecosystems in human environments. Though it is integral to our profession to design for people, I was hoping to learn about the latter.

So, when I got the opportunity to research how to design for biodiversity during my internship, I seized it with both hands. During that research I became aware of the extent of the gap between the fields of ecology and landscape architecture as described before, which I was not able to bridge in the limited available time. As such, I continued in this thesis, in the hope of inspiring others to do the same.

The process was not always easy. It would have been very unlike me to make things easy for a change. Therefore, I would like to thank everyone who helped and supported me during my thesis and with the personal struggles this thesis was accompanied by.

I would first like to thank my supervisors Rudi van Etteger and Juul Limpens for their help, support, and understanding. The critical reflections from both fields that come together in this thesis, landscape architecture and ecology, were very insightful. Thank you for helping me think outside the usual boundaries of the landscape architecture profession and thereby enabling me to create this thesis.

I would also like to thank my thesis room buddies, who (un)fortunately all graduated before me, and left me to finish by myself. Our exchange of critical thoughts, ideas and inspiration was very helpful in furthering my thesis. I am also very grateful for their company and the amazing working environment they helped to create, along with the much-needed distractions, of course.

And finally, I would like to thank my fantastic support system of friends and team mates, who had to suffer through my complaints, but refused to let me give up on myself.

I hope this thesis is an inspiration for others to follow in my footsteps, to challenge themselves and get off the beaten track.

Abstract

Fragmentation, degradation, and loss of habitats have caused serious loss of biodiversity. The main drivers behind these processes are of human origin: urbanisation and agriculture. While traditionally, conservation efforts have focussed on large natural areas, a shift towards urban areas is now clearly noticeable. It has become evident that urbanisation is one of the greatest threats to biodiversity. While at the same time, urbanisation poses great opportunities for the promotion of biodiversity. This is an opportunity to be grasped by landscape architects, as design will be essential in the conservation, protection or management of landscapes and habitats.

At the same time, current landscape architecture theory and practice does not suffice in providing landscape architects with the knowledge and tools to meet the biodiversity challenge. Current developments call for a new way of integrating ecological knowledge that is focussed more on ecological and biodiverse content in order to substantively address the loss of biodiversity in landscape designs, and thereby accommodate biodiversity conservation and strengthening.

This thesis expands the knowledge on designing for biodiversity by exploring how biodiversity can be integrated in urban landscape architecture. Thereby it addresses the overarching knowledge gap of how to design for biodiversity, specifically in urban areas. Related questions are answered in the process: which ecological knowledge is needed and/or relevant?; how can this knowledge be made applicable?; and what could that look like?

These questions are answered by developing biodiversity principles and guidelines that are accordingly applied on the case of Rivierenwijk in Utrecht to illustrate biodiversity by design. Thereby providing landscape architects with the knowledge and tools to maximise the biodiversity potential of their designs.

Keywords: landscape architecture, ecology, biodiversity, integrated approach, biodiversity potential, biodiverse design

Contents

1. Introduction

1.1 Biodiversity is under threat

In the course of their existence, humans have altered the world they inhabit. The earth's surface has increasingly and irreversibly been reshaped to accommodate human needs. More and more efficient ways have been and are being developed to exploit the landscape. The consequences for other species of flora and fauna have hardly been considered for a long time. However, these consequences can no longer be ignored (Bennett, 1999; CBD, 2000; McDonald et al, 2013).

Many natural areas have been altered and lost. Natural environments have been degraded. More and more species are disappearing (CBD, 2013; McDonald et al, 2013). Current extinction rates exceed the natural pace by 50 to 100 times. A number which is predicted to increase dramatically (CBD, 2000).

This loss of biodiversity is mainly caused by fragmentation, degradation and loss of habitats (Ahern et al, 2007; Beatley, 2000; Bennett, 1999; CBD, 2000; Farinha-Marques et al, 2011; Müller et al, 2013). These processes affect habitat size, shape, and distance between suitable habitats (i.e. isolation). In turn, alterations to these habitat characteristics will have an impact on ecological functions and processes, such as nutrient cycles, migration regimes, predator-prey relationships, etc. Fragmentation and isolation will likely limit population and gene flow, and will result in changes in species composition – specialist and sensitive species will disappear, leaving only generalist species –, but also in loss of species and entire populations or communities. The loss of populations can result in isolation of habitats, which are then no longer able to be (re)colonised (Ahern et al, 2007; Bennett, 1999; Fahrig, 2003; McDonald et al, 2013; Rosenzweig, 2003).

The main drivers of habitat fragmentation, degradation, and loss are of human origin (Ahern et al, 2007; Bennett, 1999; CBD, 2000; McDonald et al, 2013). Urbanisation (Elmqvist et al, 2013; Farinha-Marques et al, 2011; McDonald et al, 2013; Müller et al, 2013) and the transformation of land into agriculture (Ahern et al, 2007; CBD, 2000; Müller & Werner, 2010) have the largest impact. The advance of urbanisation and agriculture has coincided with environmental degradation, habitat loss and environmental change (McDonald et al, 2013). In addition, climate change will have a significant and growing impact in the future (CBD, 2000; PBL, n.d.; Solecki & Marcotullio, 2013).

1.2 Biodiversity loss in the Netherlands

The loss of biodiversity does not just occur in faraway tropical countries (Bennett, 1999). This loss has been larger in the Netherlands than average in Europe and the rest of the world. The extent of the loss of biodiversity is illustrated by the Mean Species Abundance (MSA), a biodiversity indicator that expresses the mean population size of native species in an area as opposed to these species' original occurrence. Though this indicator has been stable for the Netherlands over the past decades, the Dutch MSA only amounts to 15% opposed to 70% worldwide (figure 1.1, CBS et al, 2016).

In line with global trends, the loss of biodiversity in the Netherlands can be attributed to intensification of agriculture and urbanisation (figure 1.3). These processes have resulted in a decrease in habitat area as well as habitat quality (PBL, n.d.). As a result, populations of native species have declined and some species have even disappeared completely (CBS et al, 2016).

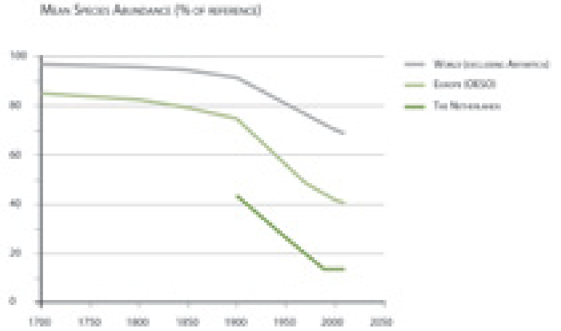


Figure 1.1 Graph illustrating the Mean Species Abundance for the Netherlands, Europe, and the world (adapted from CBS et al, 2013).

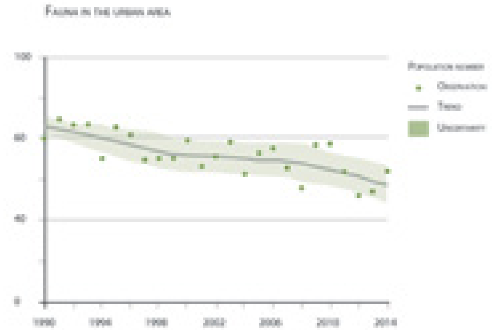


Figure 1.2 Graph illustrating the decline of fauna in Dutch urban areas since 1990 (adapted from CBS et al, 2015).

These effects have been even larger in urban areas as opposed to the stable biodiversity state of the rural landscape. The current estimated number of native species in the Netherlands amounts to over 45.000 (CBS et al, 2011; Lahr et al, 2014). About 10% of these species are predominantly urban, but the total occurrence of species in urban areas is larger (Lahr et al, 2014). Fauna in the urban area has declined since 1990 (figure 1.2). Over a course of 25 years, populations of breeding birds and butterflies have declined by 30%. This trend is mainly attributed to increasing compaction of the urban fabric and the transformation of lush green gardens into paved ones (CBS et al, 2015).

To mitigate the declining trends, the Dutch government has set a biodiversity target for 2020 to establish sustainable conditions for the preservation of all native species and populations as was their occurrence as measured in 1982 (Lahr et al, 2014, 2016; Opdam, 2010). To reach these targets, there is an increasing focus on biodiversity conservation and promotion in urban areas (CBS et al, 2015; Lahr et al, 2014; 2016).

1.3 Why should biodiversity be conserved?

Biodiversity is essential to sustaining life on earth (Ahern et al, 2007; CBD, 2000; Given & Meurk, 2000). Interactions between the various components of biodiversity make earth habitable for all species, including humans. Therefore, conserving biodiversity is of human self-interest (CBD, 2000).

There are many reasons to conserve biodiversity. First and foremost, biodiversity is at the basis of many ecosystem services that facilitate human welfare and livelihood (Ahern et al, 2007; CBD, 2000; Dearborn & Kark, 2010; Elmqvist et al, 2013; Farinha-Marques et al, 2011; Goddard et al, 2010; Harrison et al, 2014; McDonald et al, 2013; Nielsen et al, 2014; Schwarz et al, 2017). Ecosystem services are defined as "*the benefits human populations derive, directly or indirectly, from ecosystem functions*" (Costanza et al, 1997, p.253). For example, biodiversity improves regulatory services such as pollination, water flow regulation, and pest regulation. Biodiversity also provides benefits to cultural services such as recreation, and productive services such as the provisioning of building materials and food (CBD, 2000; Harrison et al, 2014). Besides providing opportunities for recreation and tourism,

Figure 1.3 An aerial photograph of Utrecht and its surroundings clearly shows the fragmented landscape of the Netherlands. Urban and agricultural lands dominate and fragment the remaining 'natural' landscape (Google Earth, 2018).

biodiversity plays other important cultural functions. Biodiversity plays an important role in forming a cultural identity. Cultural identity is rooted in the natural environment and biodiversity provides a sense of place (CBD, 2000; Miller, 2008). The cultural component of biodiversity becomes even more important in urban areas. As the world becomes increasingly urban, there are many people that only experience nature in urban areas (Dearborn & Kark, 2010; Müller & Werner, 2010). However, urban areas are facing a state of biological poverty, which occurs when urban citizens experience below-average levels of native species diversity on a daily basis (Farinha-Marques et al, 2011; Goddard et al, 2010). As a result of this shifting baseline, people are becoming increasingly disconnected from nature (McKinney, 2006). Preserving local important biodiversity – both in and outside urban areas -, and even rare and threatened species, enables people to reconnect with nature (Dearborn & Kark, 2010; Garrard et al, 2018; Goddard et al, 2010; Savard et al, 200). The preservation of local biodiversity also provides opportunities for environmental education, thereby building (active) support for biodiversity protection (Dearborn & Kark, 2010; Faeth et al, 2011; Farinha-Marques et al, 2011; Goddard et al, 2010; Nielsen et al, 2014; Savard et al, 2000).

Biodiversity also possesses benefits for human well-being. The beneficial effects of a natural environment on emotional and mental health are well-known (Faeth et al, 2011; Garrard et al, 2018; Goddard et al, 2010; McDonald et al, 2013; Miller, 2008). Positive psychological effects further increase with greater biodiversity (Dearborn & Kark, 2010; Fuller et al, 2007; Garrard et al, 2018). At the same time, a loss of biodiversity may have a negative impact (Miller, 2008).

Besides this, the loss of biodiversity interferes with the regulation of ecological functions (CBD, 2000), as also mentioned earlier in the introduction. Therefore, it is important to sustain viable populations and promote their dispersal (Dearborn & Kark, 2010).

The loss of biodiversity threatens all of these and more ecosystem services that human civilisations have been built on. Most of these services would be extremely costly or impossible to replace (CBD, 2000). As such, humans also have a moral obligation to preserve biodiversity and fulfil their ethical responsibilities towards the natural environment (Ahern et al, 2007; Dearborn & Kark, 2010).

1.4 A SHIFT TOWARDS URBAN AREAS

Traditionally, efforts to mitigate biodiversity loss have concerned the preservation or restoration of large natural habitats and ecosystems (Ahern et al, 2007; Bennett, 1999; Lovell & Johnston, 2009; Nielsen et al, 2014; Miller, 2008; Rosenzweig, 2003). This focus has led to an 'either, or' understanding of the environment. The natural landscape holds ecological relevance and should be preserved for species conservation, while the modified landscape serves its purpose for human use. As there is not much unmodified landscape left, it is time to start redefining this understanding and to start looking at the possibilities of promoting biodiversity in the modified landscape (Bennett, 1999; Rosenzweig, 2003; Weisser & Hauck, 2017).

In accordance to this view, efforts of mitigating biodiversity loss have started to shift towards urban landscapes. It has become clear that the urban realm provides major opportunities for conserving and promoting biodiversity as well (Alvey, 2006; Beatley, 2000; Felson et al, 2013; Garrard et al, 2018; Goddard et al, 2010; Ignatieva, 2010; Müller et al, 2013; Nielsen et al, 2014; Savard et al, 2000). Perhaps these opportunities are even larger than the opportunities that are held by the rural landscape (Farinha-Marques et al, 2011; Müller et al, 2013), as urban areas seemingly contain larger biodiversity than their rural surroundings (Alvey, 2006; Bräuniger et al, 2010).

Cities are disproportionally concentrated in areas with high ecosystem productivity and at junctions of ecosystems. Both characteristics support high levels of naturally occurring biodiversity (Given & Meurk, 2000; McDonald et al, 2013; Müller et al, 2013; Kühn et al, 2004; Nielsen et al, 2014). Besides this, urban areas often contain varied and distinctive habitats, among which relicts of natural and semi-natural habitats can be found (Faeth et al, 2011; Given & Meurk, 2000: Müller & Werner, 2010). In addition, urban areas contain unique ecological spaces through design, which can be inhabited by unique plant and animal communities (Kühn et al, 2004; Müller et al, 2013). Globally declining species can occasionally flourish in urban areas (Goddard et al, 2010; Ives et al, 2016; Lepczyk et al, 2017). Many species have also developed a dependence on urban areas (Müller et al, 2013), which can be attributed to a high food supply, a large variety of habitats, and the lack of predators (Müller & Werner, 2010).

As such, cities can play an essential role in meeting the CBD target of mitigating biodiversity losses, by:

1) sustaining ecosystem goods and services, 2) conserving existing biodiversity and promoting the design of urban areas to maximise their ability to support biodiversity, and 3) promoting awareness and influencing decision-making to create liveable spaces for both humans and plants and animals (Müller et al, 2013).

Even though cities are places with a high potential for biodiversity conservation and promotion, biodiversity also faces the greatest challenges in urban areas. These challenges can primarily be attributed to urbanisation and urban growth processes (Farinha-Marques et al, 2011; Nielsen et al, 2014). Already, 50% of human population resides in urban areas. A percentage that is estimated to increase to 70% in 2050 (UN, 2014). By 2030, the total urban area is expected to be three times as large as compared to its size in 2000 (CBD, 2012).

In addition to the beforementioned processes of fragmentation and loss of habitats, urbanisation is associated with processes as the introduction of exotic species – Fallopia japonica is a well-known example in the Netherlands (Nederlands Soortenregister, 2018) –, degradation and alteration of ecosystem processes and modification of natural disturbance regimes (Farinha-Marques et al, 2011; Garrard et al, 2018; Given & Meurk, 2000; Müller et al, 2013). Most of these processes are long-lasting and practically irreversible (McKinney, 2002; Rosenzweig, 2003). These processes result in a reduced species and genetic diversity, biotic homogenisation, and loss of ecological functions, such as air filtration and the regulation of water cycles (Faeth et al, 2011; Garrard et al, 2018; Given & Meurk, 2000; Goddard et al, 2010; McDonald et al, 2013; McKinney, 2002; Müller et al, 2013).

Of these results, biotic homogenisation is perhaps the most tangible. Biotic homogenisation concerns the process of replacing native species with increasingly widespread exotic species, leading to similarity between biotopes in different areas (McKinney, 2006; Nielsen et al, 2014). While exotic species were introduced purposefully for horticulture initially, they have now started to spread as invasive species (Müller & Werner, 2010). All over the world similar plant material is used, resulting in urban habitats with high resemblances. Though this phenomenon cannot fully be attributed to the use of similar plant material, cities hold surprising similarities concerning flora and fauna, independent of geographical and climatic differences. However, this phenomenon of homogenisation does lead to loss of identity and a sense of place (Ignatieva & Ahrné, 2013; McKinney, 2006).

It is clear then that urbanisation is one of the greatest threats to biodiversity (McKinney, 2002). While at the same time, it poses great opportunities for the promotion of biodiversity (Farinha-Marques et al, 2015; Garrard et al, 2018; Müller et al, 2013; Nielsen et al, 2014).

1.5 A new challenge for landscape architects

The threats that urbanisation poses for biodiversity and the opportunities that urban areas possess for the promotion of biodiversity can respectively be mitigated and seized by landscape architects and urban planners. Design will be essential in the conservation, protection and/or management of landscapes and habitats (Beatley, 2000; Felson et al, 2013; Ignatieva, 2010; Miller, 2008; Müller et al, 2013; Weisser & Hauck, 2017). By creating designs, landscape architects influence protection, change, and restoration of habitats (Ahern et al, 2007; Hunter & Hunter, 2008). In doing so, design and redevelopment can overcome some of the negative impacts of urbanisation, which in turn can have positive outcomes for biodiversity (Garrard et al, 2018).

Designing for biodiversity presents a relatively new challenge for landscape architects (Ahern et al, 2007), both in research and in practice. In the past decade, ecological problems, such as the loss of biodiversity, have been unsuccessfully addressed by ecological design approaches (Johnson & Hill, 2002; Miller, 2008; Spirn, 2014). Though these approaches draw from ecology, they often lack a deeper understanding of this field, due to an anthropocentric focus. Due to this lack of understanding, these approaches do not suffice in providing a base for landscape architects to substantively address environmental and ecological issues as the loss of biodiversity (Johnson & Hill, 2002). As a result, in practice the presence of animals is considered to be a sign of good biodiverse design, even though biodiverse considerations are not explicitly taken into account in the design process (Weisser & Hauck, 2017).

Current developments call for a new way of integrating ecological knowledge that is focussed more on ecological and biodiverse content in order to substantively address the loss of biodiversity in landscape designs, and thereby accommodate biodiversity conservation and strengthening (Johnson & Hill, 2002).

1.6 Thesis outline

In line with current developments, this thesis explores how ecological knowledge can inform landscape architecture design towards the conservation and strengthening of biodiversity in the urban realm. Thereby adding knowledge and tools to the toolbox of landscape architects to meet the biodiversity challenge.

The theoretical framework and knowledge gap that underlie this thesis are formulated in chapter 2. Chapter 3 addresses the research design, elaboration on the research objectives, questions, strategies and methods are formulated. Chapter 4 then explores the prerequisites of a biodiverse design. Thereby combining the perspectives of landscape architecture and ecology to develop principles and accordingly guidelines, based upon which the biodiversity potential of landscape architecture design can be maximised. The case study for which a biodiverse design is drafted, is introduced in chapter 5. The case study concerns a worst-case scenario in the form of Rivierenwijk in Utrecht. Chapter 5 also addresses the landscape and biodiversity analysis. Chapter 6 illustrates biodiversity by design. A biodiverse design is drafted for Rivierenwijk based on the outcomes of chapters 4 and 5. Based on these outcomes, models and design principles are drafted. These are accordingly translated into a design that is elaborated on in further detail. Lastly, chapter 7 finalises this thesis with a conclusion, a discussion of the research and its outcomes, and several recommendations for further research.

2. Theoretical framework

In order to identify the knowledge gap, light will be shed on the underlying theoretical background of the core subjects of this thesis. As such, an elaboration on biodiversity, and more specifically urban biodiversity, as well as how biodiversity is accommodated in current landscape architecture theory and practice is provided below. The discussion of these subjects, based on a review of current literature, will result in the identification of the knowledge gap.

2.1 Biodiversity and urban biodiversity

2.1.1 Definitions

Biodiversity, or biological diversity, has been defined by the Convention on Biological Diversity (CBD) as "*the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems*" (CBD, 1992, p.3). In other words, biodiversity can be described as the diversity in life forms (i.e. species richness in flora and fauna) and in ecosystems all over the world or in a specific place (Townsend et al, 2003).

There are three important notions to the understanding of biodiversity: 1) gaining an understanding of biodiversity requires a multiple scale approach (Ahern et al, 2007; Nielsen et al, 2014); 2) biodiversity cannot be separated from its physical environment (Ahern et al, 2007); and 3) biodiversity is essential to ecological processes and other functional aspects of ecosystems (Ahern et al, 2007; Farinha-Marques et al, 2011; Vold & Buffet, 2003). Besides this, biodiversity is related to socio-economic, aesthetic and ethical values (Dearborn & Kark, 2010; Farinha-Marques et al, 2011).

Urban biodiversity can be defined as: *"the variety and richness of living organisms (including genetic variation) and habitat diversity found in and on the edge of human settlements*" (Müller et al, 2010, p.xvii). Urban biodiversity is determined by planning, design and management of the built environment (Müller et al, 2010). Urban biodiversity often represents a biodiversity that is purposefully created by humans for humans (Elmqvist et al, 2013). As such, urban biodiversity reflects human culture (Farinha-Marques et al, 2011). Therefore, the general image of urban biodiversity concerns tight control, high amounts of manipulation and intensive management (Faeth et al, 2011).

Urban biodiversity is distinct from that of other areas on a number of aspects: 1) cities have distinct physical and ecological conditions; 2) cities contain a patchy, small-scale and highly diverse habitat mosaic; 3) cities harbour unique habitats with distinct dynamics, ecology and value, created by a combination of native and purposefully introduced exotic species; and 4) urban habitat types and communities differ significantly from those of other ecosystems (Bräuniger et al, 2010; Elmqvist et al, 2013; Faeth et al, 2011; Farinha-Marques et al, 2011; Müller & Werner, 2010).

2.1.2 Levels of biodiversity

Biodiversity can be regarded on different levels: genetic, species, and ecosystem.

Genetic diversity forms the basis for all biological diversity. It is concerned with the variation of genes within species, within populations and between populations of the same species (Ahern et al, 2007). Genetic diversity enables species to adapt to changing circumstances in order to secure their survival (Townsend et al, 2003; Vold & Buffet, 2008).

The species level is most commonly researched, as it is well-defined, quantifiable and easily monitored. This level refers to the variation of species within an area (Ahern et al, 2007). Species richness is the most used metric to describe the species level of biodiversity (Ahern et al, 2007; Farinha-Marques et al, 2011; Townsend et al, 2003). Species richness entails the absolute number of species that are present in a certain habitat. Abundance is another important metric. Abundance reflects the distribution of species presence relative to the presence of other species. Thereby this metric provides more information about the relative importance of the preservation of a community (Duelli & Obrist, 2003; Noss, 1990).

The ecosystem level reflects the geographic dispersion of species and communities over different ecosystems (Townsend et al, 2003). This level also concerns the ecological function of species, and the ecological processes within and between ecosystems (Ahern et al, 2007). An ecosystem is a dynamic and complex community of animals, plants and micro-organisms, complemented by abiotic elements. The collective functioning of these elements forms the basis of the ecosystem (Vold & Buffet, 2008). This level is of main importance when investigating threat of extinction and preservation of evolutionary diversity (Townsend et al, 2003).

The species and ecosystem levels are often emphasised in landscape architecture, as these levels are regarded to be affected easily and directly by design interventions (Müller et al, 2013). However, all levels hold significance. The genetic level should be considered as well, as this level is also affected by the configuration of the landscape (Ahern et al, 2007; Townsend et al, 2003). For example, fragmentation of habitats leads to smaller and isolated populations, these populations are expected to lose genetic variation. On the other hand, increasing connectivity of habitats promotes migration. The gene flow that is provided by migration leads to an increase of genetic variation (Townsend et al, 2003).

2.1.3 Ecological theories

The distribution of biodiversity can be explained by different theoretical models. The theories of species-area relationships and island biogeography are considered to hold the largest explanatory value for biodiversity levels (Bennett, 1999; Rosenzweig, 2003). Additionally, the urban-rural gradient is often used to explain biodiversity levels in urban areas (Faeth et al, 2011; McKinney, 2002; Müller & Werner, 2010).

Species-area relationships explain that the number of species present in an area is dependent on the area's size. The larger an area, the more species it contains (Rosenzweig, 2003). An increase in habitat area thus accounts for an increase in species richness (Norton et al, 2016). However, this is a process with diminishing returns (Rosenzweig, 2003). In addition, larger areas typically contain a larger diversity of habitats and therefore more habitat-restricted species. In urban areas, there seems to be a threshold to the influence of a size of an area on the species richness that is quickly saturated (Norton et al, 2016).

Island biogeography explains that the species richness of an area depends on the size of the area, as well as the distance to other habitats and source populations. This effect is determined by the rates of immigration and extinction. Immigration depends on the degree of isolation, whereas extinction is determined by the size of an area (Bennett, 1999; MacArthur & Wilson, 1967; Rosenzweig, 2003; Townsend et al, 2003). This theory can predict the success rate of the colonisation of habitats. Small and isolated patches, which are predominant in urban areas, support few species as migration and resources are limited. Populations in such patches are evidently more prone to extinction. The reverse applies to large and well-connected areas (Faeth et al, 2011; MacArthur & Wilson, 1967; Rosenzweig, 2003; Townsend et al, 2003).

The urban-rural gradient theory explains that increased levels of urbanisation have a negative effect on species richness. A loss of species richness can be observed in urban areas along a gradient from the rural surroundings to the city centre. The urban-rural gradient can also be seen as a gradient of habitat loss (Faeth et al, 2011; McKinney, 2002; Müller & Werner, 2010). Urbanisation acts as an environmental filter that excludes species with specialised habitat requirements. Isolation causes species assemblages to change into more generalist species and exotics as sensitive species and specialists move away (Nielsen et al, 2014). However, there are examples in which this theory does not apply. Species richness can peak at intermediate levels of urbanisation due to intermediate levels of disturbance (Faeth et al, 2011; McKinney, 2002; Müller et al, 2013). As the intermediate disturbance hypothesis exemplifies: urbanisation can be seen as a gradient of disturbance, "intermediate frequencies of disturbance promotes coexistence by preventing competitive dominants from excluding species" (Faeth et al, 2011, p. 75).

2.2 Biodiversity in landscape architecture

Biodiversity efforts in landscape architecture can be divided into theory and practice. In the theoretical realm, biodiversity is appropriated by a long-standing tradition of ecological design approaches. In practice, biodiversity is implicit in all work of landscape architects and planners, but only recently more explicit efforts are emerging. Both theoretical and practical efforts (perhaps in disregard of more recent work) are often criticised.

2.2.1 Ecological design theories

In the last decades, a growing amount of (design) theories have emerged that attempt to mitigate the effects of landcover change on biodiversity (Gagné et al, 2015; Garrard et al 2018). On the one hand there are branches within the field of ecology that attempt to distil practical and/or applicable knowledge from ecological theory and provide guidelines for applying this knowledge to shaping the landscape. Of main interest are landscape ecology (e.g. Dramstad et al, 1996; Forman, 1995, 2008; Forman & Godron, 1986; Odum & Barret, 1971) and urban ecology (e.g. Forman, 2014; Gaston, 2010; Niëmela et al, 2011). On the other hand, there is a niche within landscape design that devotes itself to the inclusion of ecological concepts. This niche exists out of a variety of design philosophies, which can be gathered under the name of ecological design (e.g. Beatley, 2011; Beatley & Manning, 1997; Palazzo & Steiner, 2012; Spirn, 2014; Steiner, 2012; Van der Ryn & Cowan, 2013).

There are two main differences between these two sides of the interface between landscape architecture and ecology. First, ecological design has a strong anthropocentric focus at the expense of in-depth ecological knowledge (Johnson & Hill, 2002), which is provided in applied ecological theory. And second, applied ecological theory is mainly descriptive (Opdam et al, 2001), as opposed to the more, but not necessarily, prescriptive nature of ecological design. Both applied ecological theory and ecological design are joined under the concept of ecological design theories in this thesis.

Ecological design theories claim to have found the solution to the biodiversity challenge, but they often fail to "*bridge the gap between generalization and application*" (Opdam et al, 2001, p.768, figure 2.1). The provided principles are often too broad and theoretical to be readily applied (e.g. Forman, 1995). As they rarely provide specific guidelines or interventions for implementation, it is hardly possible to translate these theories into landscape designs that substantively accommodate biodiversity (Gagné et al, 2015; Miller, 2008; Nassauer & Opdam, 2008). Even if, as argued by Forman (2008) these theories "*are to be creatively and intelligently used*" (p.224), and are "*mixed with imagination and inspiration to produce solutions for the land*" (p.223). In addition, these non-prescriptive guidelines are often complex or too technical (e.g. Brown, 2013; Brown et al, 2011) or difficult to interpret (Gagné et al, 2015).

Neither do these theories explain how to balance biodiversity goals with other objectives and socio-economic constraints (Gagné et al, 2015; Garrard et al, 2018). Gagné et al (2015) add to this list of limitations that ecological design guidelines often include numerous items (e.g. Dramstad et al, 1996; Forman, 2008), which are rarely presented in a sequential manner. The latter becomes problematic when there are mutually-conflicting items. As such, the application of ecological design theories has been very limited (Gagné et al, 2015; Garrard et al, 2018).

Another point of critique is delivered by Gagné et al (2015), stating that the application of these theories is restricted by the requirement of species-specific information. Research is often performed on single species, but results are rarely translated into "*generalized knowledge on the relation between landscape pattern and biodiversity*" (Opdam et al, 2001; p.768). This precise knowledge would be very helpful for landscape designers, as it would eliminate their need of detailed ecological understanding – which they generally do not obtain in their education (Johnson & Hill, 2002; Nassauer, 2002) – by providing a general understanding of a variety of species responses to the landscape and specific landscape patterns (Opdam et al, 2001). On the other hand, species-specific information is in fact essential to provide direction to a design (Weisser & Hauck, 2017).

Besides these limitations, there are other problems with ecological design theories. Despite recognising the importance of biodiversity, ecological design theories often fail to accomplish a full inclusion of the concept as they are mainly directed at cultural well-being (Johnson & Hill, 2002). As such, these theories translate a general understanding of ecological principles as diversity, scale and connectivity into designs that are directed at creating green and pleasant environments that are optimally adjusted to and supportive of human needs (e.g. Beatley, 2012; Hester, 2006; Palazzo & Steiner, 2012; Spirn, 2014; Van der Ryn & Cowan, 2013). Furthermore, included design propositions are often (very specific) standard solutions, such as creating green roofs or providing nesting facilities for certain animals (Ignatieva, 2010).

Figure 2.1 Ecological design claims to be the solution to the biodiversity challenge, but fails to do so. Ecological design is therefore not biodiverse design.

2.2.2 Biodiverse design in practice

"*Biodiversity is already implicit in virtually all of the work of planners and landscape architects, and many signs point toward increased global interest and support for biodiversity planning*" (Ahern et al, 2007, p.4). Often unintentionally, most designs alter spatial configurations, and thereby ecological patterns and processes (Ahern et al, 2007).

However, biodiversity is usually not the driver behind design projects. If explicitly stated as a goal at all, biodiversity is often secondary or minor to other rationales for promoting green space in urban areas (Ahern et al, 2007; Norton et al, 2016). In practice, any urban green project is assumed to increase biodiversity levels (Lepczyk et al, 2017; Norton et al, 2016; Schwarz et al, 2017; Weisser & Hauck, 2017), but other project or management goals might in fact conflict with biodiversity goals (Norton et al, 2016). A complex ecological approach in which not only the appropriate plant material is selected but also wildlife is attracted is still under development (Ignatieva, 2010).

As mentioned in the introduction, biodiversity is a relatively new focus area for landscape architects. For landscape architects to fulfil their role as potential protectors and restorers of biodiversity, it is important to integrate biodiversity goals at the core of their projects. (Ahern et al, 2007). Biodiversity goals, as such, need to be well defined (Norton et al, 2016; Weisser & Hauck, 2017).

Achieving these goals requires an interdisciplinary approach (Ahern et al, 2007; Felson, 2016). Landscape architects are often not experts in ecology and are therefore reliant on ecologists (Ahern et al, 2007). However, when looking at the involvement of ecological experts in landscape design, it becomes apparent that the involvement of ecologists is generally limited to the initial assessment of the landscape (Lovell & Johnston, 2009). In some cases, ecological experts are also involved in other stages, however, their involvement is usually restricted to a review of the steps that have been taken and advice on how to improve on them (Felson et al, 2013). Both Lovell & Johnston (2009) and Felson et al (2013) argue that there are many more aspects of landscape design, such as the actual drafting of a design, in which ecologists should be involved actively in order to create wholesome ecological designs.

Current designs are based upon translations of broad ecological theory. Often these theories represent solutions that may not even be applicable in urban contexts. Designers may also not fully understand ecological theories and thereby even employ the wrong theories (Felson, 2016). Another problem for landscape architects with the creation of biodiverse designs is that often information is missing. Site- and species-specific information can be difficult to obtain (Ahern et al, 2007; Lepczyk et al, 2017; Lovell & Johnston, 2009), while generalised knowledge on species responses on landscapes and landscape patterns are also lacking (Opdam et al, 2001). Additionally, monitoring is rarely conducted due to which it remains unclear if biodiverse projects achieve the intended results (Ahern et al, 2007; Lepczyk et al, 2017; Lovell & Johnston, 2009). And similarly, there is limited involvement and/or peer review by ecological experts to ensure that designs are ecologically sound (Felson, 2016). These shortcomings limit the ability of landscape architects to learn from their projects and develop their designs to address biodiversity more effectively (Ahern et al, 2007; Lepczyk et al, 2017; Lovell & Johnston, 2009).

The lack of a sound basis for biodiverse designs has not stopped developments from continuing. Many cities and governments have taken up the biodiversity challenge and are now actively working on biodiversity plans (e.g. Marie de Paris, 2018). In the Netherlands, the government is mainly focusing on building inhabiting species in urban areas (RVO, n.d.). Large interventions in public space to accommodate biodiversity, such as the biodiversity plan for Barcelona (Ajuntament de Barcelona, 2013) are still scarce.

2.2.3 Knowledge gap

As has been illustrated above, a multiplicity of knowledge gaps can be identified in the interface between landscape architecture and ecology. For example: a lack of applicable theoretical knowledge, as the available knowledge from design theories is often untranslatable into practice for several reasons (Gagné et al, 2015; Miller, 2008; Nassauer & Opdam, 2008; Opdam et al, 2001). But also, a lack of knowledge on how to design for biodiversity and to thoroughly inform these designs, resulting in unsubstantial designs (Lepczyk et al, 2017; Norton et al, 2016; Schwarz et al, 2017; Weisser & Hauck, 2017).

This multiplicity in knowledge gaps can be attributed to several causes, which can be gathered under the lack of an integrated approach between the fields of landscape architecture and ecology (Ahern et al, 2007; Johnson & Hill, 2002; Lovell & Johnston, 2009; Nassauer, 2002). There is insufficient communication between the two fields, as well as a lack of applied research to inform biodiverse design and provide guidelines (Lovell

& Johnston, 2009; Nassauer & Opdam, 2008). Similarly, there is a need for a more experimental – or exploratory – approach to the application of ecology in design (Felson et al, 2013) in contrast to the current situation in which "*the contribution of ecology to the design process, beyond initial landscape assessment, has been limited*" (Lovell & Johnston, 2009, p.212).

Researchers and practitioners have not managed to come up with a way to fully integrate ecological knowledge in the landscape architecture design in order to conserve or strengthen biodiversity on either side of the realm (Ignatieva, 2010). Though examples can be found that address ecology in a more substantive way (e.g. Beatley, 2000; Brown, 2013; Felson et al, 2013; Lovell & Johnston, 2009; Palazzo & Steiner, 2012), there is no existing design approach that describes how to design for biodiversity (Lovell & Johnston, 2009). Since addressing the whole range of knowledge gaps, as illustrated above, will extend far beyond what is feasible, this thesis focusses on the question of how to design for biodiversity, specifically in urban areas (figure 2.2). It is therefore important to ask the following questions: which ecological knowledge is needed and/or relevant?; how can this knowledge be made applicable?; and what could that look like?

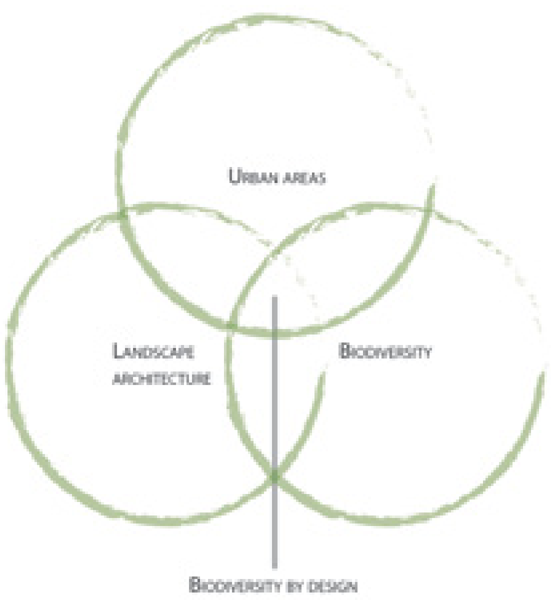


Figure 2.2 The knowledge gap for this thesis addresses the question of how to design for biodiversity in urban areas.

As Nassauer (2002) exemplifies: "*landscape architects need to become sufficiently expert in ecology to draw from it directly*" (p.222) as this could lead to the "invention of landscapes that meld ecological processes into valued places for human experience" (p.228). It seems to be the right time to provide landscape architects with the appropriate knowledge and tools to do so.

3. Research design

Within the research design, the perimeters of the research and design that has been executed in this thesis are defined. Firstly, the problem and objective are briefly reiterated, after which the research and design questions are presented. This is followed by an elaboration of the research strategy and accompanying methods. This chapter finalises with a statement about the significance, validity and reliability of the research and design.

3.1 Problem statement

Both researchers and practitioners recognise the potential role of planners and architects towards conservation or even strengthening of biodiversity, especially in urban areas (Beatley, 2000; Felson et al, 2013; Ignatieva, 2010; Müller et al, 2013). However, researchers and practitioners have not yet come up with a way of integrating ecological knowledge in landscape architecture design that provides landscape architects with the knowledge and tools to maximise the biodiversity potential of their designs (Igantieva, 2010; Johnson & Hill, 2002; Lovell & Johnston, 2009; Nassauer, 2002). Though landscape architects have the potential to make a difference, they do not yet have the means to do so.

3.2 Research objective

The objective of this thesis is to expand the knowledge on designing for biodiversity by exploring how biodiversity can be integrated in urban landscape architecture. Besides the overarching question of how to design for biodiversity, specifically in urban areas, this thesis will also provide answers to the following related questions: which ecological knowledge is needed and/or relevant?; how can this knowledge be made applicable?; and what could that look like? By answering these questions, the objective of providing landscape architects with the knowledge and tools to maximise the biodiversity potential of their urban designs is achieved.

3.3 Research and design questions

The main research and design question to be answered in this thesis is as follows:

How can the biodiversity of urban areas, such as Rivierenwijk, be maximised by landscape architecture design?

This question will be answered by the help of several sub-questions:

1. Which principles and design guidelines concerning biodiversity can be developed?

2. What is the biodiversity of Rivierenwijk and what is its biodiversity potential?

3. How can these principles and guidelines be employed to maximise the biodiversity potential of Rivierenwijk and similar urban areas?

There are two side notes to be made concerning these research questions:

1. Maximising the biodiversity could simply mean eradicating the neighbourhood and developing nature in its place. This is not the intention or purpose of this thesis. The neighbourhood should remain functional even with a maximised biodiversity.

2. Maximising biodiversity could entail introducing as many species as possible to the neighbourhood that are not necessarily native or suited to the local ecosystem. This is not the intention or purpose of this thesis either. The newly introduced biodiversity or created potential should suit the local system and be able to maintain itself in that system.

3.4 Research strategy

The research for this thesis is aimed at exploring how landscape architecture design can maximise the biodiversity potential of (sub-)urban neighbourhoods. Though the research is performed for one specific case, the findings are made generalisable for broader application. Thereby expanding landscape architects' knowledge and tools to design for biodiversity in urban areas.

Since there is little available knowledge, this involves developing theory – or meaning – on how this can be done. As such, this research is conducted from a constructivist worldview. Entailing that theory is generated through interpretation of both personal values and of sources that have been drawn on, instead of starting with a predefined theory. Consequently, a qualitative approach will be assumed regarding this thesis. Meaning that qualitative methods of inquiry will be used to collect and analyse qualitative, open-ended data (Creswell, 2014).

In this thesis, the research strategies of research for design and research through design are combined. The main research strategy is research for design, whereby research is employed to inform the creation of a design (Lenzholzer et al, 2013). This strategy is used to gather the necessary information that is required to design for biodiversity, for example information about the current biodiversity of the site, and foraging and habitat requirements of target species.

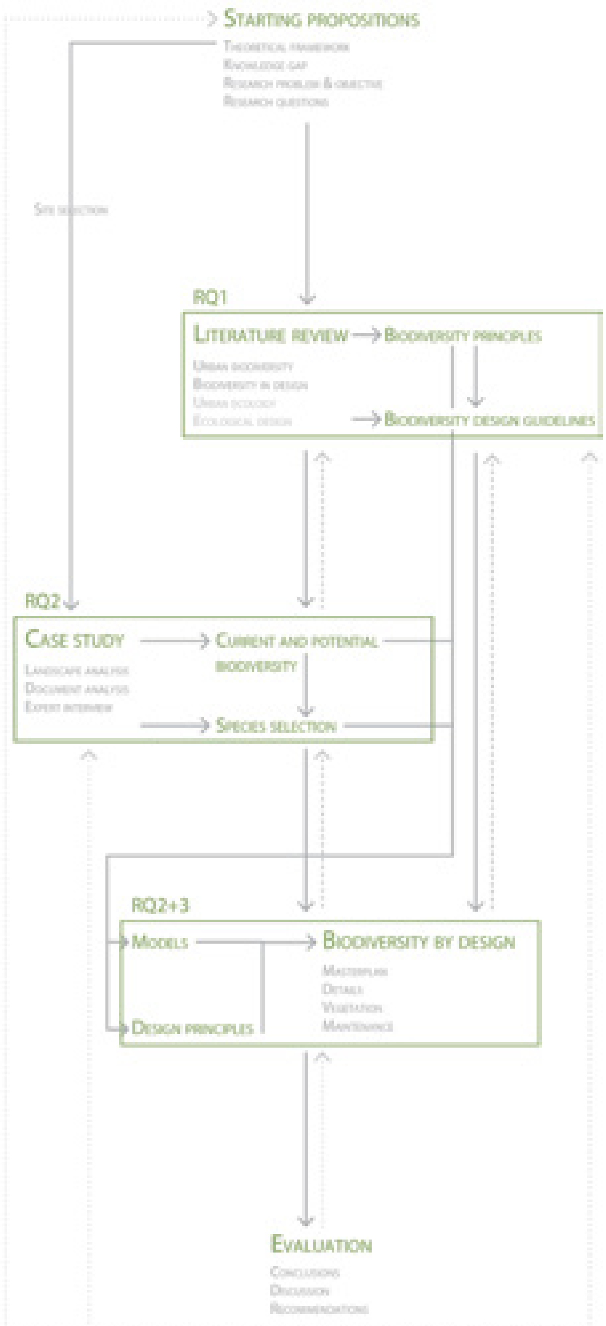


Figure 3.1 Flowchart depicting the research strategy and methods for this thesis.

In the strategy of research through design, the activity of design itself becomes a research method. Through designing, new knowledge is generated (Lenzholzer et al, 2013). To elaborate, this strategy is employed to translate theoretical outcomes of the performed research, for example biodiversity principles, into a biodiverse design. The outcomes are evaluated during the design process, which can lead to new input for further design exploration.

This research is characterised by an explorative and interpretive nature as it is performed in an upcoming field in which little concrete knowledge is available. Exploratory research is directed at investigating unexplored grounds and thereby characterises an emergent research design (Hannington & Martin, 2012; Hesse-Biber & Leavy, 2010; Lenzholzer et al, 2013). An interpretive approach focuses on the seeking meaning or understanding of a certain phenomenon. This meaning is constructed from the interpretation of sources about the subject at hand (Deming & Swaffield, 2011; Hesse-Biber & Leavy, 2010). The interpretation of results is highly dependent on the researcher and cannot be seen as completely objective. Therefore, it is important that there is a critical reflection on the role of the researcher on the outcomes of this thesis (Creswell, 2014; Deming & Swaffield, 2011).

3.5 Methods

A variety of qualitative methods is employed to perform the research for this thesis. Each of these methods is described below, along with the knowledge that is generated by their use. Figure 3.1 depicts how the strategies and methods are interrelated in the research and design process of this thesis.

3.5.1 Literature review

A literature review is performed in order to gain an understanding of the factors that influence biodiversity levels in a landscape (see section 4.1 on biodiversity principles), and accordingly provide basic input for the development of biodiversity design guidelines (section 4.2).

The leading literature sources that are investigated concern the subjects of urban biodiversity and biodiversity in design. With these subjects as a starting point, other relevant literature is reviewed to provide additional input, e.g. literature on urban ecology and ecological design. The main criterion for the selection of sources is their relevance for landscape architecture design, i.e. sources (1) contain any direct links to design or (2) contain knowledge or tools that can be made applicable for design.

Correspondingly, the relevant sources are reviewed for: (1) readily established guidelines, (2) direct links to design or application, and (3) other relevant knowledge or tools that are indirectly linked to design.

3.5.2 Case study

Following the literature review, a case study is performed (chapter 5). A case study is useful in exploratory research in order to research the effects of a new program (Hannington & Martin, 2012). In this instance, the case is used to explore how the application of the biodiversity principles and guidelines can be employed to maximise the biodiversity of the case. But before this, the case study first explores the current state of the biodiversity of the site in order to illustrate the additive biodiversity value of the design exploration. In accordance to the case study exploration, a design for the case is drafted and guidelines for application in other cases are derived from the case study and design exploration.

The case for this thesis is Rivierenwijk in Utrecht. This case has been selected according to the following criteria: (1) the site concerns an urban neighbourhood, (2) information about the existing biodiversity of the site (and its surroundings) is available or can be obtained, (3) the site possesses a low level of biodiversity, (4) there are opportunities to promote the biodiversity of the site.

Rivierenwijk does not serve as a representative case for average Dutch neighbourhoods. Instead, Rivierenwijk can be seen as an extreme or extraordinary case that represents a worst-case scenario, making it a relevant case for this thesis (Hannington & Martin, 2012).

The case study results in an overview of the current and potential biodiversity of Rivierenwijk, as well as a selection of species. In order to obtain these results, several methods are employed within the case study: a landscape analysis, a document analysis, and an expert interview.

Landscape analysis

A landscape analysis is performed based on (interactive) maps, site visits and photographs in order to gain an understanding of the Rivierenwijk and its surroundings, the current biodiversity and the biodiversity potential. During the site visits, first person observation is employed. The observations are recorded by photographs and field notes.

Document analysis

The document analysis is employed to gain an understanding of the site and its context, the municipality's biodiversity policy, and the direction of future urban developments within Utrecht. Municipality policy documents concerning green policy, Rivierenwijk and its encompassing district Zuidwest, and future urban developments are reviewed. The document analysis is also used to supplement and verify the results of the landscape analysis.

A document analysis is also performed to gain an understanding of the habitat and foraging requirements of the selected target species. The main sources are government issued research documents.

Expert interview

An expert interview is held with Mies van Aar, city ecologist of the municipality of Utrecht (appendix B). This interview is held in order to gain an understanding of the ecology and biodiversity policy of the municipality and how this policy is translated into practice. Specifically concerning Rivierenwijk, the interview is aimed at gaining an idea of relevant target species groups, as well as to verify results of the landscape and document analysis. Lastly, a notion of the direction of future developments in the municipality is obtained.

3.5.3 Design

The results from the literature review and the case study are congregated in order to create a design for Rivierenwijk to exemplify biodiversity by design (chapter 6). The design phase consists out of multiple iterative and intertwined rounds of design. After each round, new input is provided to further develop and specify the design.

In contrast to existing ecological design approaches – i.e. those approaches that have an anthropocentric focus –, the design process for this thesis is directed at optimally accommodating the selected target species, based on their habitat and foraging requirements, as well as on the biodiversity principles. Humans usually take a central stage in urban design. While they will be taken into account, fauna and flora are given priority.

Firstly, the biodiversity principles and the potential biodiversity of the site are combined to create four alternative design models. These models are then evaluated according to their potential effect on the biodiversity of Rivierenwijk as well as on their impact on the functionality of the neighbourhood, and a preferred model is selected. Secondly, the biodiversity principles and guidelines are combined with the habitat and foraging requirements of the selected species groups to create design principles. Then, these principles are employed for the elaboration of the preferred model for a section of the neighbourhood, forming the masterplan. Accordingly, design details, a vegetation selection and a maintenance scheme are drafted as an elaboration of the masterplan. The result of the design illustrates how the biodiversity potential of Rivierenwijk can be maximised. This result is evaluated and reflected on in order to distil general recommendations for biodiverse design that in turn might be applied in other cases.

3.6 Validity and reliability

It is important to ensure the validity and reliability of the research at hand. Validity in qualitative research concerns itself with the plausibility and credibility of the results (Creswell, 2014; Deming & Swaffield, 2011; Hesse-Biber & Leavy, 2010). Creswell (2014) mentions several strategies to implement in a research to ensure validity. In this research, the main strategy is triangulation of methods and results. Triangulation is used to affirm research outcomes from different angles by converging multiple methods or sources for the same research question (Deming & Swaffield, 2011; Denzin, 2017; Hannington & Martin, 2012; Hesse-Biber & Leavy, 2010). In this case, both methodological and theoretical triangulation are employed. The former entailing that multiple methods are used, the latter that different theoretical perspectives are used to examine the subject at hand (Denzin, 2017). As such base knowledge is gathered using a literature review, after which this knowledge is supplemented by an expert interview and document analysis. Sources are used from both a landscape architecture and an ecology perspective, and outcomes are converged.

Reliability is concerned with the consistency of the executed research (Creswell, 2014). As Deming & Swaffield (2011) emphasise: "*the question of reliability in design research relates not to the specific details of every step in a process, but to the overall logic and structure of the investigation*" (p.207). Additionally, reliability is concerned with the extent to what the research is repeatable. A single case is never enough to support or reject a hypothesis, but it might shed light on theory. In order to establish undisputable reliability in a research, ideally its findings should be cross verified by different investigators or in different cases (Creswell, 2014; Hannington & Martin, 2012; Sommer & Sommer, 2002). As cross verifying the research is not possible for this thesis, this report contains a careful documentation of the entire procedure of the investigation and all steps taken in the research and design process. Similarly, all the decisions that are made during the research and design process are described and substantiated and thereby made insightful. Both actions ensure that other researchers are able to validate this research and continue or repeat it.

4. Designing for biodiversity

In order to be able to design for biodiversity, it is important to know what ecological knowledge is needed and/or relevant. Similarly, it is important to know how to apply this knowledge in a design. As such, factors that influence the biodiversity level of an area are investigated and reformulated into biodiversity principles (section 4.1). Section 4.2 then explains how to approach a design for biodiversity. The steps that are needed to be taken in the design process and what other things to consider are explained in terms of biodiversity design guidelines.

4.1 Biodiversity principles

Factors that influence the level of biodiversity of an area can roughly be divided into two groups: landscape and local factors (Beninde et al, 2015; Farinha-Marques et al, 2011; Müller et al, 2013). Below, the most important landscape and local factors, and how they influence biodiversity levels, will be explained.

4.1.1 Landscape factors

Landscape factors determine habitat quantity. These factors are concerned with the spatial layout and distribution of habitats. Thereby landscape factors define the permeability of the landscape for species dispersal (Beninde et al, 2015; Bennett, 1999). The most important landscape factors are habitat area (or patch size) and habitat connectivity.

Landscape factors are good predictors for the level of biodiversity in terms of general species richness (Beninde et al, 2015; Garden et al, 2007; Goddard et al, 2010). This relation can be explained by species-area relationships and island-biogeography theories as elaborated on in section 2.1.3. Roughly stated: the larger an area is, the more species it is potentially able to harbour (Alvey, 2006; Cornelis & Hermy, 2004; Fahrig, 2003; Gagné et al, 2015; Nielsen et al, 2014; Norton et al, 2016; Rosenzweig, 2003). Similarly, the more connected an area is, the more species are potentially able to find their way there (Bennett, 1999; Farinha-Marques et al, 2011; Savard et al, 2000).

In urban areas, a limited patch size and a high level of isolation result in a change of species assemblages. Highly urbanised areas often contain more generalist species and exotics, while specialists and sensitive species disappear. To maintain the latter, it is therefore important to provide sufficient habitat area and connectivity (Bräuniger et al, 2010; Nielsen et al, 2014). Shwartz et al (2013) discovered that even small changes in area may already increase biodiversity. The largest benefits to urban biodiversity will be obtained by spatial arrangements in which habitat area is maximised and isolation is minimised (Goddard et al, 2010).

However, merely increasing the size of an area will not necessarily increase the species richness. The species richness of large areas is also attributed to the fact that they often contain a larger diversity of habitats than smaller areas do (Cornelis & Hermy, 2004; Nielsen et al, 2014; Rosenzweig, 2003; Werner & Zahner, 2010). So, it is important to not only expand an area to the largest extend possible, but also to diversify the habitats an area contains (Farinha-Marques et al, 2011; Gagné et al, 2015; Goddard et al, 2010; Lovell & Johnston). Diversifying habitats can be done by varying local factors, which will be explained in the next section.

Connectivity is second to habitat area in terms of influencing species richness. Connectivity facilitates species movement between patches (Bennett, 1999). A determinant is therefore the distance between habitat patches (Beninde et al, 2015). The level of connectivity in a landscape can vary highly for different species. For highly mobile species with a wide range – e.g. birds –, high connectivity is much easier achieved than for less mobile species – e.g. small mammals. The second group will require a much more fine-grained configuration, consisting of a continuous network of similar high-quality habitats and connections, than the former (Bennett, 1999).

There are different ways to maximise connectivity, which influence biodiversity levels to a different degree. Several researches mention that corridors have a stronger positive effect than stepping stones. Stepping stones merely decrease the distance between patches, while corridors provide functional habitat that actually connects patches. On the other hand, corridors also bring along more risks of spreading pathogens or invasive species (Ahern et al, 2007; Beninde et al, 2015; Bennett, 1999; Garrard et al, 2018; Werner & Zahner, 2010).

However, the actual functionality of corridors and stepping stones is still debated. Several researches point out that they might not function as optimum dispersal routes for many species. In many cases, corridors and stepping stones simply form additional habitat, instead of serving as a dispersal route. Limiting the distance between habitat patches to create additional habitat, might therefore be more effective than creating actual corridors (Angold et al, 2006; Bennett, 1999; Lepczyk et al, 2017; Werner & Zahner, 2010).

4.1.2 Local factors

Local factors determine habitat quality (Beninde et al, 2015; Bennett, 1999). These factors are concerned with the build-up of habitats and thereby determine habitat suitability for specific species (Beninde et al, 2015; Bennett, 1999). As mentioned, local factors are the variables that determine habitat diversity (Farinha-Marques et al, 2011). In urban areas, these factors are largely in control of designers (Faeth et al, 2011; Nielsen et al, 2014).

Habitat structure and habitat composition are the most important local factors. Of these two local factors, habitat structure has a larger influence on the level of biodiversity. Habitat structure should be seen as the vertical layering of vegetation. In general, it can be stated that a more layered vegetation structure is more biodiverse than a lesser layered one (Bräuniger et al, 2010; Farinha-Marques et al, 2011). Habitat composition is determined by the floristic build-up of an area. The more diverse the flora composition, the larger the diversity of fauna can be expected to be in an area (Beninde et al, 2015; Bräuniger et al, 2010). Even though local factors have a lesser influence on general levels of species richness than landscape factors, they are very significant. Firstly, local factors are of main importance when a project site does not allow for the increase of habitat area and connectivity. In these cases, improving habitat structure and composition can be the main strategy for promoting biodiversity (Beninde et al, 2015; Farinha-Marques et al, 2011; Shwartz et al, 2013).

Secondly, local factors can be far more influential on the presence of specific species than landscape factors. Habitat quality may override a limited size and the isolation of an area (Nielsen et al, 2014; Shwartz et al, 2013). This applies specifically to highly mobile species such as birds and butterflies (Angold et al, 2006; Bräuniger et al, 2010; Garden et al, 2007; Lizée et al, 2012; Werner & Zahner, 2010). Species richness and abundance are largely dependent on structural vegetation complexity (Farinha-Marques et al, 2011; Goddard et al, 2010; Savard et al, 2000). Most species rely on particular structural features to fulfil their habitat and resource requirements, such as nesting and shelter (Farinha-Marques et al, 2011; Garden et al, 2007; Threlfall et al, 2017).

Of the two local factors, habitat structure has a larger influence on the diversity of fauna, as most fauna species are more dependent on the presence of particular structural features than on particular vegetation species or composition (Beninde et al, 2015; Bräuniger et al, 2010; Farinha-Marques et al, 2011). To illustrate: if a habitat exists of a particular type of vegetation that attracts a particular type of fauna, diversifying the floristic composition of this vegetation type, will create a higher floristic biodiversity, but the fauna diversity remains the same. If other types of vegetation are added to this habitat, it will now also attract a higher diversity of fauna instead of only obtaining a higher floristic diversity.

However, a habitat that possesses a large floristic diversity does have a larger potential to support a larger species richness (Beninde et al, 2015; Bräuniger et al, 2010; Farinha-Marques et al, 2011). And the floristic diversity of a habitat of course, can have a large influence on the fauna present (Beninde et al, 2015; Bräuniger et al, 2010; Faeth et al, 2011; Nielsen et al, 2014). Additionally, a high floristic diversity increases the resilience of vegetation compositions. Large scale outbreaks of diseases in areas dominated by a single species are not unknown, diversity can prevent this (Alvey, 2006).

In general, native flora species are preferred in vegetation compositions (Farinha-Marques et al, 2011; Given & Meurk, 2000; Ignatieva, 2010; Miller, 2008). Native flora can improve habitat suitability (Farinha-Marques et al, 2011; Threlfall et al, 2017). However, native flora might not be adapted anymore to the changed urban circumstances. It is therefore important to select the right species for the right places (Müller et al, 2013).

The presence of exotic flora in the vegetation composition can have both negative and positive effects (Nielsen et al, 2014). Exotics can outcompete native vegetation when left unmanaged (Ahern et al, 2007), leading to biotic homogenisation. At the same time, an increase of exotic vegetation often has a negative impact on certain fauna that are dependent on specific native flora, the presence of these species will be compromised when exotics outcompete native vegetation (Nielsen et al, 2014). On the other hand, some exotic vegetation is known to attract a high diversity of certain fauna (Miller, 2008; Rastandeh et al, 2018), an example of which is the butterfly bush, Buddleja davidii (Shwartz et al 2013). Miller (2008) even argues that it might be counter-productive in some cases to fully eliminate exotic vegetation. For example, climate change effects, such as the urban heat island, have resulted in conditions that are no longer suitable for native flora in some cases (McKinney, 2006; Miller, 2008). Due to these circumstances, it would be valid to expand vegetation selections to include flora species from a larger climate range.

The age of a habitat can also be of influence on fauna diversity. However, the overall effect of age on biodiversity remains unclear (Norton et al, 2016). Park age can be seen as a predictor of structural habitat complexity. Older habitats may also meet the needs of fauna species with very specific habitat requirements, such as urban avoiders. However, this does mainly seem to apply to habitats that include old trees or forests. Concerning these particular habitats, older areas tend to have a larger fauna species richness than younger areas (Honnay et al, 1999; Nielsen et al, 2014). Ecological succession that occurs with age generally increases total diversity. However, it often reduces the presence of exotic species, which often rely on disturbance to sustain their populations, thereby also decreasing particular diversity (McKinney, 2002). In contrast, it is also known that total species diversity is highest in urban habitats in an early successional stage, which also undergo frequent disturbances (van Aar et al, 2016; Farinha-Marques et al, 2011). Management (see 4.2.5) might therefore be a more important influence than habitat age.

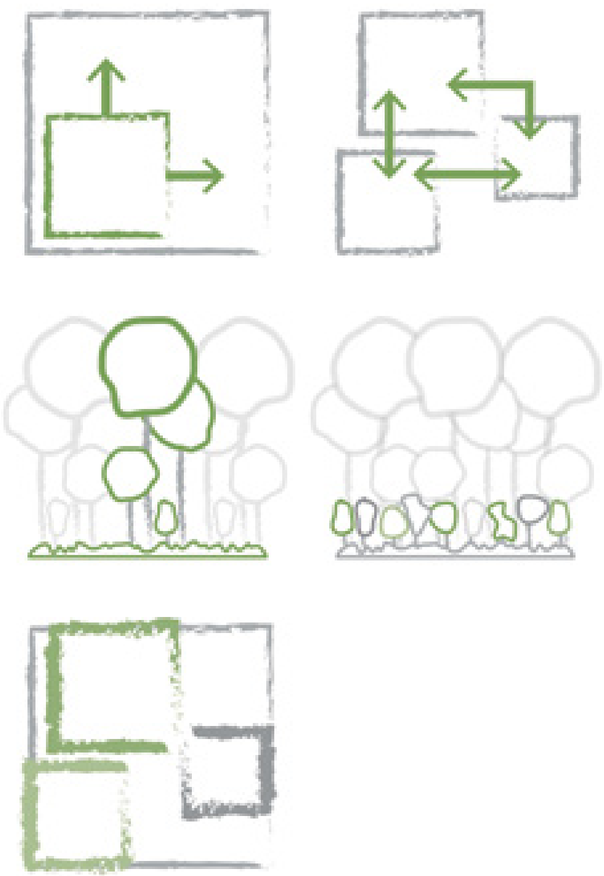


Figure 4.1 The biodiversity principles, LRTB: habitat area, habitat connectivity, habitat structure, habitat composition, and habitat diversity.

4.1.3 Conclusion

It can be concluded from the literature review that the following factors have the largest influence on the biodiversity levels of an area: habitat area, habitat connectivity, habitat diversity, habitat structure, and habitat composition (figure 4.1).

While habitat area and connectivity determine habitat quantity, habitat structure and composition determine habitat quality. Diversity is related to both habitat quantity and quality. Figure 4.2 shows that both qualitative and quantitative factors are required to maximise a site's biodiversity potential. Solely focussing on increasing habitat quantity can establish a general expectation of species richness. On the other hand, a focus on increasing habitat quality can result in the creation of habitat for specific species. Quality cannot be established without a certain amount of habitat quantity. Whereas habitat quantity can be established without any notion of biodiverse quality. The latter is often the case in urban greening projects. In these projects, habitat quality is not explicitly considered, as they generally serve different purposes (e.g. mitigating the urban heat island effect or water retention) than maximising biodiversity (both flora and fauna).

Besides these five main principles, there are of course other factors to consider. These factors are addressed in the next section.

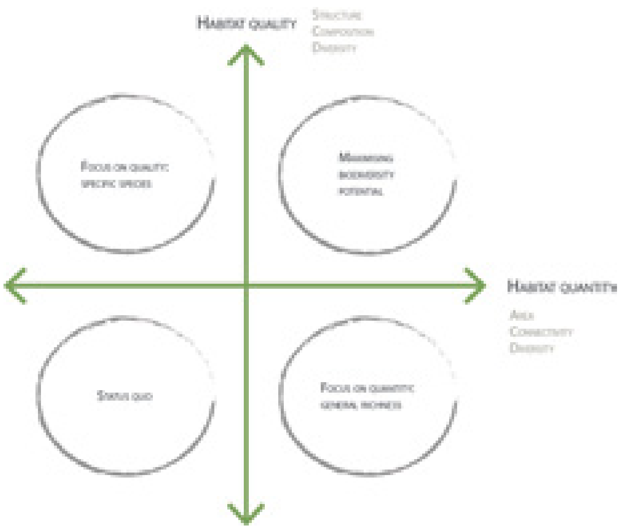


Figure 4.2 Quadrant scheme depicting the outcomes of the investigation on biodiversity principles.

4.2 Biodiversity design guidelines

A design for biodiversity and the design process leading to it takes a slightly different form than a 'normal' design and process. This approach towards biodiverse design will be explained step-by-step. Figure 4.3 depicts the additional factors that are to be considered when designing for biodiversity. These factors are elaborated on subsequently. How these factors are addressed in the creation of a biodiverse design, is elaborated in chapter 6.

4.2.1 Designing for biodiversity step-by-step

The steps that are to be taken in a biodiverse design process are very similar to that of any other design project: performing an analysis, drafting design principles and models, translating these principles and models into more definite designs and details, and accordingly reflecting on the work and possibly reworking steps (Bell, 2012; Lawson, 2006; Milburn & Brown, 2003). However, the design process in order to draft a design for biodiversity differs from that of other projects due to its strong focus on biodiverse aspects, such as the quality and quantity of habitats, floristic compositions and presence of fauna.

The approach that is described below is amended in the design phase of this thesis. Steps one and two are employed in the case study (chapter 5), while steps three and four are amended for the actual design

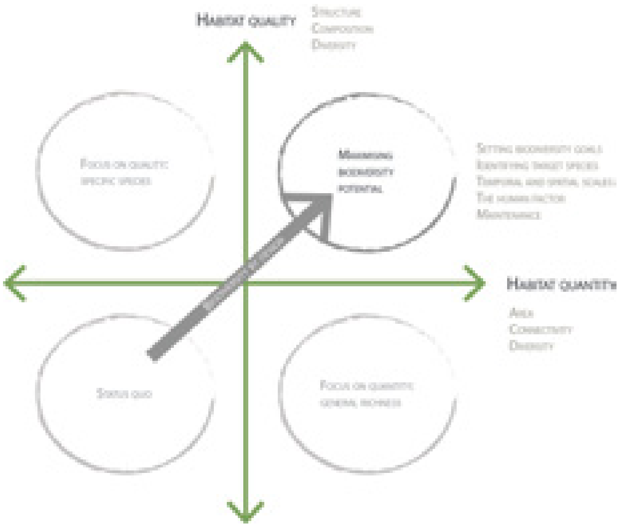


Figure 4.3 Quadrant scheme depicting the requirements of any biodiverse design.

(chapter 6). Step 5 is not included in the design process as it exceeds the scope of this thesis.

Step 1: site selection and assessment

The first step in a biodiverse design process is similar to that of any other. This step concerns the selection of a site and an assessment of its qualities. The landscape analysis for a biodiverse design distinguishes itself by a strong focus on the assessment of biodiverse qualities. It is important to gain an understanding of what is there (Alvey, 2006; Garrard et al, 2018; Savard et al, 2000): the quality and quantity of green areas, other habitat opportunities, the floristic characteristics of the site, and the presence of fauna. To be thorough and comprehensive, this investigation should take place on multiple scale levels (Lovell & Johnston, 2009).

Step 2: identify biodiverse potential

The second step is to identify the biodiverse potential of the site (Garrard et al, 2018). Building on the outcomes of step 1, it is now important to identify the site's possibilities and constraints, to know what can and what cannot be changed, as well as what the limits are. This investigation includes both physical and socio-economic limitations and opportunities (Gagné et al, 2015). Besides an investigation of the physical landscape – which results in an overview of the possibilities of maximising habitat quantity and quality –, it is therefore also important to take local policy into account. If possible within the constraints of the research and design, it would also be important to consider the wishes, demands, and/or dislikes of users.

Next to these considerations, this step includes the identification of potential target species to be accommodated in the design (see section 5.3.6.2.1). Accordingly, it is key to identify the habitat and foraging requirements of these species (Rosenzweig, 2003; Savard et al, 2000; Weisser & Hauck, 2017).

Step 3: set biodiversity targets

The next step is to clearly identify the goal of the design (Garrard et al, 2018). This step not only includes the selection of target species, but also concerns the functionality of the design. For example, will the design exclusively focus on the maximisation of biodiversity and ignore user's values? Or will the design combine both: promoting biodiversity as well as functionality and aesthetics?

In addition, the scale that is worked on should be identified (Savard et al, 2000). Ideally, all scales ranging from city-wide to singular streets are taken into account in order to create the most comprehensive design (Miller, 2008). However, there are many constraints that do not allow this inclusiveness for many projects, among which this thesis. It is therefore important to identify the appropriate scale for the intended result. The outcomes of the design will be quite different between a city scale or a neighbourhood scale for example (Savard et al, 2000).

Identifying these targets will give clear direction to the design, but it also sets some additional constraints.

Step 4: design

Based on the previous steps, the design is drafted. The drafting of a design for a biodiversity project naturally distinguishes itself by focussing on taking the steps that are necessary to maximise the site's biodiversity (figure 9). So, models should show the range of possibilities from minimal impact on the site's configuration and functionality to maximised opportunities for the development of biodiversity while minimising disturbance and limiting functionality to the minimal requirements (Gagné et al, 2015). Design principles are to be developed based on species requirements combined with biodiversity principles. The design principles are then combined with the preferred model and translated into a masterplan. The masterplan should then contain diversified habitats that are assembled to optimally accommodate target species (Rosenzweig, 2004; Savard et al, 2000; Weisser & Hauck, 2017). However, it should also be considered that not all species requirements are compatible with the human environment.

The vegetation selection should also be central to the biodiverse design process. And of course, a thorough maintenance scheme should be included. Both are more important in a biodiverse design project than in other projects as these largely determine the success of the project.

This design process can be iterative. For example: opportunities might be identified to support additional species, which are then to be included in the design; or it might turn out that certain interventions do not work or conflict with other considerations and must be reworked.

Step 5: monitoring and evaluation

As a final step, a monitoring scheme is developed and executed. The monitoring of an executed design will show if the intended results were achieved or not. Monitoring enables landscape architects to learn from their designs and improve their skills in order to create even more comprehensive biodiverse designs (Lovell & Johnston, 2009). However, developing a monitoring scheme is beyond the scope of this thesis and is therefore not included.

4.2.2 Selecting target species

In order to create a biodiverse design, it is important to identify and select desirable species for conservation or promotion (Savard et al, 2000). *"Selecting species for biodiversity planning presents a great dilemma: to be truly inclusive many species need to be considered, yet there is rarely enough species-specific knowledge, information, or time to support this type of inclusive approach"* (Ahern et al, 2007, p.13). This information is not easily obtainable for landscape architects (Weisser & Hauck, 2017). As a result, indicator or target species are usually chosen. While target species are often selected for their value in conservation politics, indicator species provide information on the overall condition of an ecosystem (Ahern et al, 2007). As the term target species is more widespread, this is the term that will be used in this thesis.

There are different reasons for the selection of a target species. An ecological indicator signals the effects of disturbances on other species with similar habitat requirements. Keystone species determine the diversity of a large part of a community, they function in close association with landscape processes and disturbances (Ahern et al, 2007; Noss, 1990). Umbrella species require large habitat areas in which the conditions for many other species can also be provided. Flagships are popular or well-known species that serve as symbols for conservation initiatives (Ahern et al, 2007; Noss, 1990; Savard et al, 2000). Vulnerable species are rare species that require very specific habitat conditions and/or are prone to extinction (Ahern et al, 2007; Noss, 1990). Economically valuable species are needed by local consumers or hold value in commerce. And lastly, a species guild represents a group of species that uses a particular resource in a similar way (Ahern et al, 2007).

In practice target species are more commonly selected by investigating the presence of species in the vicinity of a project site. Accordingly, species that hold conservation value are selected (M. van Aar, personal communication, 11-04-2018). An obvious choice is for species that are already in the area, but this is not always necessary choice. Species can also be chosen as they are attractive for the design. These species may inspire the creation of new habitats that protect additional species. Thereby expanding the range of species that can be conserved (Weisser & Hauck, 2017).

After target species have been selected, it is then vital to understand habitat requirements and sensitivities (Garden et al, 2007). A target species requires very specific conditions concerning habitat quality and quantity. These preconditions provide a sharp focus for the design, as they provide hands on information that can be used to directly inform the design. This information can be used as a checklist and provide an overall outline for the spatial configuration (Weisser & Hauck, 2017).

4.2.3 Working on different scale levels

A multi-scale approach is necessary to properly address biodiversity questions: scales are interdependent and hierarchically linked (Savard et al, 2000; Farinha-Marques et al, 2011). Understanding the hierarchical nature of biodiversity across multiple scales, provides the context for biodiversity projects (Ahern et al, 2007).

Design interventions will influence biodiversity differently on different scale levels (Miller, 2008; Nielsen et al, 2014; Savard et al, 2000). Effects of any intervention on any scale level should therefore also be considered on higher and lower scales. The investigation of multiple scales will help understand the interplay between the city-wide configuration and neighbourhood green spaces (Angold et al, 2006; Lizée et al, 2012; Miller, 2008; Savard et al, 2000; Werner & Zahner, 2010).

Designs often primarily focus on one scale level: either site design or the landscape scale, with little interplay between them (Miller, 2008). As different measures are taken at different scales, the scale level is quite important in determining the type of project. At the larger city scale, biodiversity networks can be created consisting of green spaces and connections between them. On district and neighbourhood levels, green spaces size and location can be optimised. And on smaller scales, biodiverse quality and implementation is of main concern (Savard et al, 2000).

Next to spatial scales, it is also important to consider temporal scales (Norton et al, 2016; Savard et al, 2000). Temporal scales include both short term and long-term temporal changes. Both types can have significant effects on biodiversity levels, but the effects are not well-studied yet (Norton et al, 2016).

4.2.4 Acknowledging the human factor

When designing for an urban area, it is also important to acknowledge the human factor (Miller, 2008). Though it is tempting to disregard and minimise human influence and disturbance, and some researches strongly suggest doing so (e.g. Bennet, 1999; Gagné et al, 2015), urban areas are first and foremost designed for humans and this fact should be recognised in a biodiverse design. Not all species requirements and design options will therefore be compatible with the human environment and user's preferences. Additionally, biodiversity in urban areas is frequently perceived as hazardous and untidy. And many people hold safety concerns (Given & Meurk, 2000; Ikin et al, 2015). "*Ecological quality tends to look messy, and this poses problems for those who imagine and construct new landscapes to enhance ecological quality. What is good may not look good, and what looks good may not be good*" (Nassauer, 1995, p. 161).

Nonetheless, promoting biodiversity in urban environments holds significant benefits for their inhabitants (see section 1.3). And it is very well possible to create biodiverse urban areas that take humans into consideration (Miller, 2008). People prefer green cities (Hunter & Hunter, 2008). But for people to accept biodiversity in their living environment, biodiversity needs to be aesthetically pleasing (Hunter & Hunter, 2008; Nassauer, 1995). There needs to be a look of human intention, which can be provided by cues to care. A biodiverse design cannot look like wilderness, but needs to look cared for (Ikin et al, 2015; Nassauer, 1995).

This look might not be the "*'controlled beauty' people associate with garden design*" (Hunter & Hunter, 2008, p.193). But biodiversity might result in the introduction of a new aesthetic. In order to accept biodiversity, people need to be familiarised with new forms (Nassauer, 1995) that reframe the user's reality (Hunter & Hunter, 2008). As Rosenzweig (2003) mentions: "*human beings can get used to almost anything. And what we get used to, we come to prefer*" (p.176).

Therefore, multifunctionality is important (Weisser & Hauck, 2017). Multifunctionality will promote people-wildlife interactions (Ikin et al, 2015; Savard et al, 2000) and reconnect people with nature so that they will embrace biodiversity in their direct environments (Hunter & Hunter, 2008).

4.2.5 Maintenance considerations

In order to sustain the biodiversity that is created by a biodiverse design, it is important to draft a maintenance scheme. Adequate management and maintenance may positively influence biodiversity levels and even create opportunities for rare and sensitive species (Farinha-Marques et al, 2011), while faulty management may prevent some species from occurring at all (Faeth et al, 2011).

The maintenance of designed plant communities often requires vast amounts of energy and resources. When this effort is not made, rapid successional changes and immigration can occur that lead to the domination of invasive species. The desired result may disappear rapidly (Faeth et al, 2013). Active management can ensure more species to be maintained in an area than would naturally occur (Müller et al, 2013).

However, maintenance itself supersedes ecological processes and thereby constraints processes such as succession and immigration (Faeth et al, 2011). Less intensive management is therefore required to promote biodiversity. Extensive management stimulates natural regeneration (Alvey, 2006).

Some researches even explore the concept of rewilding in urban areas. This concept explores the possibilities of quitting maintenance and letting natural and ecological processes take over completely (Garrard et al, 2018; Müller et al, 2018). However, the feasibility of this concept in practice is questioned (M. van Aar, personal communication, 11-04-2018).

5. Case study

The case study for this thesis concerns the neighbourhood Rivierenwijk. Rivierenwijk is located in the district Zuidwest of Utrecht (figure 5.1). It is a diversified neighbourhood that resembles the average of Utrecht when it comes to demographics. However, Rivierenwijk is not average in its urban configuration, as it is one of the most densely built and stony neighbourhoods of the city. Simultaneously, the neighbourhood has always had a strong desire for more green. A desire that remains to be fulfilled (Gemeente Utrecht, 2013d).

The case of Rivierenwijk is used to explore how the application of the biodiversity principles and guidelines can be employed to maximise the biodiversity of urban areas. As such, the current and potential biodiversity of Rivierenwijk is investigated. Before elaborating any further on Rivierenwijk, it is important to understand its context. Below, first, the municipality's policy and other developments are discussed, with a special focus on green. Next, a brief look into Zuidwest is provided. After this, Rivierenwijk is discussed into more detail by a landscape and biodiversity analysis. Following this case study exploration, a design is drafted in chapter 6.

5.1 Utrecht

The municipality of Utrecht emphasises the necessity of sustainable development of the urban environment due to climate change and a decreasing biodiversity. Since 1997, the city of Utrecht has been realising projects that resolve ecological bottlenecks and improve opportunities for urban nature. Thereby, these projects are directed at sustaining and promoting biodiversity (Gemeente Utrecht, 2017a; b).

As the city continues to grow – expected inhabitant count of 410.000 in 2030 – the pressure on green space is rising. Already, a clear distinction can be made within the city between districts and neighbourhoods that are abundantly green and those that are considered to possess a poor amount of green. Due to the municipality's vision of inward expansion (Gemeente Utrecht, 2016c), the latter will become more prevalent. Simultaneously, the need for green increases. While inhabitants of the city have a strong desire for recreational green, the municipality desires the realisation of multifunctional green. In addition to its recreational value, green space is to fulfil an important role in urban climate mitigation, water retention, and sustaining a certain level of biodiversity (Gemeente Utrecht, 2017a; b; M. van Aar, personal communication, 11-04-2018).

In order to account for these developments, the municipality of Utrecht has formulated both a 'groenstructuurplan' and a 'meerjaren groenprogramma'. With these policies, Utrecht is working on establishing a main green structure (figure 5.2) to improve the quantity and quality of green in and around the city. Additionally, the policies focuss on improving the green structure in neighbourhoods that possess comparatively little green. Though mainly directed at increasing usability and accessibility of green space, these plans should also result in higher levels of biodiversity (Gemeente Utrecht, 2017a; b).

In addition to the developments that have been formulated in these policy documents, the municipality is exploring alternative possibilities for creating green space. A development that the municipality considers to be promising is establishing a municipality owned roofscape that would be amended as public space. This development would create additional space for recreation, water retention, and possibly biodiversity (M. van Aar, personal communication, 11-04-2018).

In many of the city's urban development projects, biodiversity remains a minor or secondary project goal. However, the municipality is actively working on integrating biodiversity into their policy by protecting

Figure 5.1 Rivierenwijk is located in the district Zuidwest in the city of Utrecht.

species and promoting animal friendly construction methods (Gemeente Utrecht, 2013b; 2016b). Additionally, 'natuurwaardekaarten' are being developed to gain insight in the ecological value of existing green spaces. These maps will be amended for the protection and promotion of the city's biodiversity (Gemeente Utrecht, 2017a; b). Perhaps they will also help to make biodiversity a more important project goal.

Figure 5.2 On the top the existing green structure in the municipality of Utrecht. On the bottem, also the areas and corridors that are to be realised (adapted from Gemeente Utrecht, 2017a).

Besides a clear focus on establishing a higher quality and quantity of green spaces, the inward growth of Utrecht has called for a different direction in the municipality's mobility policy. Inward expansion reduces citizens' dependence on cars. Citizens are more likely to walk or cycle in a densely built city. As such, pedestrians and cyclists are given priority above other traffic streams. The mobility policy therefore focusses on improving the connectivity of cycling paths and pedestrian walkways by creating intricate traffic networks, to stimulate these modes of transportation (Gemeente Utrecht, 2016a). Besides this, the municipality aims to reduce the amount of street level parking spaces to create more space for pedestrians and cyclists. In addition, the municipality encourages alternative modes of transportation, such as car sharing. Car sharing is used as a policy instrument to relieve parking pressure in densely built areas. One shared car can eventually replace four regular cars. As shared cars will become more prevalent, a share of street level parking spaces can eventually be transformed for other uses (Gemeente Utrecht, 2013a).

5.2 Zuidwest

The district Zuidwest is made up of the neighbourhoods Rivierenwijk, Dichterswijk, Transwijk, and Kanaleneiland (figure 5.3). The district is characterised by a strong blue structure, consisting of the Amsterdam Rijnkanaal, the Merwedekanaal, and the Vaartsche Rijn (figure 5.4). Concerning its green structure, Zuidwest is one of the districts that can be considered as poor in green areas. But even within Zuidwest, there are large

Figure 5.3 The neighbourhoods of Zuidwest.

differences in the availability of green (figure 5.5). Green space is divided unequally between the different neighbourhoods. While Kanaleneiland and Transwijk have a green and spacious urban configuration, the opposite is true for Dichterswijk and Rivierenwijk (Gemeente Utrecht, 2013d). As such, while inhabitants of Kanaleneiland and Transwijk are relatively satisfied with the quality of green in their neighbourhood, inhabitants of the Dichterswijk and the Rivierenwijk are a lot less content (Gemeente Utrecht, n.d. c).

This distinction becomes very visible in the district's green structure plan (figure 5.6). The areas that make up the main green structure are all located in Kanaleneiland and Transwijk: Park Transwijk, sports park Welgelegen and the Marco Poloplantsoen. Connected by the Amsterdam Rijnkanaal and the Merwedekanaal, these areas are also part of the citywide green network. In addition, these areas perform important ecological functions. For example, Park Transwijk harbours a varied bird population, and the canals form important orientation points for birds and bats (Gemeente Utrecht, 2013d).

A map of green typologies of Zuidwest (figure 5.8) additionally shows that Dichterswijk and Rivierenwijk

Figure 5.4 The water structure of Zuidwest.

Figure 5.6 Green structure plan of the district Zuidwest (Gemeente Utrecht, 2013d).

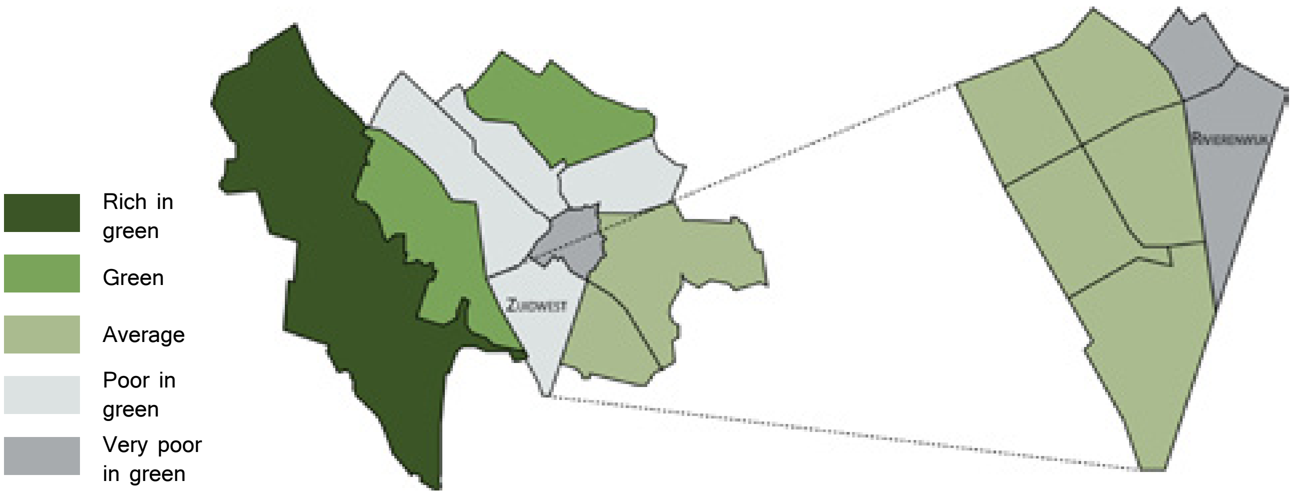


Figure 5.5 Depiction of availability of green in the different districts of Utrecht and the different neighbourhoods is Zuidwest (based on Gemeente Utrecht, n.d. c).

predominantly possess small and scattered patches of green, as opposed to Kanaleneiland and Transwijk, which possess quite a variety of green typologies, with a good amount of surface area.

The district's green structure plan is elaborated on by 'wijkgroenplannen' on neighbourhood scale. 'Wijkgroenplannen' are greening plans designed in collaboration with inhabitants to increase the quantity, quality, and accessibility of neighbourhood green. Most of these small-scale greening plans are drafted for Rivierenwijk and Dichterswijk. Meanwhile Rivierenwijk tends to come off poorly in comparison to the other neighbourhoods of Zuidwest in district-wide greening plans (Gemeente Utrecht, 2013d, figures 5.6 and 5.7).

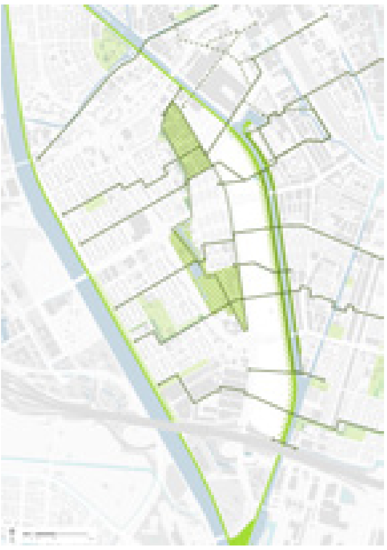


Figure 5.7 Development plan for recreational green in Zuidwest (received from Maria Hoogendijk, landscape architect at the municipality of Utrecht).

Currently, the Merwedekanaalzone is being redeveloped. This redevelopment is the first test of the new mobility policy of the municipality as described in 5.1. As such, the redevelopment of Merwede is an ambitious promotion of car reduction and the promotion of other types of mobility. A new mobility concept is introduced in which parking norms are lowered to 0,3 per household. In addition, car sharing is promoted, as are public transport, cycling and walking. It is mentioned that one shared care can replace nine to thirteen other cars. However, the municipality of Utrecht upholds to the assumption that one shared car will replace four other cars. With these developments, Merwede will set an example for the rest of Utrecht (Goudappel Coffeng & REBEL, 2018). Perhaps other (re)development projects will follow this example.

5.3 Rivierenwijk

5.3.1 Development

The development of Rivierenwijk started around 1918. The initial development concerned the construction of single-family housing for the working class. Since then, the neighbourhood underwent several major redevelopments. In the 70's and then again in the 90's. The result is a diversified neighbourhood with a varied housing supply (figure 5.9), ranging from pre-war working-class housing, characterised by two storeys and a pitched roof, to new apartment buildings,

Figure 5.8 Green typologies in the district Zuidwest (Gemeente Utrecht, 2013d).

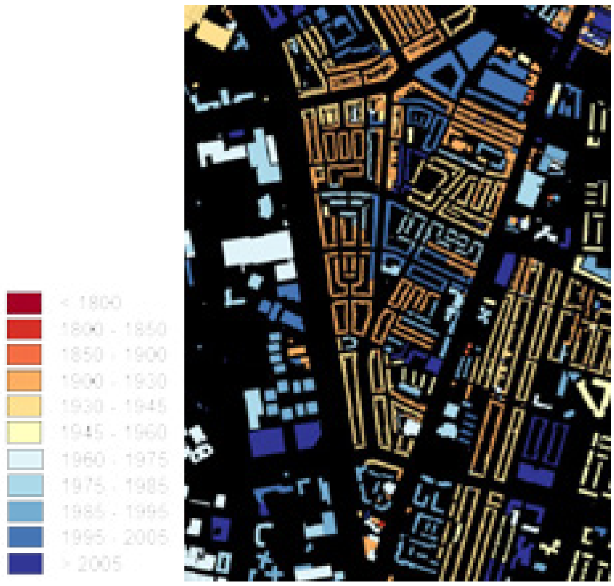


Figure 5.9 Map depicting the age of buildings in Rivierenwijk (Spaan, 2015).

with a simple and modern architecture. Rivierenwijk is thus also architectonically very diverse (Gemeente Utrecht, 2013c; d; 2015, figure 5.12 A-D).

The housing supply is split almost equally between single family homes and apartments. A third housing typology in Rivierenwijk is that of house boats (figure 5.12 E), which are located along the Merwedekanaal and the South of the Vaartsche Rijn. About half of the houses is owner-occupied. The other half is rent housing (WistUdata, 2018).

Over time, the neighbourhood obtained a good amount of facilities. Important shopping facilities are provided along the Rijnlaan, which is considered the main axis of the neighbourhood (figure 5.12 F-G). There are four primary schools, as well as a ROC and a graphic lyceum. Then there is a church and there are two neighbourhood centres, which form an important part of the neighbourhood's community life (Gemeente Utrecht, 2013c; d; 2015, figure 5.12 H).

The redevelopments of the neighbourhood also took the public space into account. Over the years, Rivierenwijk obtained several squares. However, this was not enough to fulfil the neighbourhood's longstanding desire for more public space and green in particular. This wish still stands today (Gemeente Utrecht, 2013c; d; 2015).

In its current configuration, 79% of the 7.7 hectares that the neighbourhood encompasses, is covered by hard surface. 64% of this is paved and 15% is built. Only 13% of the neighbourhood consists of green space. The remaining 8% consists of water cover (Kleerekoper, 2015). As a result of its configuration, Rivierenwijk is vulnerable to climate change induced problems such as flooding during peak rainfall and heat island effects (Klimaateffectatlas, n.d. a; b, figure 5.10-11).

5.3.2 Paved surfaces

Rivierenwijk is a very stony and densely built neighbourhood. Of the 7.7 hectares that the neighbourhood encompasses, 79% is covered by hard surface. Of this, 64% is paved (figure 5.13) and 15% is built (Kleerekoper, 2015).

Most of the paved surface concerns traffic space. The neighbourhood has a well-developed car infrastructure that causes an increasing amount of traffic and parking pressure (Gemeente Utrecht, 2013c). The Rijnlaan is the main infrastructural axis of the neighbourhood. Rivierenwijk is connected to the surrounding neighbourhoods By the Balijelaan and Vondellaan to the north, the Socrateslaan in the south and the Waalstraat in the middle. Together with the Jutfaseweg, which runs along the Vaartsche Rijn, these form the main roads (Gemeente Utrecht, 2015; 2013d). The main roads are also the only asphalted roads in the neighbourhood. The residential roads are brick paved. In contrast to the main roads, the residential

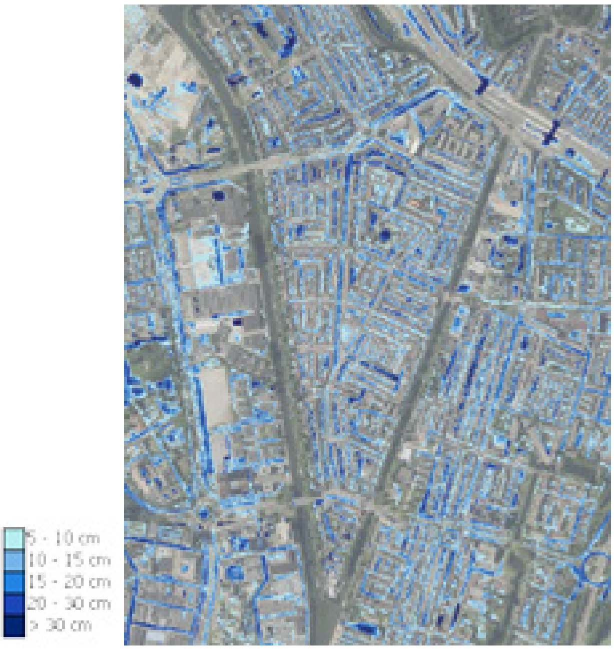


Figure 5.10 Areas that will suffer from water nuisance in instances of heavy rainfall (adapted from Klimaateffectatlas, n.d. b).

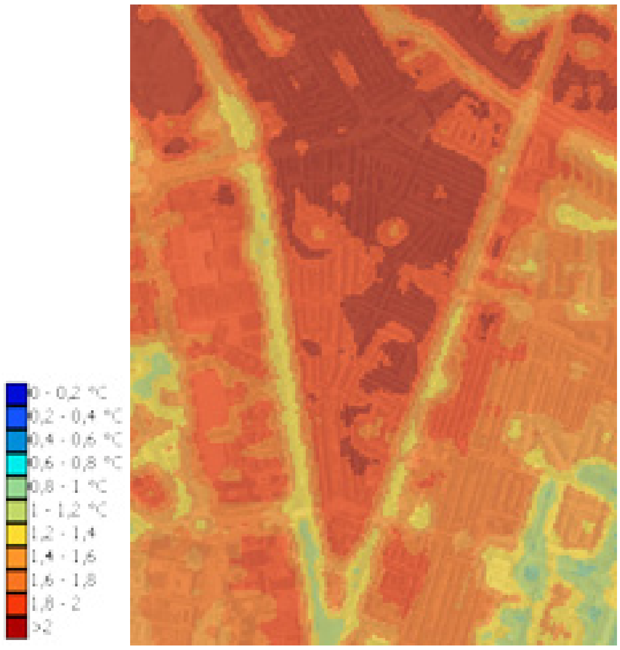


Figure 5.11 The urban heat island effect for Rivierenwijk and its surroundings (adapted from Klimaateffectatlas, n.d. a).

Figure 5.12 Photographs displaying a sample of the diverse architecture of Rivierenwijk, and its facilities.

streets predominantly provide one-way access (figures 5.15 A-C). Parking spaces can be found abundantly throughout the neighbourhood. All streets are lined with parking spaces. As a result, cars take up a large part of the streetscape (figure 5.15 A-B).

Separate bicycle lanes provide a clear cycling infrastructure along the main roads. In the residential streets, cyclists share the road with the car traffic (figure 5.15 D).

Sidewalks are provided throughout the neighbourhood. The sidewalks in Rivierenwijk are quite broad. Most sidewalks exceed a width of two meters. Some sidewalks are even wider than four meters. A separate pedestrian path is provided along the Merwedeplantsoen that runs between the park and house boat properties (figure 5.15 E-F).

Besides all the traffic space, there are also several squares and paved playgrounds in the neighbourhood. Together with the green space, the squares make up the public space that can be used for recreational purposes (figure 5.15 G-H).

Rivierenwijk is very accessible by public transport (figure 5.14). There are several bus stops along

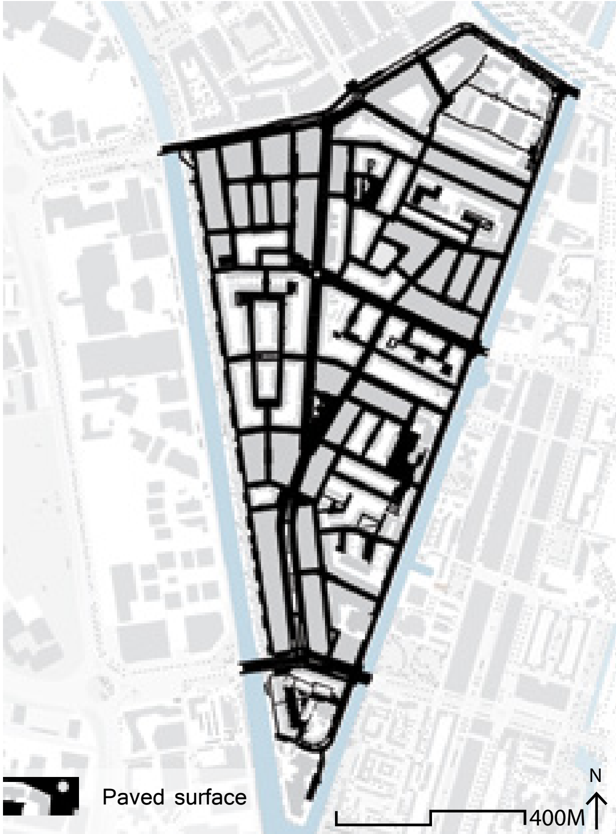


Figure 5.13 The paved surfaces of Rivierenwijk.

Figure 5.14 The public transport coverage of Rivierenwijk. On the left the bus stops and their service area. On the right train station Vaartsche Rijn and its service area.

Figure 5.15 Photographs displaying a sample of the paved surfaces in Rivierenwijk.

the Rijnlaan. Also, the Socrateslaan, Balijelaan and Vondellaan have their own bus stops. As of this, from every corner of the neighbourhood, a bus stop is within 400 meters reach.

In 2016, train station Vaartsche Rijn has opened, providing a new public transport connection for Rivierenwijk and its surroundings. The furthest edge of Rivierenwijk is within 2000 meters reach of the train station.

5.3.3 Green space

13% of Rivierenwijk consists of green space (Kleerekoper, 2015, figure 5.16). There is no coherent green structure that ties Rivierenwijk together. Instead, the green is limited to small patches here and there.

The Merwedeplantsoen, which is located along the Merwedekanaal, makes up for the largest share of green space in Rivierenwijk (figure 5.17 A-B). This park consists out of grass and trees, accompanied by hedgerows here and there. It contains several playing and sitting areas and is popular amongst dog walkers and runners (Gemeente Utrecht, 2013d). The rest of the green space consists out of small neighbourhood parks and roadside greenery. The neighbourhood's

Figure 5.16 Overview of the municipally owned green space.

small parks mainly function as football fields or play grounds, some of which are lined with shrubs, perennials and the occasional trees. Additionally, there are a few designed parks, in which the green serves a more aesthetical function (figure 5.17 C-D). A few spots in the neighbourhood are also overgrown with taller shrubs.

The roadside greenery mainly consists of trees, which are accompanied by grass along the Vaartsche Rijn and by hedges along the Socrateslaan. Along the southern part of the Rijnlaan, the road verge is vegetated with grass, shrubs and perennials (figure 5.17 E).

Most residential streets have trees in them, though not all do and the streets that do contain streets, do not contain many. Also, most trees are small. There are only a few residential streets that contain older and taller trees, such as the Zaanstraat (figure 5.17 F). Only a few streets contain front gardens. Most of them are paved and contain some shrubs and perennials, however some are also more abundantly vegetated. Façade gardens can be found throughout the neighbourhood, though they are not vey abundant in all corners of the neighbourhood, and even absent in other parts (figure 5.17 G).

The municipality stresses that any interventions to improve public space need to be green. A few examples of this on neighbourhood initiative can be found throughout the neighbourhood. In some spots, understory has been added underneath street trees and larger pottery has been placed to embellish the streets (Gemeente Utrecht, 2013d, figure 5.17 H).

5.3.4 Water

Rivierenwijk is enclosed by two canals: the Merwedekanaal to its west and the Vaartsche Rijn to its east (figure 5.18).

The Merwedekanaal was originally constructed as a shipping canal, but it is currently used for rowing by Utrecht's rowing associations and additionally serves increasingly as a recreational waterbody (Bureau Buiten, 2016). House boats are located along the entire east bank of the canal along Rivierenwijk. As these boats occupy terrain on the canal bank, there is no real bank on that side. On the other side, the bank consists of a small grass slope with water bank protection (figure 5.19 A-B).

The current use of the Merwedekanaal is conflicting. The house boats and the recreational use complicate the functionality of the canal for rowing. The house boats have taken away part of the width of the canal.

Figure 5.17 Photographs displaying a sample of the green spaces in Rivierenwijk.

Additionally, due to the water bank protection and the hard edge that is formed by the house boats, the increasing amount of recreational boats cause a lot of waves (Bureau Buiten, 2016).

The presence of the house boats restricts the ecological functioning of the water banks (Gemeente Utrecht, 2007). There is little to no vegetation in the canal and along its banks. The canal is also very poor on fauna. This state is mainly caused by the absence of natural banks (Royal Haskoning DHV, 2013). Due to the house boats, it is also impossible to create natural banks and resolve these problems (Gemeente Utrecht, 2007).

The Vaartsche Rijn has a main recreational function. There are only house boats located along the southern part of its west embankment. The rest of the west embankment consists of a steep slope with grass and trees with water bank protection (figure 5.19 C-D). Small boats can dock along it. The east bank of the Vaartsche Rijn has a vertical water bank protection. Like the Merwedekanaal, the Vaartsche Rijn is poor on water vegetation (Royal Haskoning DHV, 2013).

Figure 5.18 The two canals surrounding Rivierenwijk.

Figure 5.19 Photographs displaying the waterbanks of the Merwedekanaal (top) and the Vaartsche Rijn (bottom).

5.3.5 Soil

The soil of an area is determinant for the selection of specific vegetation. However, often little is known about the soil of an urban area. Extrapolating from the soil map (figure 5.20), Rivierenwijk was built on low-lime clay soil (PDOK, n.d.). However, no information about the current soil beneath Rivierenwijk is available.

5.4 Biodiversity

5.4.1 Current biodiversity

Species in Rivierenwijk

The amount of species, both flora and fauna, that are present in Rivierenwijk are illustrative for the lack of green. In 2017, 1997 different species of flora and fauna were observed in the municipality of Utrecht. Of these species, 444 have also been observed in the district of Zuidwest, and 94 have been observed in Rivierenwijk. 124 of all the species that have been observed in Utrecht are protected under the municipalities' protected species policy. Of these species, 32 have been observed in Zuidwest, and twelve have been observed in Rivierenwijk (Gemeente Utrecht, 2018a. figure 5.21).

The largest share of the protected species that have been observed in Zuidwest are birds. But the list also includes several mammals, reptiles and amphibians, and plants (figure 5.24). For Rivierenwijk, nine of the observed species are birds, two are bats, and the twelfth is a plant (Gemeente Utrecht, 2018a).

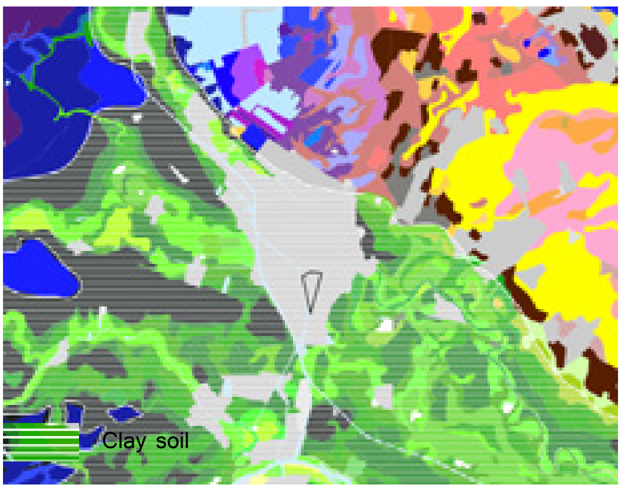


Figure 5.20 Soil map of Utrecht and its surroundings (adapted from PDOK, n.d.).

The municipality has distinguished four habitat groups: stone and buildings; trees, forests, and shrubs; water banks and water; and grass and herbs (Gemeente Utrecht, 2013b). The largest share of protected species that have been observed in Rivierenwijk and its surroundings inhabit the first two habitat groups. No species that inhabit the last habitat group have been observed in Rivierenwijk and its direct surroundings (Gemeente Utrecht, 2018a).

Naturally, species with a habitat of stone and buildings are observed more frequently in Rivierenwijk and other densely built neighbourhoods, such as Tolsteeg and Hooggraven (figure 5.25). Rivierenwijk harbours more species from this habitat group than from the others. Common swifts (*Apus apus*, gierzwaluw) have been observed most frequently, followed by grey wagtails (*Motacilla cinerea*, grote gele kwikstaart) and house sparrows (*Passer domesticus*, huismus).

Species who inhabit trees, forests, and shrubs have been observed most frequently in the city's green spaces, but also along the canals (figure 5.26). In Rivierenwijk, these species occur most frequently in the Merwedeplantsoen and along the Vaartsche Rijn. The species that have been observed most frequently are great spotted woodpeckers (*Dendrocopus major*, grote bonte specht), common buzzards (*Buteo buteo,* buizerd), and common kingfishers (*Alcedo atthis,* ijsvogel).

Species who inhabit water banks and water have been observed most frequently along the canals and other water bodies (figure 5.27). In Rivierenwijk, these species are observed along the Merwedekanaal and the Vaartsche Rijn. Interesting species include grey wagtails, and common kingfishers.

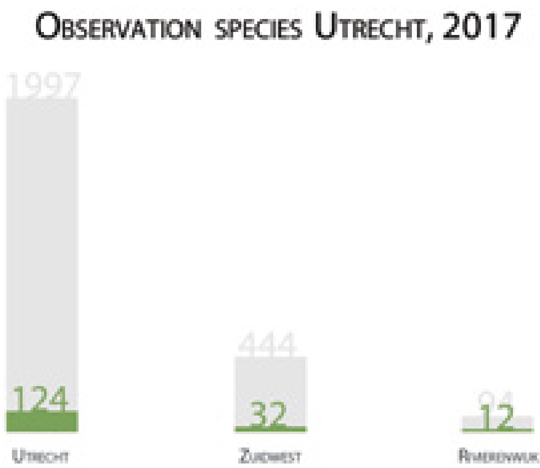


Figure 5.21 An overview of the observed species in Utrecht, Zuidwest, and Rivierenwijk. The total number of species is depicted in grey, the number of protected species in green.

Even though these species have been observed in Rivierenwijk, it is highly uncertain that they inhabit the neighbourhood. Of the beforementioned species, only the common swift and house sparrow have been observed to breed in the area in recent years (Gemeente Utrecht, 2018a). In addition, the common pipistrelle (*Pipistrellus pipistrellus,* gewone dwergvleermuis) is known to forage in Rivierenwijk (figure 5.22). The two canals and the tree structure of the Rijnlaan form important foraging habitat for this species (M. van Aar, personal communication, 11-04-2018). The common swift, house sparrow and common pipistrelle are also specifically focused on in Utrecht's policy for building-inhabiting species (Gemeente Utrecht, 2016).

The diversity of green typologies

At first sight, Rivierenwijk does not contain a large variety of green spaces. Within each typology, green spaces seem quite similar in their build-up. However, after a second investigation, with a focus on vegetation structure and composition, it turns out that there is quite a variety within the different typologies. This section discusses the diversity of green of and within parks, streets and water banks.

Figure 5.22 Map indicating the presence of the common pipistrelle, the common swift, and the house sparrow in Rivierenwijk (adapted from Gemeente Utrecht, n.d. b and based on information received from Mies van Aar).

Parks

Five of the neighbourhood's parks with a different vegetation build-up, functionality or design are discussed below (figure 5.23).

The Merwedeplantsoen (figure 5.28 A) is the largest park of Rivierenwijk. This park functions as a foraging area for both birds and bats. The park's structural diversity is made up of a canopy that mainly consists of large and older trees, but also some smaller ones, and understorey of grass and some hedgerows. These structural layers do not occur everywhere. Hedgerows are only present in a few places, and there are areas in which the canopy layer is absent as well.

The hedgerows each consists of a singular species. There are two types: hornbeam (*Carpinus betulus*, haagbeuk) and privet (*Ligustrum*, liguster). The tree species in the Merwedeplantsoen are very diverse. There are 46 different tree species in the park in total. The European linden 'Pallida' (*Tilia x europaea 'Pallida',* koningslinde 'Pallida') is the most common. Only 11 of the tree species are native. The largest share

Figure 5.23 Location of the parks that are discussed.

Figure 5.24 Inventory of the locations of the observed species in Rivierenwijk and its surroundings.

Figure 5.25 Overview of the observed protected species in 2017 that inhabit a habitat of stone and buildings.

Figure 5.26 Overview of the observed protected species in 2017 that inhabit a habitat of trees, forests, and shrubs.

Figure 5.27 Overview of the observed protected species in 2017 that inhabit a habitat of water and water banks.

is a cultivar and the remainder are exotic (Gemeente Utrecht, n.d. a).

The Lekplantsoen is a small park with a recreational and aesthetic purpose (figure 5.28 B). The park's vegetation structure consists of two grass fields, hedgerows of field maple (*Acer campestre,* veldesdoorn), variety of shrubs, and a few trees. The park contains one large tree, which is a common oak (*Quercus robur*, zomereik), and five smaller trees, which are four different species that are either cultivars or exotics (Gemeente Utrecht, n.d. a).

The Roerplein (figure 5.28 C) is a relatively new park vegetated with a variety of perennials, fruit bearing shrubs and several young trees with the purpose of luring bees, butterflies and birds (Gemeente Utrecht, 2013d). The park contains three different tree species: Callery pear 'Chanticleer' (*Pyrus calleryana 'Chanticleer'*, sierpeer), kobus magnolia (*Magnolia kobus*, Japanse magnolia), and common walnut (*Juglans Regia*, walnoot) (Gemeente Utrecht, n.d. a).

The Wielingenplein (figure 5.28 D) functions as a football field, but has five ornamental green areas with a high structural diversity on its corners. These green areas are maintained by the residents of the parks surrounding houses (Wielingenplein, n.d.). The corner vegetation consists of small to medium height trees, shrubs of varying heights and some perennials. The species composition is quite diverse. Amongst the shrubs, there are butterfly bushes (*Buddleja*, vlinderstuik), barberry (*Berberis*), and roses (*Rosa*, roos). Amongst the perennials there are vervain (*Verbena*, ijzerhard), coneflowers (*Rudbeckia*, zonnehoed), and bellflowers (*Campanula*, klokje). The fourteen trees are composed of a mix of nine different native, exotic and cultivated species (Gemeente Utrecht, n.d. a).


A


B


C


D


E

Figure 5.28 Photographs displaying the five discussed parks.

The Waalstraatpark has a main ornamental function (figure 5.28 E). The park's vegetation structure consists of a grass field with a strip of perennials at its centre and a tree at each corner. In contrast to the other parks, the vegetation in the Waalstraatpark is planted in larger groups of a singular species. Between the four trees, there are two different cultivated cherry species (Gemeente Utrecht, n.d. a). The strip of perennials contains New York aster (*Aster novi-belgii,* herfstaster) and daylilies (*Hemerocallis*, daglelie) amongst others.

Streets

The predominant vegetation structure in the streets are singular trees without any undergrowth. More than 30 different species of trees are planted in the streetscape of Rivierenwijk. A large share of them is a cultivated species from the Rosaceae family, most of which are relatively young and small. Only a few streets contain large older trees, such as the Waalstraat (*Ulmus glabra 'Exoniensis',* pluimiep), and parts of the Gouwestraat (*Acer pseudoplatanus,* gewone esdoon) and Scheldestraat (*Acer pseudoplatanus 'Leopoldii'*) (Gemeente Utrecht, n.d. a, figure 5.29-5.30 A).

Some tree species are repeated frequently, while others only occur a few times. For example, to the east of the Rijnlaan, many streets are planted with Callery pear 'Chanticleer'. Other species that occur frequently are wild cherry 'Plena' (*Prunus avium 'Plena'*, zoete kers), cherry plum 'Nigra' (*Prunus cerasifera 'Nigra'*, kerspruim), and duke cherry 'Schnee' (*Prunus x gondouinii 'Schnee'*, sierkers) (Gemeente Utrecht, n.d. a).

Figure 5.29 Map depicting the distribution of old/large, medium, and young/small municipal trees in Rivierenwijk.

Most streets only contain one species of trees, though there are a few exceptions, for example: the Spaarnestraat, the Schipbeekstraat, and the IJsselstraat (figure 5.30 B).

The tree lanes along the Rijnlaan and the Jutfaseweg are important foraging structures for bat species (Gemeente Utrecht, 2013d, figure 5.30 C). Both streets' tree structures are composed of linden. The Rijnlaan to the south of the Waalstraat and the Jutfaseweg contain European linden 'Pallida'. To the north of the Waalstraat, the Rijnlaan contains silver linden (*Tilia tomentosa*, zilverlinde) (Gemeente Utrecht, n.d. a). In addition to a tree structure, there is a green strip between the two road halves along the southern part of the Rijnlaan. This green strip consists of grass for the largest part, but also contains a few trees (honey locust, *Gleditsia triacanthos*, valse christusdoorn), strips of butterfly bushes, and strips of perennials, which contain coneflowers, asters and thyme (*Thymus*, tijm).

Most trees do not have any undergrowth, apart from a little basal shoot. In some instances, perennials have been planted in the tree's planting box (figure 5.30 D). However, along the southern part of the Rijnlaan, a diversity of shrubs is planted underneath the tree lanes and along the Socrateslaan, hedgerows are planted underneath the trees (figure 5.30 E-F).

Other street green can be found in the form of large ornamental planting boxes or pottery, as well as façade gardens. There are also several residual spaces that are filled up with vegetation. The planting boxes can only be found in a few places and contain small shrubs or perennials, mostly one or two species. Façade gardens are spread throughout the neighbourhood. Their composition can be very diverse, though their vegetation structure predominantly exists of perennials (figure 5.30 G).

Some residual spaces that have been vegetated can be found along the Amstelstraat and the Spaarnestraat. The Amstelstraat contains a green strip between two strips of parking spaces. This green strip contains a variety of perennials, shrubs and small trees. Two other green strips are located besides a parking place at the Spaarnestraat. These strips contain a variety of shrubs, as well as a few trees (figure 5.30 H).

Figure 5.30 Photographs displaying the diversity of street green in Rivierenwijk.

Water banks

The two water banks of Rivierenwijk are also considered to be an important part of the neighbourhood's green structure (Gemeente Utrecht, 2013d). However, the Merwedekanaal hardly has a water bank as of the house boats. The parts where there are no house boats are covered in grass and possess very little water or water bank vegetation due to the water bank protection. To the south of Rivierenwijk, around the Socrateslaan, there is a small area without house boats. A wildered vegetation of bramble (*Rubus*, braam) can be found on the edge of the water bank there (figure 5.19 A).

Along the Vaartsche Rijn, the water bank vegetation consists of grass. On top of the steep bank are the beforementioned linden trees along the Jutfaseweg. Also here, there is little water and water bank vegetation due to the water bank protection and the docking spots for recreational boats (figure 5.19 C).

5.4.2 Potential biodiversity

Increasing habitat quantity

Despite the scarcity of and competition for space, Rivierenwijk harbours numerous opportunities for the creation of a higher quantity of green (habitat area and connectivity). The municipality has investigated and appointed opportunities for greening (figure 5.31). The opportunities include sidewalks that are wider than four meters and several residual paved strips (figure 5.32 A-B). These opportunities are recognised in a publication by Aorta, mentioning that despite the compact configuration of the neighbourhood, the street profiles are wide with a lot of unused, paved space (Van der Heide et al, 2014).

As figure 5.31 shows, these opportunities mainly affect the area of available habitat and not so much the connectivity of habitats, in terms of creating a fine-grained connected network of habitats.

In addition to the opportunities that have been identified by the municipality, there are others that can be found in the public space of the Rivierenwijk (figure 5.33). Most of these opportunities can be amended without altering the functionality of the neighbourhood. As figure 5.33 shows, amending these opportunities would not only increase the amount of available habitat, but would also enable the creation of a fine-grained connected network of habitats. Thereby also increasing habitat connectivity.

First, sidewalks that extend a width of two meters can be greened (figure 5.32 C). The municipality adheres to a minimal sidewalk width of 1.8 meters (BAT, 2014). Since many sidewalks in the neighbourhood extend beyond this width, the excessive width can be amended for greening.

Second, Rivierenwijk counts several squares, playgrounds and school yards (figure 5.32 D). These spaces could also be turned into green alternatives.

Third, vertical structures can be greened. Public buildings, such as the Sint-Gertrudis church and the schools and neighbourhood centres, could be provided with a new green façade. The bridge structures that span the Merwedekanaal and the Vaartsche Rijn, as well as blind walls could also get a green makeover using meshwork or cables (figure 5.32 E).

Lastly, all residual paved strips can be greened, in addition to the ones that the municipality has identified for greening.

Amending all of these opportunities would double the amount of green space within the neighbourhood.

Besides these four, there are more opportunities. However, they would require making some alterations

Figure 5.31 Opportunities for greening as identified by the municipality of Utrecht (adapted from Pasma & Roelofs, 2017).

Figure 5.32 Photographs displaying opportunities for increasing habitat quantity.

to the functionality of the neighbourhood. Amending any of these additional opportunities would increase both the amount of available habitat area, and increase the resilience of the connected network of habitats.

Firstly, the neighbourhood's parking spaces could be transformed into green space (figure 5.32 F). This intervention would take away the parking function. Since the neighbourhood is covered very well by the city's public transport network, this measure would not be completely impossible. But it would require a massive life-style change of all the inhabitants. However, since the municipality is already considering severely limiting the amount of car parking spaces in new neighbourhood developments (Goudappel Coffeng & REBEL, 2018), it is worth to take the consideration of transforming parking spaces into account.

Secondly, new artificial water banks can be created along the Merwedekanaal and Vaartsche Rijn. Currently, the Merwedekanaal does not have a water bank on the side of Rivierenwijk due to the presence of house boats (figure 5.32 G). A new water bank could be created on the back-side of these house boats by creating floating gardens or similar constructions.

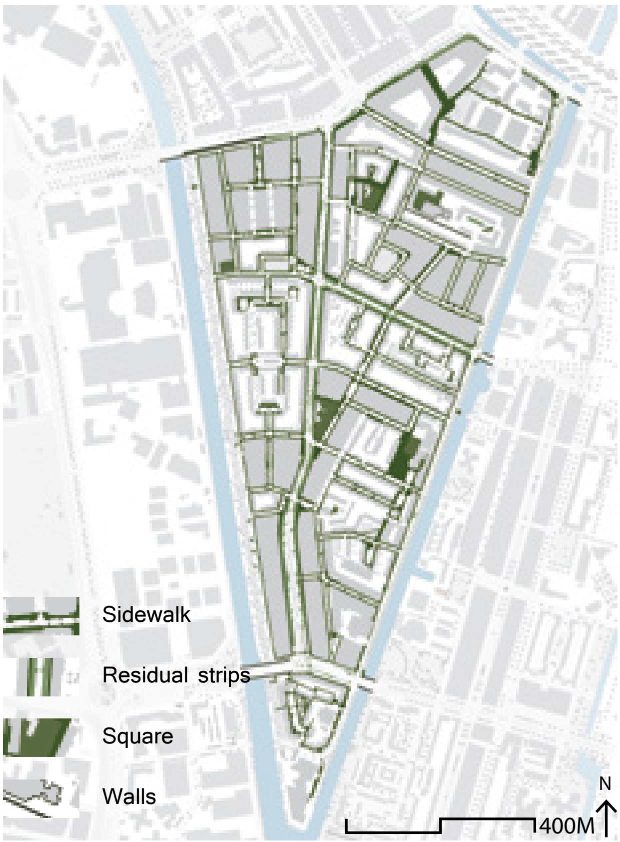


Figure 5.33 Opportunities for greening in addition to those identified by the municipality of Utrecht.

Amending both options would add the same amount of additional green space as the previous four measures to the neighbourhood.

The last option would be to close off (parts of) a street. By reconfiguring traffic circulation, parts of a street might become obsolete (figure 5.32 H). In such a case, this area could be transformed into a park. This opportunity would optimise habitat connectivity, as transforming streets into parks overcomes traffic barriers and replaces them with habitat connections.

Increasing habitat quality

From the literature review, it resulted that the best options to increase habitat quality are to maximise vegetation structure and composition, of which the first was deemed the most important.

To maximise the vegetation structure, extra layers of vegetation should be added to the existing green space. A maximised vegetation structure would consist of 1) undergrowth of herbaceous plants, 2) a low shrub layer, 3) a layer of small trees and tall shrubs, 4) a canopy layer. In addition, climbers could be added, which are not necessarily bound to any of the layers. Not all these layers can be created in all instances. In the larger green spaces, all could be added, but the possibilities of adding extra vegetation layers to street greenery are limited. So, vegetation layers should be added according to what the size of a green space allows.

For the different green space typologies of Rivierenwijk, maximising vegetation structure would entail the following:

- Parks would have all layers added. For the Merwedeplantsoen, this would entail adding all layers of understorey. Other parks would also get a canopy layer in addition to the understorey.
- Underneath street trees, a layer of herbaceous plants and climbers would be added. In case that the planting box is large enough, one or more low shrubs would be added.
- Along the water banks, layers of herbaceous plants and (low) shrubs would be added.
- Other green strips would have layers added according to what their size allows.

To maximise vegetation composition, the flora of the area should be as diversified as possible. Maximising vegetation composition would thus entail the following for the different green space typologies of Rivierenwijk:

- Replacing street trees so that there are as many different tree species as possible in a street.
- Replacing hedgerows by mixed hedges.
- Diversifying perennial and shrubs species that

are applied in green strips, parks and ornamental street green.
- Diversifying the vegetation species selection between and within green space typologies to create diverse habitats.

Target species

In order to identify species to be targeted in a biodiverse design for Rivierenwijk, Mies van Aar (personal communication, 11-04-2018) recommended to investigate what species are already present and possess conservation value. The protected species that reside in or in the vicinity of Rivierenwijk have been mentioned in section 5.3.6.1.1. Three species that possess conservation value for Rivierenwijk are specifically focused on in Utrecht's policy for building-inhabiting species: common pipistrelle (Pipistrellus pipistrellus, gewone dwergvleermuis), common swift (Apus apus, gierzwaluw), and house sparrow (Passer domesticus, huismus) (Gemeente Utrecht, 2016). As of their conservation value for the city and the neighbourhood, the biodiverse design for Rivierenwijk will focus on promoting their presence. As such, these species can be seen as flagship species.

It is accordingly important to identify the habitat and foraging requirements of these species. Below, a brief description of the beforementioned species is provided, along with their habitat and foraging requirements. For the common pipistrelle, only foraging requirements are provided as this species only forages in Rivierenwijk and does not inhabit the neighbourhood.

Common pipistrelle

The common pipistrelle (figure 5.34) is the most common bat in the Netherlands. It is also one of the smallest bat species, with a weight of 3,5 to 8 grams and a span width of 18 to 24 centimetres. The females live in colonies that share genetic similarities, whereas the males live alone or in small groups outside of the mating season.

The common pipistrelle resides in buildings in the urban environment year-round. In each of the stages of its life cycle, it has different requirements to its habitat. It forages in gardens, parks, estates, along lanes, tree rows, wood walls, planted dikes, forest edges, cemeteries, and sheltered ponds and waterways. In absence of wind, it may also forage in more open landscapes.

Foraging does not happen during the winter. During this season, the common pipistrelle remains in its winter residence. In all other seasons, it forages from sundown and during the night. During the day, it resides in its residence.

The common pipistrelle forages on insects, such as mosquitos, midges, caddis flies, as well as mayflies, lacewings, moths, and occasionally beetles. It is important that the foraging habitat is sheltered and has a high insect count. Three distinct foraging habitats can be identified: 1) open areas with a size of one to three adult trees in a densely vegetated area; 2) wind sheltered areas along linear upright vegetation or wind sheltered areas along water; and 3) open areas without trees, especially along water banks and reed beds.

When new foraging habitat is created, the following things can be considered:
- Create double tree rows or a dense tree vegetation with a planting distance of 0,5x tree height or 0,75x tree height in case of adult trees. Trees should not be pruned until they reach a height of 10 meters.
- Create dense understorey of shrubs under tree rows for wind shelter.
- Plant trees and shrubs of varying height and growth speed.
- Create a varied vegetation structure of deciduous trees, shrubs, overgrown grass, and sheltered open water with natural banks on which water bank vegetation can develop.
- Plant three to five rows of trees on both sides of water bodies that exceed a width of 10 meters, and create a three to five-meter-wide strips of low vegetation between the water and the first row of trees.

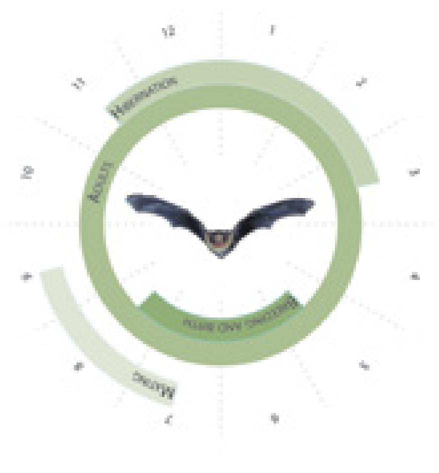


Figure 5.34 Diagram depicting the life cycle of the common pipistrelle (adapted from Hauck & Weisser, 2015).

Next to these interventions, it is important to minimise light disturbance, as lighting can have a repellent effect on bats. This can be done by the following:

- Utilise a bat-friendly light colour, for example amber.
- Change the amount and/or position of lamp posts, or utilise lamp posts with a focussed beam that do not disperse light into foraging habitat or flying routes.
- Place vegetation to diminish the dispersal or disturbance of light.

(BIJ12, 2017a; Gemeente Utrecht, 2016; RVO, 2014a).

At the same time, it is important to recognise that light affects insects. Certain insects that form prey for the common pipistrelle, such as moths, are attracted to light. Bats are known to exploit the high prey density of night-time lights (Geffen, 2015).

Common swift

The common swift (figure 5.35) is a seemingly inexhaustible flyer. It is a small to medium sized bird with a size of 17 to 18,5 centimetres. It has an average weight of 42 grams and a wingspan of 40 to 44 centimetres. Common swifts form pairs for life, they migrate, forage, and sleep as a pair.

The common swift is strongly associated with urban areas, where it resides in buildings. Each pair will utilise the same nesting spot for years in a row. If there is a high supply of nests, common swifts tend to form colonies.

Common swifts are distinct summer birds that reside in our country from April until October strictly. From May until July, their numbers are highest. It is in this period that they breed. In the winter months, they reside in tropical African regions.

Common swifts forage in flight on flying insects, such as mosquitoes, (hover)flies, butterflies and moths. They avoid insects that can sting. They forage within a radius of eight kilometres of their nesting spots.

A common swift spends most of its life in the air. It only comes to the surface to breed. It creates its nests in dark cavities in ventilation shafts, cracks in walls, underneath roof tiles and in church towers. It also makes use of nesting boxes. This nesting habitat can mainly be found in older buildings.

Common swifts only have a few requirements of their functional living environment. For them to leave their nests, they need to let themselves fall. This action requires a free flying depth of at least three meters with a width of minimal one meter. Besides this, the flying routes to and from their nests should be free from blockages, such as trees, flag posts, and other upright elements (BIJ12, 2017b; Gemeente Utrecht, 2016; RVO, 2014b).

House sparrow

The house sparrow (figure 5.36) is a typical resident bird. It is a small bird with a size of 14 to 16 centimetres and a maximum weight of 35 grams. Males and females have a distinctly different appearance.

House sparrows reside in the presence of humans. They nest in buildings and often do not disperse themselves further than 100 metres from this nest. They breed, forage, bathe, sleep and disperse in groups.

Figure 5.35 Diagram depicting the life cycle of the common swift (modelled after Hauck & Weisser, 2015).

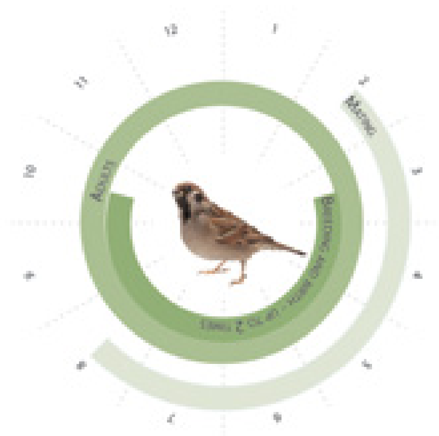


Figure 5.36 Diagram depicting the life cycle of the house sparrow (adapted from Hauck & Weisser, 2015).

They occur frequently in urban areas where buildings are alternated with green areas. Their functional living environment should include a number of habitat features within a small radius of several meters of food sources and a slightly larger radius of a couple hundred metres of their nests. These habitat features include nesting facilities, food sources for both young and adults, shelter, spots for dust baths, and drinking water.

Nests can be found under roof tiles, in nesting stones, and in cracks and holes in walls. They can also be found behind rain pipes, vegetated walls, and nesting boxes. Nesting spots should be located at a height of at least three meters. Ideally, they are located on the east or north side of a building or in another shaded spot.

House sparrows require a continuous food source. As such, they are strongly dependent on what humans have to offer. Adult house sparrows forage on seeds, grasses, and weeds. This diet is supplemented with insects and their larvae, berries and flower buds. In urban environments, a prime food source are bread crumbs and other leftovers from humans and their pets. During breeding season, females need a high supply of protein. Young house sparrows primarily eat soft protein rich insects, such as plant lice, mosquitos, midges, flying ants, lacewings, caterpillars, and spiders in the first weeks of their life. After a while, this is supplemented by plant food.

House sparrows forage in areas with no or low vegetation, such as road verges and gardens. Preferably, these areas are maintained extensively. They can also find insects in certain tree species, such as oaks, willows and birches and other native green. However, there should not be too many large trees. It is important that their foraging habitat is sufficiently sheltered, as house sparrows are frequently preyed on. Shelter can consist of prickly shrubs, evergreen shrubs and climbers, conifers, and hedgerows. This vegetation can also function as resting places in winter and collective sleeping places. Green that functions as shelter should have a height of at least three meters to be effective (BIJ12, 2017c; Gemeente Utrecht, 2016; RVO, 2014c).

Pollinators

The common pipistrelle, common swift and house sparrow share two commonalities: 1) they nest in buildings; and 2) they forage on insects. To ensure a sufficient food supply, a fourth target species group is therefore added: pollinator insects (figure 5.37). There are many types of insects, but pollinators are threatened species that are recognised for their conservation value. Pollinators include bees, butterflies, flies, moths, beetles, wasps, thrips, and ants. Almost all bees are pollinators, flies are the second largest pollinator group (Potts et al, 2016).

The municipality of Utrecht has executed projects for the conservation of solitary bees in previous years (Utrecht Natuurlijk, 2016). Several solitary bees have also been included in the municipality's species list for conservation. Besides this, they have adapted their maintenance schemes to stimulate butterfly populations (Gemeente Utrecht, 2018b). As such, these pollinator groups will mainly be considered in the design.

The Netherlands counts around 350 bee species. Only one of these is the honeybee. The others are solitary bees (Breugel, 2014). Most of these species are threatened. 99 bee species have been observed in Utrecht in recent years (Gemeente Utrecht, 2018a). In their life-cycle, bees and other pollinators take on different forms. The different life stages are: egg, larva, pupa, and adult. Different bee and pollinator species are in different life stages in different times of the year. Figure 5.38 illustrates the six main types of life-cycles.

Figure 5.37 Bees and butterflies are well-known examples of pollinators.

In order to promote the presence of bees and other pollinators, both nesting facilities and foraging habitat need to be provided. Different species of solitary bees nest either above or underground. An underground nest is a so-called bee burrow. These burrows are preferably created in sun exposed sandy terrain, and steep sandy dunes, but also in brick pavement.

There is a large variety of above ground nesting possibilities, such as hollow stems, existing bore holes, rot affected or dead wood. Additional nesting facilities for bees that nest above ground can be created by creating bore holes in nesting blocks; bundling different types of hollow tubular materials, such as bamboo reed, and cardboard tubes. But also, readymade bee hotels can be placed. Another possibility is the creation of stacked stone walls or insect walls. These nests can also be used by other animal species.

The inhabiting of nesting facilities is largely dependent on a sufficient food supply in its vicinity. The foraging habitat should be present within 100 meters of a nesting facility. Adult bees feed on nectar, while larvae require pollen to develop. To collect nectar and pollen, they require a foraging habitat of flowering vegetation. Some solitary bees are specialists and require specific flowers, but most are generalists and forage on a variety of flowers. A vegetation with a varied structure and a large diversity of preferably native species should be created. This vegetation would consist of a large variety of perennials, shrubs and trees. Solitary bees profit more from perennials than from annual plant species, as they require a yearly similar flower supply (Breugel, 2014; Van Rooij et al, 2016).

Foraging habitat for bees is also suitable for butterflies. In addition, they need host plants for their reproduction (Breugel, 2014). In contrast to solitary bees, most butterflies are specialists. They can be very particular when it comes to which flowers they gather nectar from. Diversity in vegetation composition is therefore even more important. Caterpillars can be even more picky. They often forage on one specific host plant or host plant group.

In addition, butterflies require hibernation spots. In winter, they seek shelter between pruning residue and dead or dry plant materials. The presence of dead plant material in winter is important for their survival (Vlinderstichting, n.d. c).

Another important factor is maintenance. Early, large scale and frequent mowing can destroy the food supply, which is detrimental for the bees (Breugel, 2014). More on maintenance can be read in section 6.6.

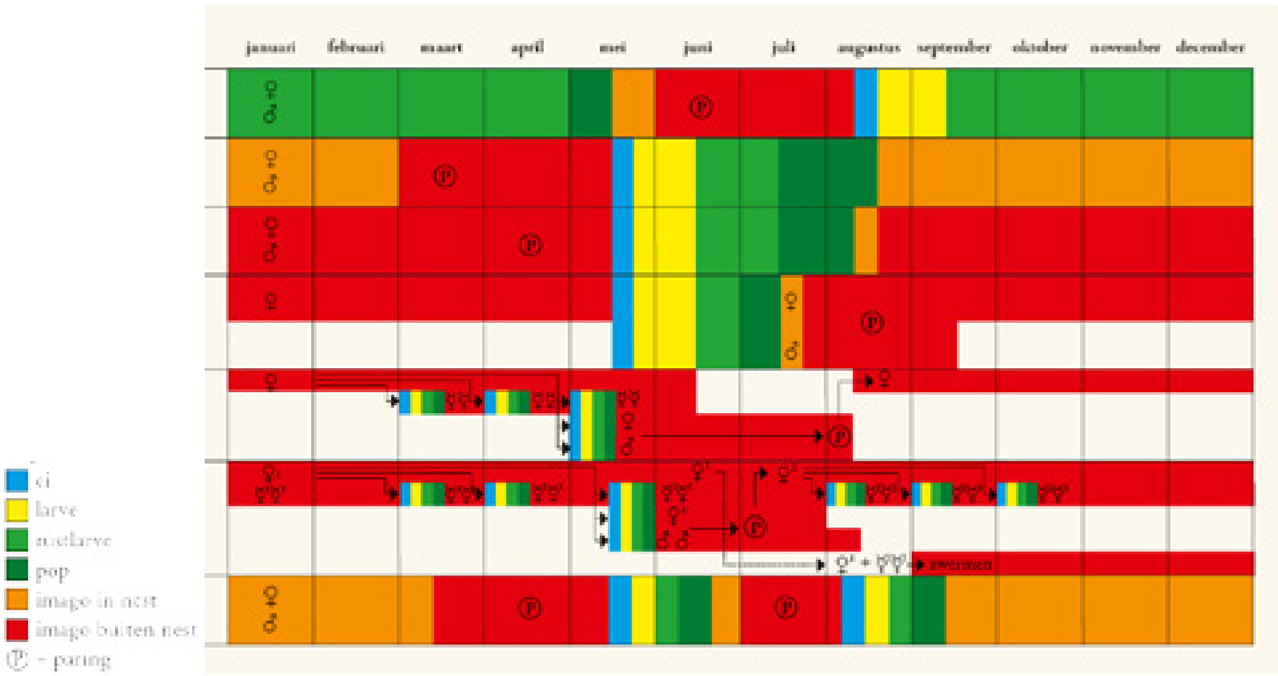


Figure 5.38 The six main types of pollinator life cycles (Peeters et al, 2012).

Additional species

In addition to the beforementioned species, opportunities were found during the design process to also promote other species or species groups. Along the canals, opportunities were found to promote or help water insects, such as dragonflies, amphibians and other aquatic life, as well as bird species, such as the grey wagtail and the common kingfisher. In the street scape and parks, winter guests and other bird species can also be accommodated.

These species will not be addressed further in this section. However, in the elaboration on the design, they will be touched upon in relation to the interventions that were implemented for them.

6. Biodiversity by design

This chapter elaborates on the creation of a biodiverse design for Rivierenwijk. In section 6.1, the goal of the design will be stated based upon the results of the case study. Section 6.2 then elaborates on the models that have been drafted as an exploration of the possible design options. Section 6.3 explains the design principles that have been drafted based upon the literature review and species' requirements. In section 6.4, the preferred model is combined with the design principles and translated into a design for a section of Rivierenwijk. This masterplan is further explained with detail maps, sections and visualisations, as well as a vegetation selection and a maintenance scheme.

6.1 Design goal

The biodiversity goal for the design of Rivierenwijk is to maximise the biodiversity potential of the neighbourhood. This goal concerns optimising the population numbers of the common pipistrelle, the common swift, the house sparrow, as well as optimising the diversity and population numbers of pollinators. This goal will be achieved by maximising the quantity and quality of habitat in the neighbourhood's public space and design them according to the habitat and foraging requirements of beforementioned species as described earlier.

The maximisation of habitat quantity and quality, as well as the implementation of the species' requirements will be weighed against the functionality of the neighbourhood. Since the design site concerns a residential neighbourhood, the biodiverse design should also be functional and aesthetically pleasing. This includes preserving the recreational value of existing green spaces. In this way, the design will illustrate how biodiversity can enhance an urban neighbourhood without limiting its functionality, as well as how it can enhance a neighbourhood's aesthetics. In addition, the design aims to illustrate that biodiversity can be combined with other functionalities as well, such as mitigating the urban climate and water retention.

The design will not be limited to accommodating only the aforementioned species. When opportunities are come across during the design process that can help accommodate other species with simple design interventions that do not compromise the target species' requirements, they will be taken into account and implemented as well. An example of a different species that is taken into account is the common kingfisher (see 6.5.3).

Being aware of the importance of including different spatial scales, this design will nevertheless focus on the neighbourhood and underlying scale levels and disregard higher spatial scales in the further elaboration of the design. The municipality of Utrecht already has a basis for a green network and comprehensive plans to further develop it (see Gemeente Utrecht, 2017a). Therefore, it is not deemed necessary to make propositions on a city wide scale within the scope of this thesis.

6.2 Models

For the exploration of the possibilities of maximising the biodiversity potential or Rivierenwijk, with the beforementioned goals in mind, four models have been drafted. The models are based on the biodiversity principles that have been identified in section 4.1, which have been combined with the opportunities that resulted from the landscape and biodiversity analysis.

The four models explore the scope of what is possible on a range from the current layout of the neighbourhood to a layout of the neighbourhood in which opportunities for biodiversity have been maximised (figure 6.1). Each model builds on the previous one. Accordingly, habitat quality and quantity have been maximised within the bounds of each model. The models are not yet adjusted to the requirements of the target species.

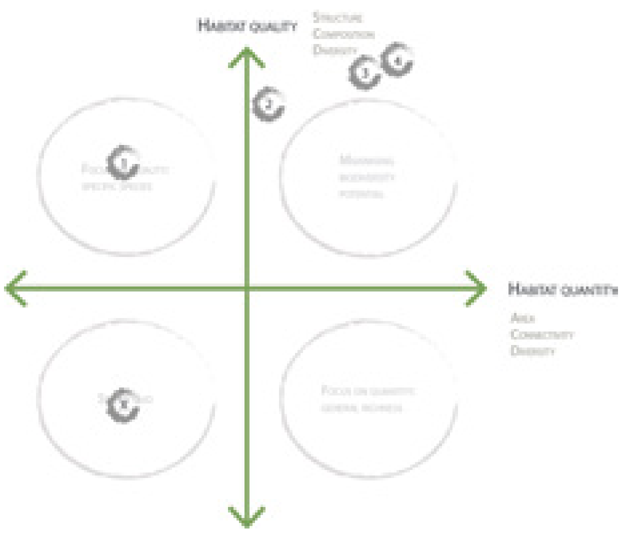


Figure 6.1 The range of models depicted on the quadrant scheme. Mark X represents the current state of Rivierenwijk, in which both quality and quantity are relatively low. Mark 1 to 4 represent the four models that have been drafted for Rivierenwijk to explore the possibilities of maximising biodiversity levels.

6.2.1 Model 1: improving existing green space

While not adding any extra green space, model 1 focusses on maximising the quality of existing green space (figure 6.2). Maximising the quality of existing green space entails maximising vegetation structure and composition. As explained in 4.1.2. maximising vegetation composition leads to a high floristic diversity, while also maximising vegetation structure, should lead to a diverse fauna presence.

To maximise the vegetation structure of existing green space, additional layers of vegetation will be added according to what the size of the green space allows. For the different green space typologies of Rivierenwijk, maximising vegetation structure entails the following:

- Layers of forest understorey are added to the Merwedeplantsoen. This entails adding undergrowth of herbaceous plants, a low shrub layer, and a layer of small trees and tall shrubs.
- In the other parks, a canopy layer will be added in addition to adding the layers of understorey.

Figure 6.2 Model 1 projected on the map of Rivierenwijk.

- Underneath street trees, a layer of herbaceous plants and climbers will be added. In case that the planting box is large enough, one or more low shrubs will also be added.
- Along the water banks, layers of herbaceous plants and (low) shrubs will be added.
- Other green strips will have vegetation layers added according to what their size allows.

To maximise vegetation composition, the flora of the area should be as diversified as possible. Maximising vegetation composition will thus entail the following for the different green space typologies of Rivierenwijk:

- Replacing street trees so that there are as many different tree species as possible in a street.
- Replacing hedgerows by mixed hedges.
- Maximally diversifying perennial and shrubs species that are applied in green strips, parks and ornamental street green.
- Diversifying the vegetation species selection between and within green space typologies to create diverse habitats.

Evaluation

Model 1 illustrates the possibilities of the current green space. Though more habitat quality can be created, this is limited. The possibilities will be even more limited if the recreational function of existing green spaces is considered and preserved in a design. Additionally, the green space remains scattered and scarce as no extra habitat is created.

6.2.2 Model 2: employing excess opportune space

In model 2 (figure 6.3) excess opportune space, as identified in section 5.4.2, will be converted into new habitat in addition to the interventions that are proposed in model 1. The interventions that are proposed in this model add approximately 67.000m2 green space, increasing the share of green space in Rivierenwijk from 13% to 21%.

All sidewalks that extend a width of two meters will be reduced to this width. The space that is gained from this, will be converted into green strips. Residual paved strips will also be converted into green strips. These green strips will be planted with a diversity of perennials and low shrubs. If their size allows it, the green strips will also contain taller shrubs and/or (small) trees.

Squares will get a green makeover that is similar to that of the parks in model 1. With a maximised vegetation structure, the new green spaces will have an undergrowth of herbaceous plants, a low shrub layer, a layer of small trees and tall shrubs and a canopy. Thereby the green spaces become tiny forests throughout the neighbourhood. However, to provide habitat diversity, several squares will be transformed into pollinator gardens with a main vegetation structure of perennials and shrubs.

Playgrounds and schoolyards will be turned into green alternatives that will not only provide opportunities for biodiversity, but also provide new opportunities for playing and learning.

Vertical structures in public space will be greened. Public buildings, such as the church of Sint Gertrudis, schools and neighbourhood centres, will get a green façade. Bridges and blind walls will also be greened using meshwork or cables.

Evaluation
Model 2 resolves the scattered green space by making use of all the opportunities of habitat area expansion that exist within the current urban configuration. Small green strips can be created throughout large parts of the neighbourhood and several larger green areas will be added. However, the green strips are predominantly very slim and thereby fragile. Also, some sections of the neighbourhood remain without green strips. And, like model 1, the possibilities of creating high quality habitats are limited when the recreational function of existing and converted green space is considered.

6.2.3 Model 3: reconfiguring the neighbourhood

In addition to the interventions of models 1 and 2, model 3 (figure 6.4) proposes to convert parking spaces into new habitat and introduces a new river bank along the Merwedekanaal. This model could potentially add 110.000m2 of habitat to the current situation of which 43.000m2 is additional to model 2. However, the absolute amount depends on the extents of the new river bank. The share of green space in Rivierenwijk will be increased up to 27% by this model.

As a first intervention, all parking spaces in the neighbourhood will be converted into green space. The new habitat that this creates is added to the green strips that are proposed in model 2, which will make the strips more robust. As the green space now takes up a significant share of the streetscape, it is feasible to reconfigure the layout of the residential streets. In conventional street layouts the green space is located

Figure 6.3 Model 2 projected on the map of Rivierenwijk.

Figure 6.4 Model 3 projected on the map of Rivierenwijk.

on both sides of the street between the sidewalks and the road. But there are other possibilities, for example to relocate the green strips between the houses and the sidewalks. As such, the public green forms a larger green space together with front or façade gardens if they are present. Or the green strips from both sides of the streets can be merged into one larger green space. Though separate green strips on both sides of the streets provide a buffer between pedestrians and car traffic, and thereby promote safety, one large green strip provides more benefits to biodiversity. For one, a more diverse vegetation structure and thereby habitat can be created in larger areas. In addition to the perennials and low shrubs that can be placed in small green strips, more tall shrubs and large trees can be placed in these larger ones. Secondly, a larger area is more robust than a smaller one.

The second intervention is to create a new river bank along the Merwedekanaal. An extensive green strip of floating gardens or similar constructions will be created at the backs of the house boats that are located along the Merwedekanaal over the whole length of Rivierenwijk. These floating gardens will be vegetated with water and water bank vegetation. This new water bank could stimulate aquatic life and could mitigate the problem with waves in the canal.

Evaluation
Model 3 enables the creation of more robust green strips throughout the whole neighbourhood. As the green strips that are proposed in this model are larger, it can be investigated if they can serve more purposes than only for biodiversity and aesthetics. Additionally, the new water bank can provide interesting new habitat opportunities. However, the conversion of all parking spaces may not be feasible as it conflicts with the functioning of the neighbourhood. Similarly, the new water bank might conflict with the use of the Merwedekanaal.

6.2.4 Model 4: a large neighbourhood park

Model 4 (figure 6.5) explores the possibilities of closing off a road in order to further expand the green area. As such, the Rijnlaan is closed off between the Waalstraat and Socrateslaan and replaced by the Rijnlaanpark. Model 4 adds another 16.000m2 of green space to the previous models, resulting in an increase of 126.000m2 of green space as opposed to the current situation. 29% of Rivierenwijk will thereby consist out of green space.

In order to create the Rijnlaanpark, a large part of the Rijnlaan would have to be closed off and traffic will have to be redirected. On the north side, traffic can be redirected along the Waalstraat, from where it can disperse over the neighbourhood. On the southside, the Jutfaseweg and the parallel road of the Socrateslaan will serve the same purpose. The Rijnlaanpark can harbour a diversity of habitats from forest-like to pollinator gardens, but could also, for example, contain natural playgrounds. The park would also from a connection between the green spaces in the east and west side of the neighbourhood, which in all previous models are separated by the barrier that is formed by the Rijnlaan.

Evaluation
Model 4 eliminates a barrier between the green spaces on either side of the neighbourhood as the Rijnlaan would partially be converted into a park. In addition to promoting biodiversity, this intervention could also significantly reduce the car traffic pressure on Rivierenwijk, which fits the municipality's mobility policy. However, since the Rijnlaan is the main traffic axis of Rivierenwijk, this intervention could also put a severe strain on the functioning of the neighbourhood. Not only will car traffic be affected, but also public transport. The latter goes against the municipality's policy.

Figure 6.5 Model 4 projected on the map of Rivierenwijk.

6.2.5 Conclusion

The four models provide a good range of the possibilities of creating a biodiverse Rivierenwijk. In order to select a model that is elaborated into a design, all models have been evaluated briefly on both their potential and their impact on the functioning of the neighbourhood.

An immediate distinction that can be made is that models 3 and 4 require alterations to the neighbourhood's configuration as opposed to models 1 and 2. These alterations will have an impact on the functioning of the neighbourhood, more so in model 4 than in model 3.

Models 1 and 4 are eliminated as the impact on biodiversity levels presumably will be limited in model 1 and model 4 might have too large of an impact on the functioning of Rivierenwijk.

Model 2 would thus be the most that can be done without interfering with the functioning of the neighbourhood. However, this model also has its limits, which can be overcome by model 3. Furthermore, model 3 provides more promising additional opportunities.

To overcome the constraints that model 3 imposes on the neighbourhood's functioning, a compromise will be struck. A share of the parking space will be conserved in line with the municipalities policy for new urban developments such as Merwede (see 5.2). The redesign of Rivierenwijk will equally adhere to the mobility concept of Merwede. As such, parking norms are lowered to 0,3 per household, and car sharing is introduced, by which one shared car will replace four other cars (Goudappel Coffeng & REBEL, 2018). Hereby, a large share of the parking spaces in Rivierenwijk can be removed and thus converted into green.

6.3 Design principles

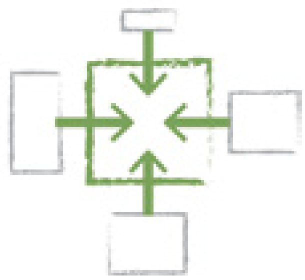
Different design principles were created based on the biodiversity principles and guidelines, target species' habitat and foraging requirements, and outcomes of the case study. The general design principles will be explained below. Design principles that concern a specific section of the design will be explained in the elaboration of the design and its details (sections 6.4 and 6.5).

The literature review showed that the highest levels of biodiversity can be achieved on a site by maximising habitat quantity and quality. Habitat quantity is mainly determined by habitat size and connectivity, while habitat quality is determined by vegetation structure and composition. A high habitat diversity, which is created by variances in vegetation structure and composition, has additional beneficial effects on biodiversity levels.

The target species all have (slightly) different habitat and foraging requirements. The common pipistrelle requires insect rich, wind sheltered foraging grounds along high rising vegetation structures. The common swift has little requirements to its direct living environment, and also forages on insects. The house sparrow requires a diversified habitat structure for both shelter and foraging in a close range to its nest. And in addition to insects, it requires seed and fruit bearing vegetation to feed on. Lastly, pollinators require wind sheltered and sun exposed habitats with a varied vegetation structure within a short radius of its foraging ground. The foraging ground should provide both sources of pollen and nectar to satisfy foraging requirements in different stages of pollinators' life cycles. Hibernation spots should be included as well.

In addition to the target species' requirements, the municipality's and user's wishes as retrieved from the document study are also considered. As such, multipurpose spaces should be created that accommodate these wishes.

As such, the following general design principles have been formulated:

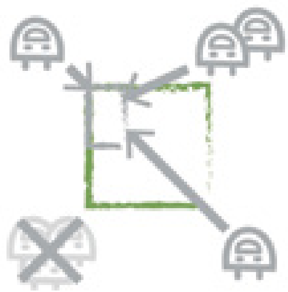


1. Green space is clustered together to form the largest possible connected habitat area(s).

Figure 6.6 Design principle 1

Larger and well-connected areas are more resilient and can support more species and larger populations (Alvey, 2006; Cornelis & Hermy, 2004; Fahrig, 2003; Gagné et al, 2015; Nielsen et al, 2014; Norton et al, 2016; Rosenzweig, 2003). Therefore, the new green spaces are added to the existing urban configuration in such a way that they form the largest possible areas (figure 6.6), without limiting the functioning of the site (for example, traffic through fare).

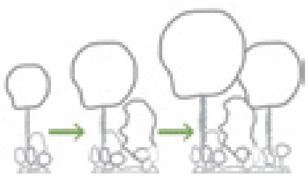
Though this reasoning makes is logical to also connect the new habitat areas to private green, the choice has been made not to do so. By connecting public green to private green, it is possible that people will see the new green spaces as extensions of their private gardens. People might start to appropriate parts of the public green and alter it to their preferences. This is not supposed to happen to the newly created green spaces. As such, only public green is connected to form the largest possible habitat areas.



2. Disturbances are minimised and/or clustered together.

Figure 6.7 Design principle 2

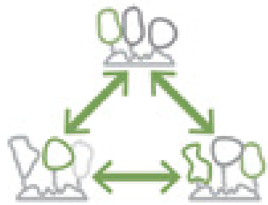
To not limit the functioning of the neighbourhood, certain disturbances that could have a negative impact on the level of biodiversity should be preserved. For example, car parking. In order to minimise the impact that these disturbances might have, they are first reduced to the minimal requirements. Then the remainder is dispersed throughout the neighbourhood in clusters. These clusters are located in smaller habitat areas in favour of the preservation of larger ones (figure 6.7).



3. As many structural vegetation layers as the size and the function of a green space allow are implemented.

Figure 6.8 Design principle 3

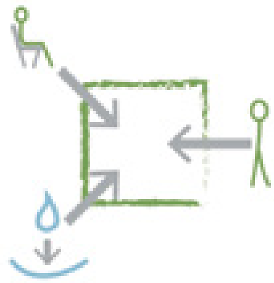
A maximised vegetation structure would consist of 1) undergrowth of herbaceous plants, 2) a low shrub layer, 3) a layer of small trees and tall shrubs, 4) a canopy layer. In addition, climbers could be added, which are not necessarily bound to any of the layers. The implementation of these layers in certain habitats will be weighed against their function and size. Larger habitat areas that are assigned a more natural look will obtain all layers included. In smaller habitat areas, this might not have the desired effect, so some layers will be disregarded (figure 6.8). As such, different habitat typologies are defined (see section 6.5), which each have their distinct vegetation structure.



4. Vegetation composition is diversified between and within different habitat typologies

Figure 6.9 Design principle 4

Similar to the variances in vegetation structure, variances in vegetation will be created throughout the neighbourhood (figure 6.9). A distinct vegetation selection is created based on the desired habitat typology. Nevertheless, there can be some overlaps in the vegetation selection of the different typologies. A wide range of vegetation is selected for each of the typologies as to enable the creation of compositional variances within typologies as well. The vegetation composition is mainly based on the foraging and habitat requirements of pollinator species and house sparrows. Accordingly, the programme SynBioSys (Hennekes et al, 2010) was used to supplement the selected vegetation and draft sound vegetation communities.



5. Multifunctional use of the newly created green spaces is stimulated.

Figure 6.10 Design principle 5

To accommodate current and desired use of the neighbourhood and its green spaces, as well as to mitigate other urban challenges as climate change adversities, multifunctional green spaces are created wherever possible (figure 6.10). Small green spaces will be monofunctional and only accommodate biodiversity, as their size does not allow the inclusion of additional functions. But larger green areas will also include recreational components and provide water retention possibilities depending on their size.

6.4 A biodiverse design for Rivierenwijk

By applying the abovementioned design principles on the preferred model, a biodiverse design is created that has been elaborated for a section of Rivierenwijk (figure 6.12). This design transforms the overly stony Rivierenwijk into a lush green and biodiverse neighbourhood. The newly created habitat supports foraging and habitat requirements for pollinators, house sparrows, common swifts and common pipistrelles. n total approximately 16000m2 new and/or qualitatively improved habitat area is created in this section of Rivierenwijk.

This amount of new habitat is achieved by several measures. First, all pavements that exceed a width of two meters are reduced to a width of two meters. Pavements that were already limited to this width or smaller, remain so. Second, almost three quarters of the parking spaces are removed in line with the traffic concept for the redevelopment of the Merwedekanaalzone (Goudappel Coffeng & REBEL, 2018). Of the parking spaces in this section of the neighbourhood, 128 remain. These are clustered per street to minimise impact on the created habitat. Third, residual strips of pavement are transformed into green space. Fourth, squares, playgrounds and schoolyards are transformed into green alternatives (see section 6.5.2). The areas that became available by these interventions are accordingly clustered together to create the largest possible connected habitat areas. Fifth, a new artificial water bank is created along the Merwedekanaal by implementing floating gardens (see section 6.5.3). Finally, vertical green is created on vertical structures, such as the bridge that spans the Merwedekanaal and its supporting structure.

In addition to the creation of new habitat area, existing green spaces are given a qualitative upgrade. This concerns supplementing their vegetation structure appropriate to the existing function of the green space, and diversifying their vegetation composition.

Though the rest of Rivierenwijk is not further elaborated on in design images, the same measures are implemented throughout. Three distinct habitat typologies are created by this biodiverse transformation of Rivierenwijk: the streetscape; parks, playgrounds and schoolyards; and water banks. Each habitat typology has distinct structural and compositional characteristics that in turn vary within each typology. These different typologies and the design principles that underly them are elaborated on in section 6.5.

6.5 Habitat typologies

The design for Rivierenwijk is divided into three habitat typologies: the streetscape; parks, playgrounds and schoolyards; and water banks. Each habitat typology contains variations. All of these are elaborated on below. Their underlying design principles are explained, detail maps and sections are presented, as well as visualisations and other supporting images.

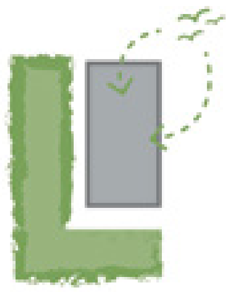
6.5.1 The streetscape

The streetscape concerns both residential streets and access roads.

Residential streets

Streetscape design principles

The design of the residential streets is based upon several design principles additional to the general ones:



1. Habitat area is located to the south and west side of building blocks.

Figure 6.11 Streetscape principle 1

By locating the habitat area directly to the south and west side of building blocks, birds obtain free flying access to their nests (figure 6.11). This is especially important for the common swift, as it requires a free fall space of at least three meters deep and one meter wide below their nest entrances/exits (BIJ12, 2017b; Gemeente Utrecht, 2016; RVO, 2014b). Both common swifts and house sparrows prefer their nests on the cooler, shaded sides of a building, i.e. the north or east side (BIJ12, 2017b, c; Gemeente Utrecht, 2016; RVO, 2014b, c). As such, the configuration of the new habitat areas, do not form obstacles for the birds when entering or exiting their nests.

In addition, pollinators require sun exposed habitat (Breugel, 2014; Van Rooij et al, 2016). Creating habitat area on the south and west side of building blocks fulfils this requirement.


Figure 6.44
Figure 6.25
Figure 6.20
Figure 6.16

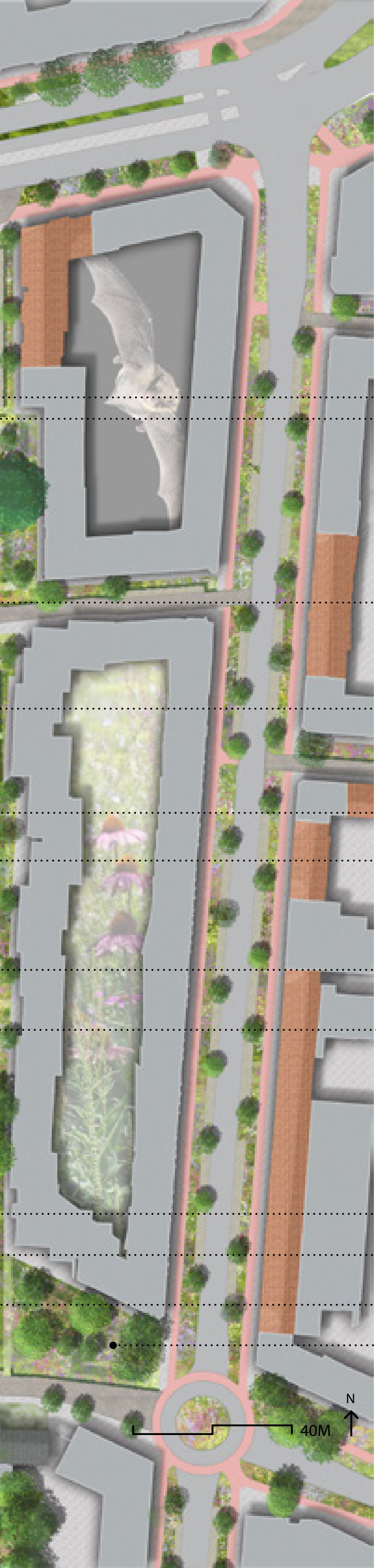


Figure 6.12 The biodiverse design for Rivierenwijk elaborated for the northwest corner of the neighbourhood.

Moreover, green space on the sun exposed sides of the building blocks enables people to reside in the sun. But for those people that do not enjoy the heat, also shadowy spots are provided. Green space on the shaded side of buildings only provides in the latter.

Configuring green spaces in this way, also has benefits for the urban climate as shade is provided in those areas that would accumulate the most heat.

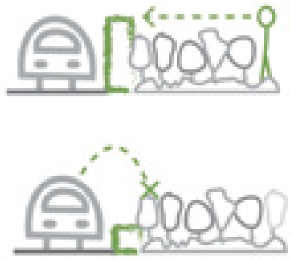
2. Higher vegetation elements are clustered together

Figure 6.13 Streetscape principle 2

In order to accommodate the habitat requirements of both pollinators and house sparrows, a diversified vegetation structure is implemented that includes tall and dense vegetation. These vegetation elements, tall shrubs (4-5m high), are clustered together with trees to not limit the sense of spaciousness and thereby intrude on the sense of security in the streetscape (figure 6.13). These clusters have a size of 10-20m2 and are located at a distance of 15-25m from one another.

Clusters of low shrubs (<2m high), on the other hand, are distributed throughout the green spaces at a distance of about 5m from one another. Three individual shrubs are placed together in a cluster.

Clustered elements of tall vegetation create small concentrations of shade on specific spots, instead of many shaded spots throughout the green strips.



3. Hedgerows are employed to limit traffic disturbance

Figure 6.14 Streetscape principle 3

All habitat area in the streetscape is lined with mixed hedgerows on the street side (figure 6.14). Hedges of 0.5 meters tall prevent cars from being parked in the green strips and thereby destroy habitat. 1.5 meter tall hedges around the parking spaces will hide parked cars from sight. This intervention will prevent the sight of cars from intruding on the experience of being surrounded by lush and biodiverse green.

Streetscape typologies

Together with the general design principles, these principles lead to three variations of residential streets: those that contain narrow, medium or wide green strips. The quality of these green strips is maximised according to what their size allows. The green strips vary in vegetation structure and composition, as well as in function. In this way additional habitat diversity is created.

1. Narrow street typology

Figure 6.15 Narrow street typology

Narrow streets (figures 6.15-16 and 6.29-30) are those that contain green strips with a width of less than 2,5 meters. These streets mainly function as pollinator habitat. The habitat structure of narrow streets consists of perennials, climbers, low shrubs and 3rd size trees. The floristic composition of each structural layer is highly diverse.

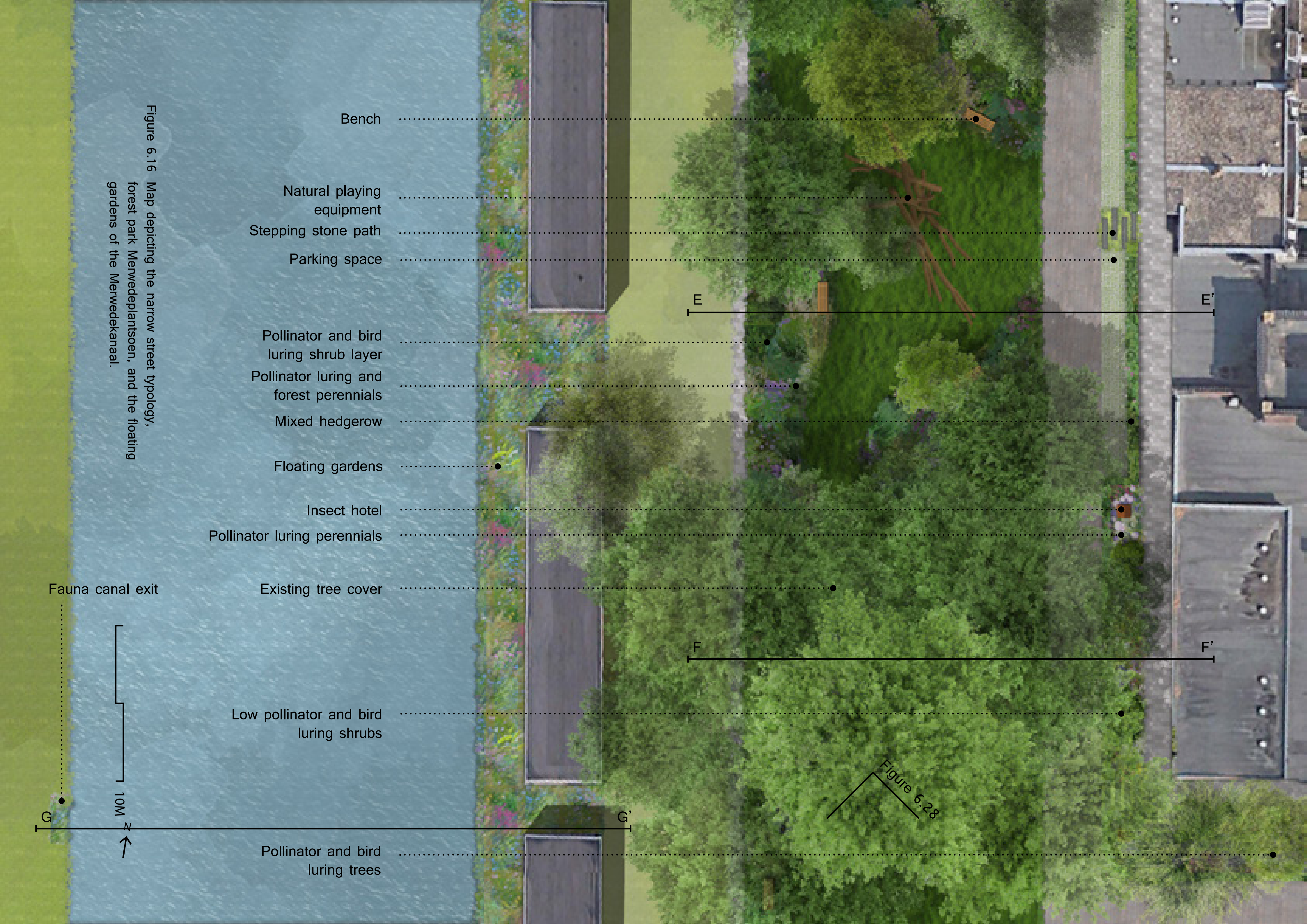
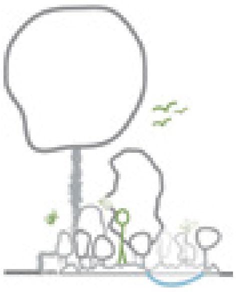


Figure 6.16 Map depicting the narrow street typology, forest park Merwedeplantsoen, and the floating gardens of the Merwedekanaal.

2. Medium street typology

Figure 6.17 Medium street typology



3. Wide street typology

Figure 6.18 Wide street typology

Medium streets (figures 6.17 and 6.20-22) are those that contain green strips with a width between 2,5 and 5 meters. These streets will function as pollinator and bird habitat. They will also be accessible for people by the provision of stepping stone pathways. The habitat structure of medium streets consists of perennials, climbers, low and tall shrubs and 2nd size trees. The floristic composition of each structural layer is highly diverse.

Wide streets (figures 6.19 and 6.23-25) are those that contain green strips that extend a width of 5 meters. These streets function as pollinator and bird habitat. They are also accessible for people by the provision of stepping stone path ways. In addition, water retention is provided by the implementation of wadis. The wadi's that run through these green strips are 2,3 meters wide and 0,3 meters deep with a slope of 1:3. The habitat structure of wide streets consists of perennials, climbers, low and tall shrubs and 1st and 2nd size trees. The floristic composition of each structural layer is highly diverse. The vegetation composition in the wadi's is different from the rest of the green strip, thereby adding higher habitat diversity.

Figure 6.19 Visualisation of the wide street typology.

Figure 6.20 Map depicting the medium street typology.

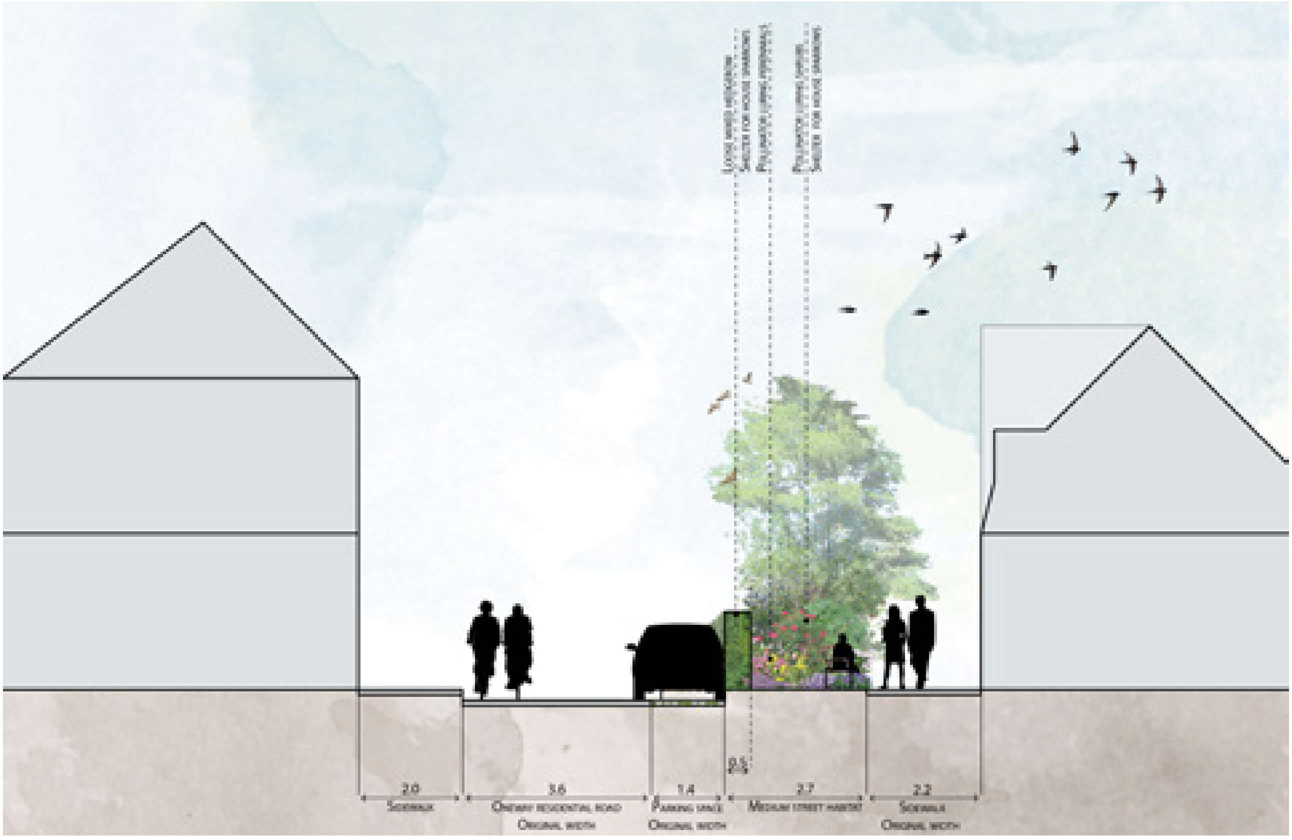


Figure 6.21 Section AA' in the medium street typology.

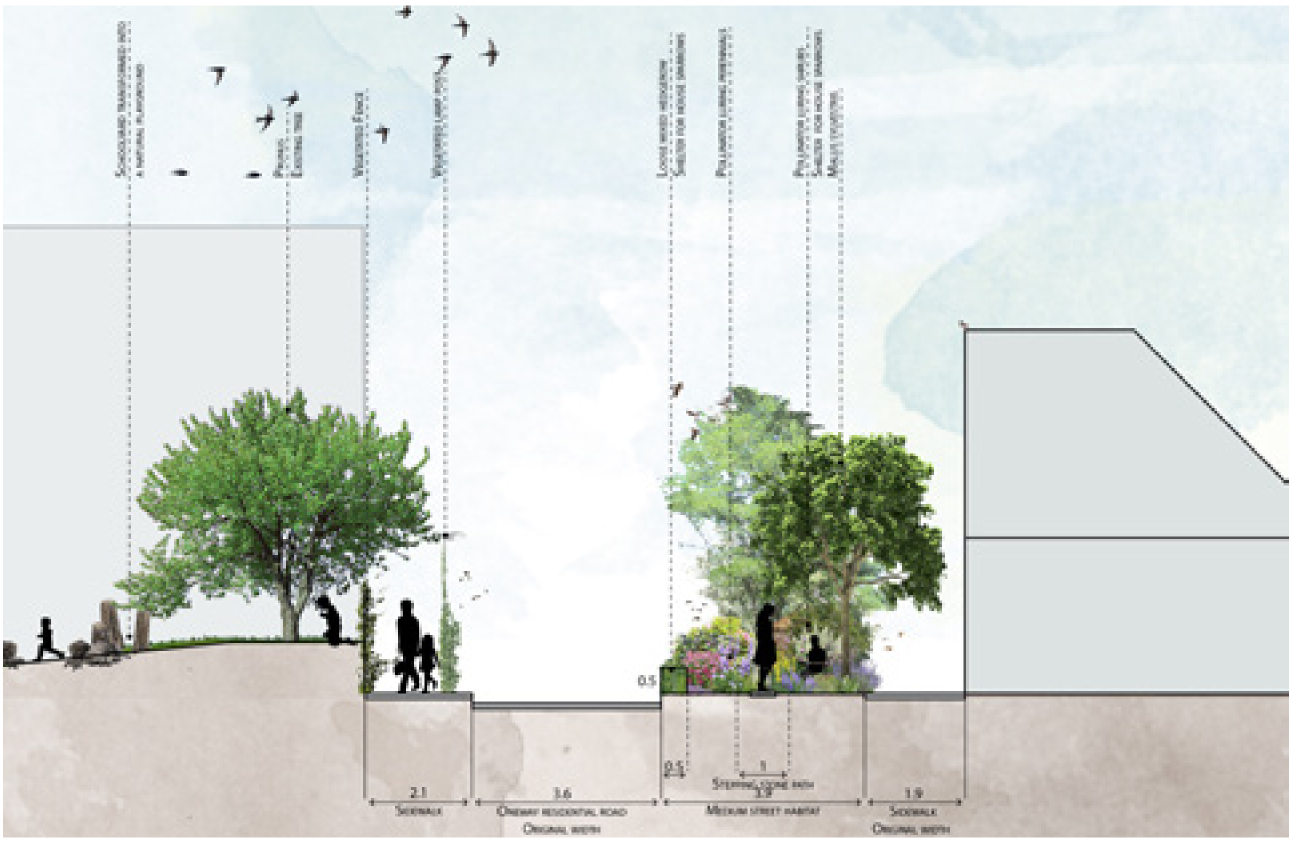


Figure 6.22 Section BB' in the medium street typology.

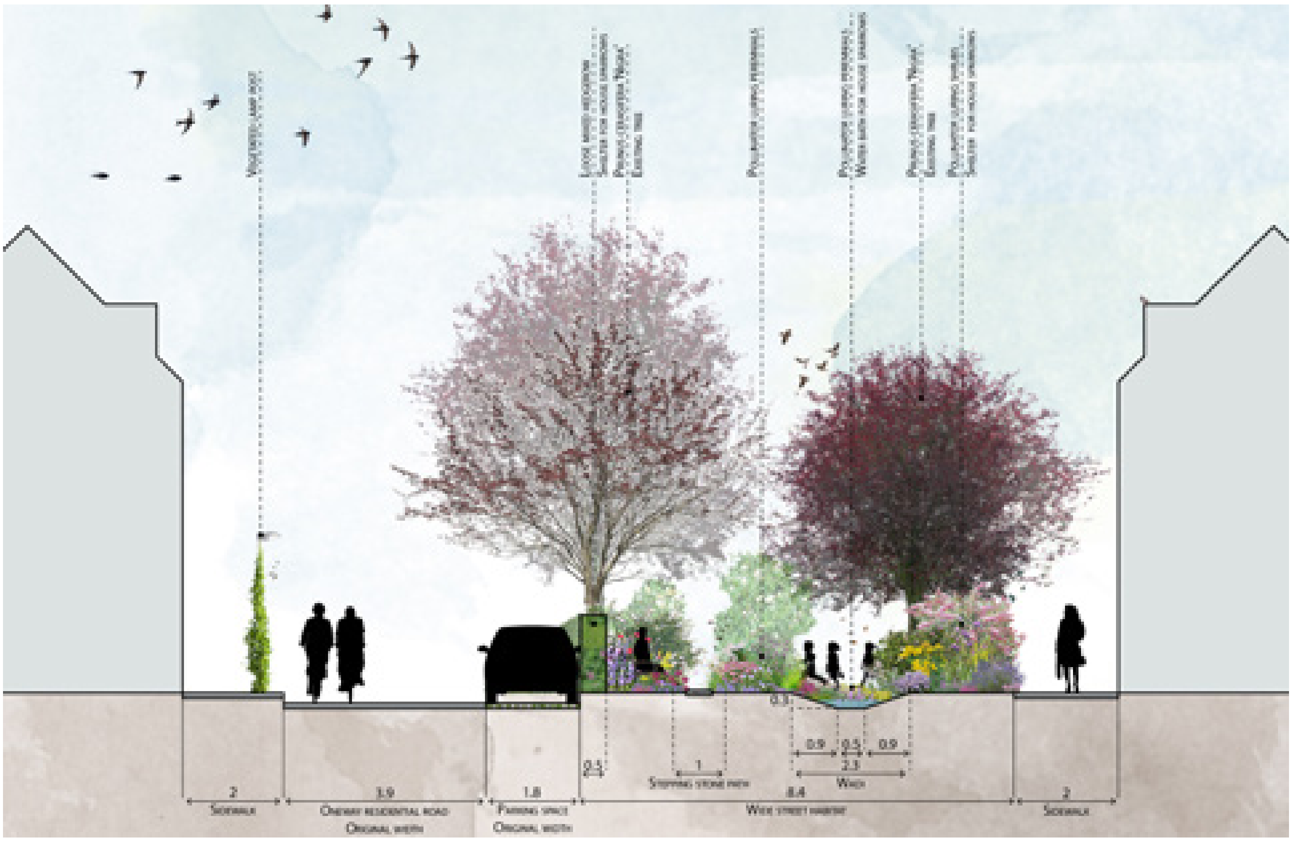


Figure 6.23 Section CC' in the wide street typology.

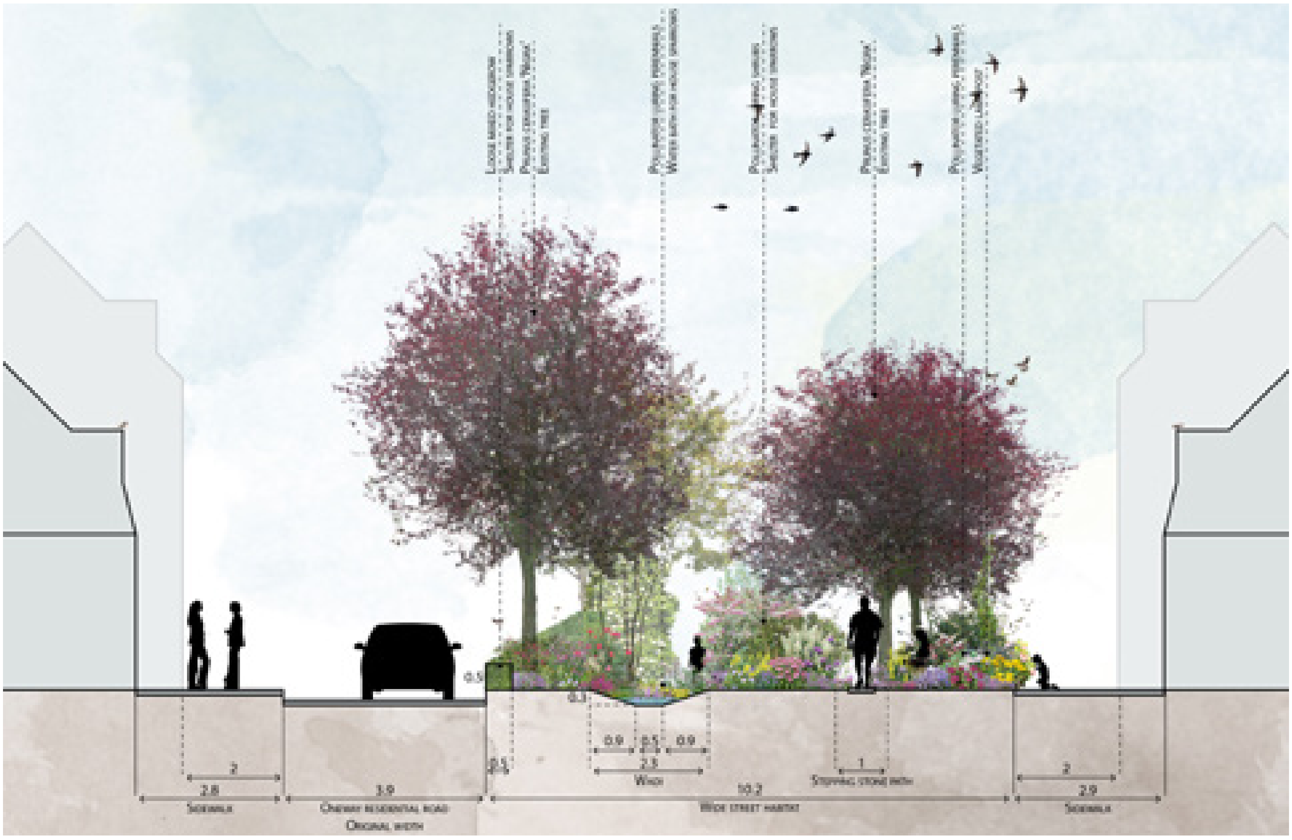
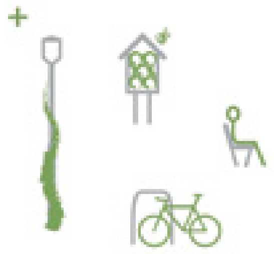


Figure 6.24 Section DD' in the wide street typology.

Figure 6.25 Map depicting the wide street typology.



Additional streetscape elements

Figure 6.26 Additional elements

In addition to the beforementioned elements, each street and/or green strip is equipped with vegetated lamp posts, insect hotels, benches and extra bicycle parking (figure 6.26).

The stepping stone pathways are made of large stepping stone tiles that are embedded in honey grate structured mats. These mats make it possible for people with strollers and rollators to make use of the pathways, while at the same time still enabling plants to grow in the paths.

The remaining parking spaces are repaved with a type of semi-pavement, which also allows for the sprouting of vegetation in between the pavement. Semi-pavement also facilitates nesting spots for pollinators and the space in between the bricks can possibly be used as a sand bath by common swifts.

The reconfiguration of the streets that is proposed by this design has a disadvantage as it requires the removal of existing trees. Some of which are already quite tall and/or old. Existing trees are kept in place as much as possible. Wherever the design requires them to be removed, trees are relocated or replaced. Relocation within the neighbourhood only applies to trees that hold significant value (e.g. those that are old and/or tall or are a native species). Exotic trees that can remain in place within the new street configuration, are replaced by native trees from the tree selection upon death or any circumstance that requires temporary removal.

Access roads

The access roads are largely kept as they are. Their configuration is not altered. However, the residual pavement strips that surround these roads is turned into habitat area. Existing green space along these roads is upgraded qualitatively. This upgrade is done in accordance to the design of the residential streets. The access roads already function as foraging grounds for the common pipistrelle. By improving and creating more pollinator habitat along the streets, foraging opportunities for the common pipistrelle are improved. As most green strips along the access roads are small, they will contain perennials, climbers, and low shrubs. The existing trees will remain. Upon death or any circumstance that requires temporary removal, these trees will be replaced by 2nd or 1st size trees out of the tree selection in order to create a more diverse vegetation composition.

6.5.2 Parks, playgrounds and schoolyards

Parks

Parks concern both existing parks and parks that are newly created by the transformation of parking lots and squares. The quality of these parks is maximised according to their function.

Existing parks with a main recreational function remain in their current state. Additional vegetation layers are added if that is allowed by their existing design without interfering with their recreational function. For example, as can be seen in figures 6.12 and 6.20, the Waalstraatpark is expanded and thereby obtains a new vegetation of perennials and low shrubs along its edges, framed by mixed hedgerows.

New parks are created in replacement of squares and parking lots. These new parks' contribution to biodiversity supersedes a recreational function. As such, the larger new areas become tiny forests and the smaller ones become pollinator gardens. These parks can still be used for quiet forms of recreation such as walking, wandering around and simply enjoying the environment, but are not suitable for very active forms of play.

A tiny forest is a densely vegetated native forest with a size of 200 to 400 m2 (about the size of a tennis court). A tiny forest contains habitat opportunities for butterflies, birds, bees, and small mammals. Besides promoting biodiversity, tiny forests offer great opportunities for education and reconnection with nature (Bleichrodt et al, 2017).

The pollinator gardens are designed in similar fashion as the wide street typology.

Figure 6.27 Forest park Merwedeplantsoen

The Merwedeplantsoen (figures 6.19 and 6.27-30) is and exception to the treatment of existing parks. This large green area is turned into a forest park. As such, additional vegetation layers are added for the park to resemble a natural forest like structure. This forest like structure is created in undulating green strips along the edges of the park. Next to the existing canopy, layers of tall and low shrubs are added, as are perennials and flowering bulbs. Hereby, its function as bird habitat is improved and new pollinator habitat is added. These interventions also improve the park's qualities as foraging habitat for the common pipistrelle.

The park's current recreational function is preserved as well. Open areas are created between the undulating forest vegetation. In these open areas, benches, picknick tables, and natural playground equipment is provided.

Playgrounds and schoolyards

Existing playgrounds and schoolyards are transformed into green alternatives (figure 6.22). These green alternatives connect children with nature and provide opportunities for adventure, discovery and development (Fjørtoft, 2004). Natural playground and schoolyards come in all shapes and sizes, and are best designed in collaboration with their intended users. Some general principles are the placement of natural playing equipment, the removal of pavement, implementing natural vegetation, providing sand, water and other materials to play with, etc. (Bienenstock, 2010). Some of these also form interesting habitat opportunities for the target species of this thesis. House sparrows require sand and water baths with are generally provided in natural playgrounds (BIJ12, 2017c; Gemeente Utrecht, 2016; RVO, 2014c). Also nesting grounds for pollinators can be found in these playgrounds (Breugel, 2014; Van Rooij et al, 2016).

Figure 6.28 Visualisation of forest park Merwedeplantsoen.

Figure 6.29 Section EE' through forest park Merwedeplantsoen and the narrow street typology.

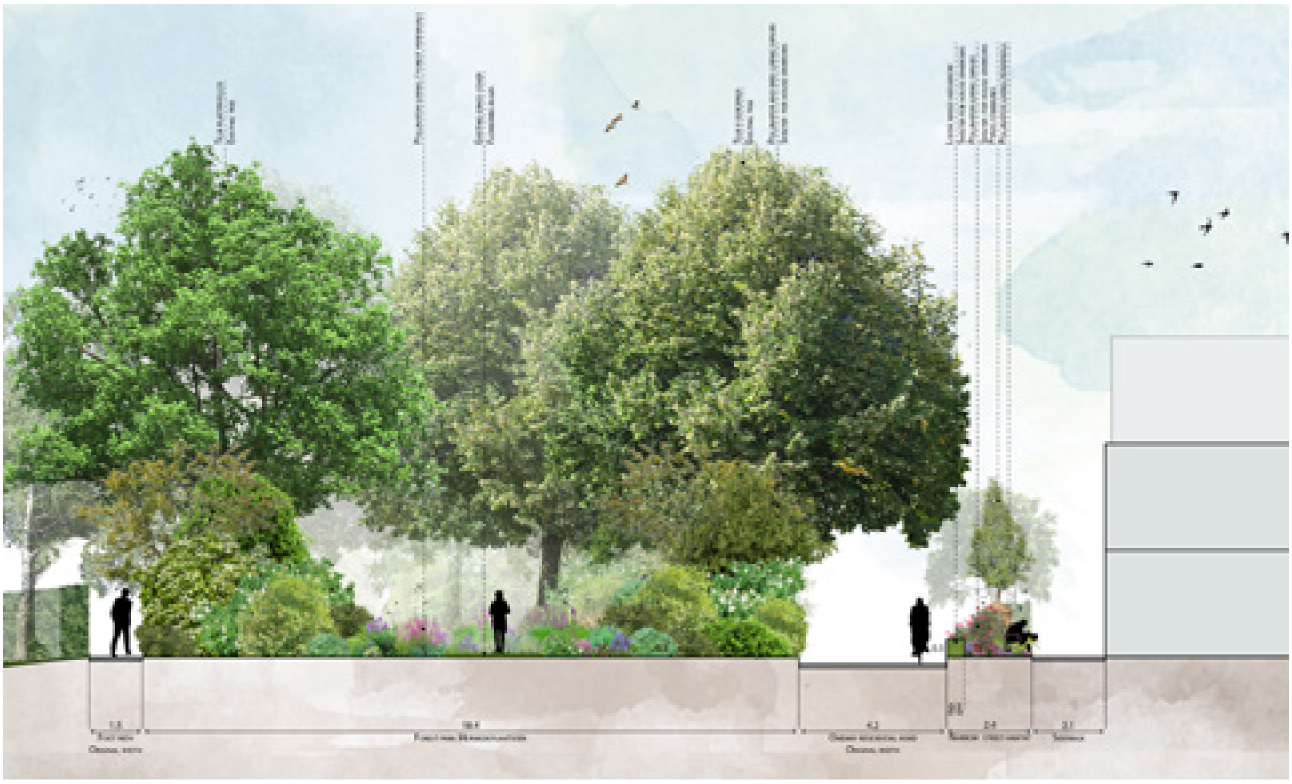
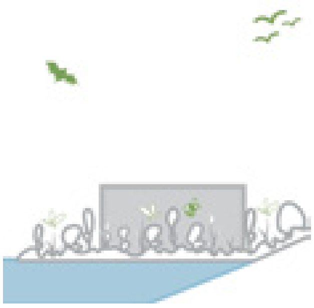


Figure 6.30 Section FF' through forest park Merwedeplantsoen and the narrow street typology.

6.5.3 Water banks

Four interventions are employed to improve the habitat opportunities of the water banks along the Merwedekanaal and the Vaartsche Rijn.



1. Floating gardens Merwedekanaal

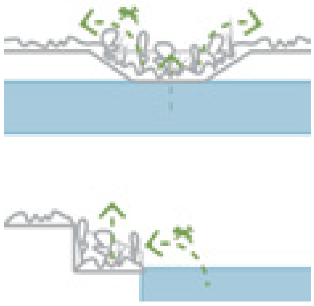
Figure 6.40 Floating gardens Merwedekanaal

A 2.5 meter wide artificial water bank existing of floating gardens is created at the backs of the house boats along the Merwedekanaal (figures 6.16, 6.40 and 6.42-44). The standard construction of floating gardens consists out of a wooden frame that is dressed with wire mesh. The meshwork is subsequently filled with dead plant material and willow cuttings. They are generally anchored to the water bank or to poles that are placed in the canal bottom. This standard construction is applied in canals that are similar to the Merwedekanaal in function (mainly recreational) (Koedood et al, 1996; Rijkswaterstaat, 2008).

The construction is subdivided into individual floating gardens of 2.5x2.5 meter. They are anchored to each other by removable chains. An anchor pole is placed every three gardens. The distance between individual segments is 0.2 meters. At anchor poles, it is 0.3 meters (Koedood et al, 1996).

The floating gardens provide new habitat for pollinators as well as foraging grounds for the common pipistrelle and birds. In addition, floating gardens have proven to have a positive influence on aquatic life. They provide new nesting and habitat opportunities for fish, amphibians and water birds. They also contribute to the improvement of water quality. And they provide new experiential value (Didderen & Paalvast, 2015; Koedood et al, 1996). The best results are achieved by floating gardens that contain root-forming water and water bank vegetation (Didderen & Paalvast, 2015). As such, this type of vegetation is applied.

The new water bank will reduce the width of the canal and therefore conflict with its use by rowing associations. However, it will also have a significant benefit as the new vegetation will absorb and reduce waves (Didderen & Paalvast, 2015). Thereby being of benefit to the rowers.



2. Fauna canal exits Merwedekanaal

Figure 6.41 Fauna canal exits Merwedekanaal

On the east bank of the Merwedekanaal, fauna canal exits (fauna-uittredeplaatsen) are implemented (figures 6.16, 6.41, 6.43, and 6.45). Fauna canal exits are created to enable (all non-flying) fauna to exit water bodies that are lined with a hard water bank protection (Wansink et al, 2011). As is the case for the Merwedekanaal (RoyalHaskoning DHV, 2013). Fauna canal exits come in different forms and sizes. Figure x shows the dimensions. To implement this construction, three meters of the water bank protection is moved backwards about one meter. Then a 1:3 slope is created from the water bank to the water edge. The lowered area along the water edge is subsequently planted with water bank vegetation. This application of vegetation enables fauna to locate the exits. The exits are placed at a 50 meter distance of each other as this is required for small fauna species (Wansink et al, 2011).

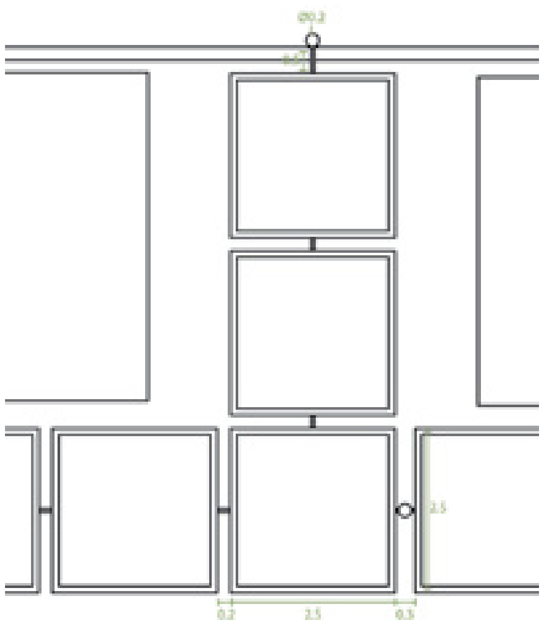


Figure 6.42 Simplified technical elaboration of the floating gardens of the Merwedekanaal

Figure 6.43 Section GG' throguh the Merwedekanaal.

Figure 6.44 Visualisation of the floating gardens of the Merwedekanaal.

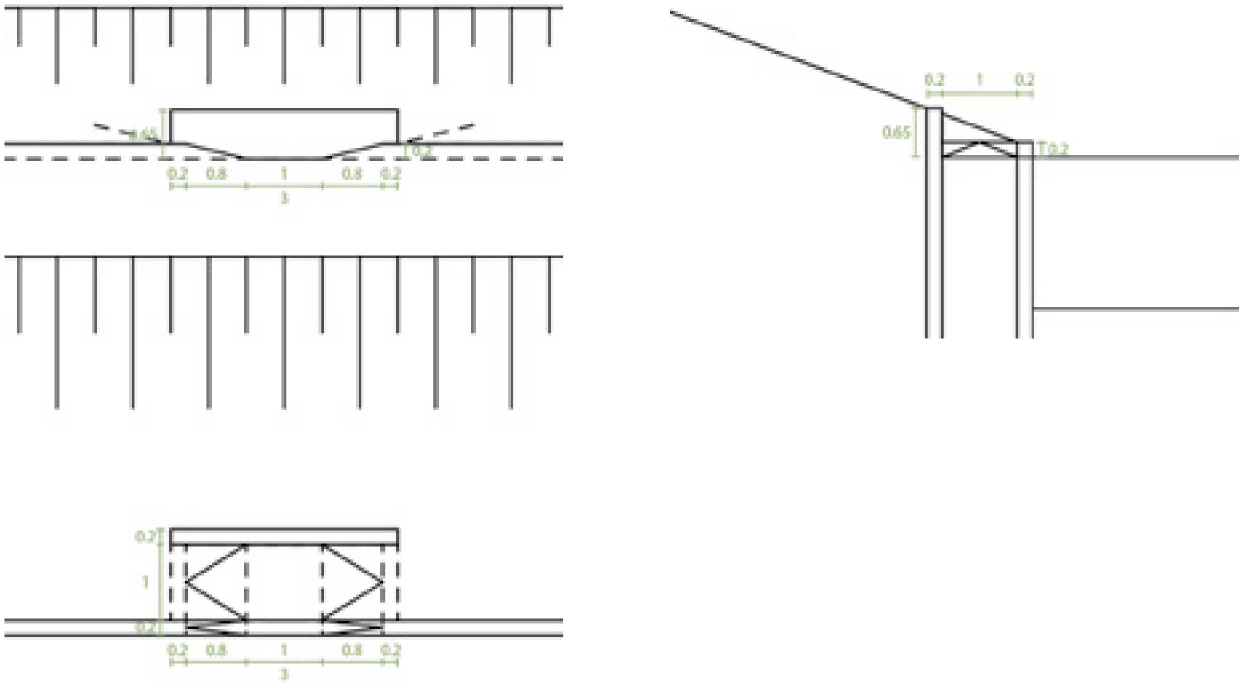


Figure 6.45 Simplified technical elaboration of the fauna canal exits. Front view (top left), section (top right) and top view (bottom).

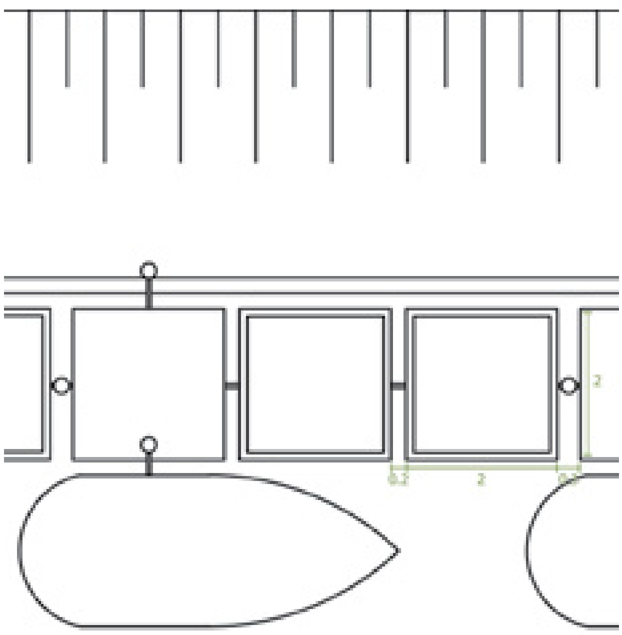


Figure 6.46 Simplified technical elaboration of the floating gardens of the Vaartsche Rijn.

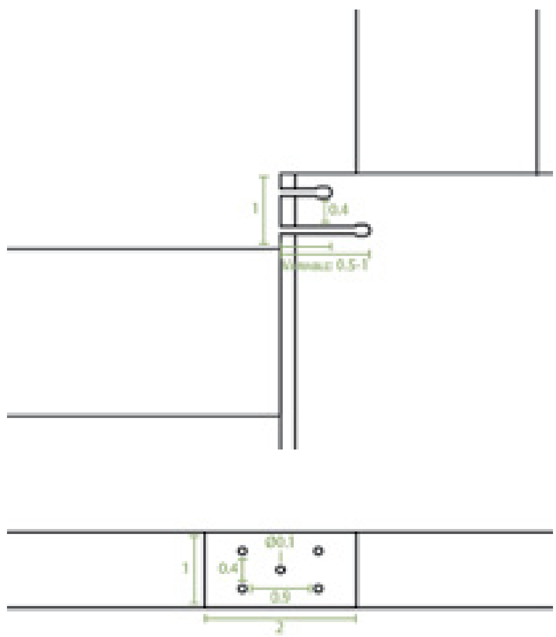
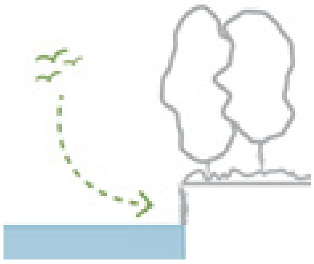


Figure 6.47 Simplified technical elaboration of the artificial bird nesting spots. Section (top) and front view (bottom).

3. Floating gardens Vaartsche Rijn

Figure 6.48 Floating garrdens Vaartsche Rijn



4. Artificial bird nesting spots Vaartsche Rijn

Figure 6.49 Artificial bird nesting spots Vaartsche Rijn

Floating gardens are also created along the east bank of the Vaartsche Rijn (figures 6.45, 6.48 and 6.49). The floating gardens along the Vaartsche Rijn are slightly smaller than those along the Merwedekanaal. The individual gardens have a dimension of 2x2 meters. Every third module is replaced by a small dock to still enable recreational boats to dock along the water bank.

The actual water bank is planted with insect luring perennials in order to create pollinator habitat. Both the floating gardens and water bank vegetation improve foraging opportunities for the common pipistrelle and birds.

On the west bank of the Vaartsche Rijn, artificial bird nesting spots are created for the common king fisher (figures 6.46-47 and 6.49-50). The existing vertical water bank protection is adapted in multiple places over multiple lengths of 1 to 2 meters. Where there is only wooden water bank protection with ground directly behind it, holes are drilled in the existing structure. The holes have a diameter of 10 centimetres. In case of a concrete water bank protection sections of 1 to 2 meters are replaced by retaining wall elements in which five holes with a 10 centimetre diameter are drilled. Overhanging vegetation is subsequently placed on top of the water bank at the spots where the nesting spots are created. This vegetation provides shelter, look-out, and resting places. No water vegetation will be placed in these areas as this will limit the free flying access of the nests (Harder, 2004).

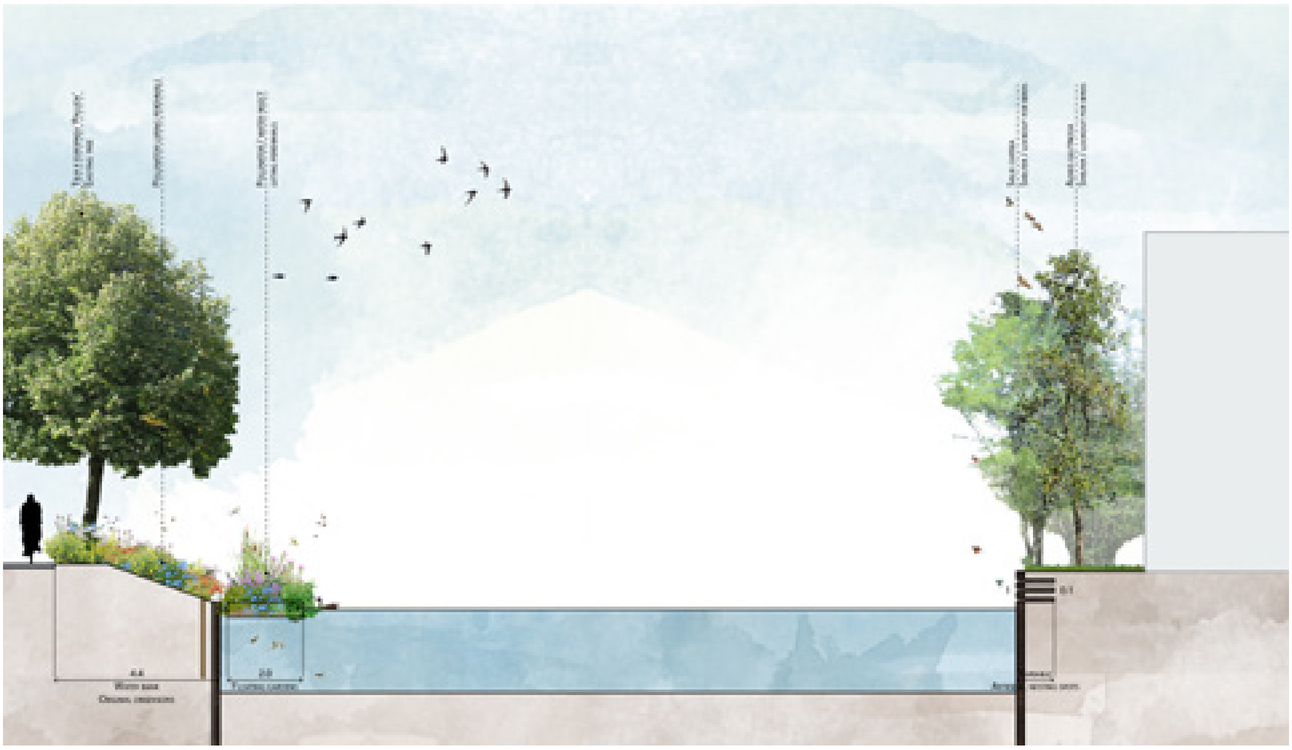


Figure 6.50 Section HH' through the Vaartsche Rijn..

6.6 Vegetation

The vegetation composition is mainly based on the foraging and habitat requirements of pollinator species (bees and butterflies) and house sparrows, but also attention has been given to birds in general and water insects.

For an initial exploration of vegetation, different vegetation lists that are compiled by experts were consulted and compared (Ferguson, n.d.; Hauck & Weisser, 2015; Imkerpedia, 2014; Koninklijke Imkersgilde De Vlijtige Bie, n.d.; Koster, n.d.; Vlinderstichting, n.d. a, b). As such, the initial selection was composed of flora species that attract the target species. Accordingly, the programme SynBioSys (Hennekes et al, 2010) was used to adjust and supplement the selected vegetation. Flora species that require very specific habitat conditions (e.g. soil or nutrient richness) were removed. Then, the co-existence of the remaining flora was checked. Flora with little overlap in co-existence with other selected species were accordingly removed and new species were added to the vegetation selection that showed large overlap other selected species. This process resulted the selection of flora that presumably make sound vegetation communities, and at the same time attract the target species throughout the whole year.

The newly created habitats all contain dynamic perennial planting compositions. Therefore, a mixed planting scheme is applied. The selected perennial species are planted in a mixed fashion: they are randomly distributed over the green strips without fixed spots. Single species are planted together in small groups of 3, 5 or 7 plants. A dynamic composition enables plants to change places. Some species will dominate, others will disappear or emerge, thereby enabling changes in species composition to occur (Hop, 2011). The outcome of this process should be a relatively stable vegetation community.

The vegetation composition of the different habitat typologies can be found in appendix A.

6.7 Maintenance

The success of a biodiverse design is largely dependent on the maintenance. As mentioned, intensive and active management can ensure more species to be maintained in an area, but also short circuit succession and immigration (Faeth et al, 2011; Müller et al, 2013). On the other hand, a lack of maintenance can lead to rapid successional changes and the domination of invasive species (Faeth et al, 2011). Extensive management appears to be the golden mean (Alvey, 2006).

The maintenance scheme for the biodiverse design of Rivierenwijk is mainly directed at stimulating insects. As insects form the main food source for the other target species, they will also benefit.

Most extensive maintenance schemes are developed for more natural vegetation such as flowery grasslands, forest vegetations and natural water banks. For less natural vegetation compositions, such as those of the streetscapes, little knowledge is available.

The common maintenance goal for the different habitat types is to create and maintain a structurally and compositionally diverse vegetation that has a large variation in flowering time. The starting point is created by the design and the proposed vegetation for each habitat typology. In order to maintain this state or even improve it, certain actions must be considered for the maintenance.

Mowing should be phased in order to maintain foraging and nesting habitat at any time. The preservation of habitat is also of importance during the winter in order to preserve hibernation spots for certain species. Mowing should only be done one or two times a year. Mowing should preferably happen in autumn, after flowering. After mowing it is both possible to leave the clippings for a short while or to remove them immediately. Both have their benefits. Leaving the clippings will enable seeds to stay behind and enrichen the local seed bank. Immediately removing the clippings will result in impoverishment of the soil, which may speed up the development of vegetations that are rich in flowers (Peeters et al, 2012; Van Rooij et al, 2016).

In the forest park Merwedeplantsoen and the tiny forests, it is important to create gradual transitions in the vegetation structure. Gradual transitions provide small scale variations in habitat, thereby providing habitat opportunities for more species. It is also important to create or maintain open spaces within the forest structure. In these places, flowering vegetation and nesting habitat can emerge naturally. In addition, old, sick, or dead trees should be preserved. These trees can form important nesting facilities for many insect species (Peeters et al, 2012; Van Rooij et al, 2016). However, these trees should be removed when they form safety concerns.

A vegetation composition consisting mainly out of perennials, as is the case in the streetscape, requires relatively little maintenance. Of main importance is a ‘spring clean-up’. Whereby dead plant material is removed after the end of the frost period. This removal can be done by raking or mowing. In case of mowing, care should be taken to not damage the growth points of the plants (Hop, 2011). Pruning of shrubs, trees, and hedges should be done after flowering. Pruning before flowering interferes with the food supply (Van Rooij et al, 2016).

Conclusion
Discussion
7. Recommendations

7.1 Conclusion

This thesis aimed to expand the knowledge on designing for biodiversity by exploring how biodiversity can be integrated in urban landscape architecture. Thereby this thesis addressed the overarching knowledge gap of how to design for biodiversity in urban areas. Related questions were answered in the process: which ecological knowledge is needed and/or relevant?; how can this knowledge be made applicable?; and what could that look like? Hereby providing landscape architects with the knowledge and tools to maximise the biodiversity potential of their urban designs.

In order to achieve this, and extensive research has been performed on urban biodiversity and the factors that influence the biodiversity levels of an area. The results have accordingly been applied on the case of Rivierenwijk. A case that can be seen as a worst-case scenario. By this research and the subsequently created design, the main research and design question has been answered: how can the biodiversity of urban areas, such as Rivierenwijk, be maximised by landscape architecture design? A short recap of the results is provided below by summarising the results that were obtained from answering the sub-research questions. After which some final notes are made on the main research and design question.

7.1.1 Which principles and design guidelines concerning biodiversity can be developed?

An extensive literature review resulted in the formulation of five biodiversity principles and design guidelines. The biodiversity principles concern the factors that influence the level of biodiversity of an area. The biodiversity guidelines describe how to approach a biodiverse design.

Biodiversity principles

Factors that influence the level of biodiversity of an area are divided into landscape and local factors.

Landscape factors are concerned with the spatial layout and distribution of habitats and thereby determine habitat quantity. Habitat quantity is determined by habitat area and connectivity. The area of a habitat determines the amount of species that it can harbour. This factor is complimented by habitat diversity. A larger area generally contains more diverse habitats and is thereby able to harbour a larger diversity of species. Habitat diversity, however, is determined by local factors. The connectivity of a habitat determines the amount of species that can migrate to and from it. Greater connectivity promotes migration.

Local factors are concerned with the build-up and suitability of habitats and thereby determine habitat quality. Habitat quality is determined by habitat structure and composition. Habitat structure concerns the vertical layering of vegetation. In general, a more layered vegetation structure holds greater biodiversity value. Habitat composition concerns the floristic build-up of a habitat. The more diverse the vegetation composition, the larger the biodiversity of an area is expected to be.

Biodiversity design guidelines

A design process for a biodiverse design takes a slightly different form than that for a ‘normal’ design. Therefore, a 5-step approach has been formulated to approach a biodiverse design.

- Step 1: site selection and assessment. Focus on biodiverse qualities: e.g. the quantity and quality of green areas; habitat opportunities, floristic characteristics; presence of fauna. Investigate multiple scale levels.
- Step 2: identify biodiversity potential. Possibilities and constraints towards maximising biodiversity are identified: e.g. the physical landscape; socio-economic opportunities and limitations; identification of potential target species and their habitat and foraging requirements.
- Step 3: set biodiversity targets. E.g. the definite selection of target species; the identification of the scale that will be worked on; and the weighing of different factors that could influence the design (e.g. biodiversity versus user value).
- Step 4: design. Focus on taking the steps that are necessary to maximise the site’s biodiversity potential: e.g. drafting a range of models based on the site’s opportunities and constraints; creating design principles based on species requirements and biodiversity principles; establishing a design; selecting vegetation; and drafting a maintenance scheme.
- Step 5: monitoring and evaluation. Develop and execute a monitoring scheme. Monitoring will show if the intended results are achieved and will enable landscape architects to learn from their designs.

7.1.2 What is the biodiversity of Rivierenwijk and what is its biodiversity potential?

The existing and potential biodiversity of Rivierenwijk have been identified in a case study, based on municipal sources and first-person observation.

Current biodiversity

Three habitat typology groups have been distinguished in Rivierenwijk: parks, streets, and water banks. In an initial investigation, the variety in green spaces appeared to be quite small. However, after a second investigation, with a focus on vegetation composition and structure, there turned out to be quite a small-scale variety within the different habitat typologies.

The variation in park structure and composition is linked to their functionality and purpose. While some parks serve a main aesthetic purpose, others invite active forms of recreation. Only a few parks serve or are designed to serve an ecological purpose. Overall, the parks contain quite a variation in perennials, shrubs and trees. While many of the perennials and shrubs are native, a large share of the trees is either exotic or cultivated.

Streets are predominantly vegetated with singular trees without undergrowth. Most trees are relatively young and small. Most streets contain only one particular species and many species are repeated throughout the neighbourhood. A large share of trees is either exotic or cultivated. Other vegetation that can be found in streets are façade gardens and ornamental planting boxes. Both can be compositionally diverse, but are structurally very monotonous.

The biodiversity of the water banks is very limited. Along the Merwedekanaal, the water bank is mostly absent due to the presence of house boats. Along the Vaartsche Rijn, the water bank is mainly covered in grass and a singular tree species.

In 2017, 94 different species of flora and fauna have been observed in Rivierenwijk. 12 of these species are protected under the municipality's policy. Most of these reside in either stony and built or forest-like habitats.

Potential biodiversity

Despite the scarcity of and competition for space, Rivierenwijk harbours numerous opportunities for the creation of a higher quantity of green. The municipality has appointed sidewalks wider than 4 meters and residual paved strips as opportunities for increasing green space quantity. Additional opportunities that do not interfere with the functionality of the neighbourhood and its configuration are: sidewalks that are wider than 2 meters; squares, playgrounds and schoolyards; and vertical structures. With several alterations to the neighbourhood's functionality and/or configuration even more opportunities for increasing habitat quantity exist: transforming parking spaces; creating new water banks; and closing of (parts of) streets.

To maximise habitat quality, vegetation structure and composition are to be maximised. A maximised vegetation structure consists of 1) undergrowth of herbaceous plants, 2) a low shrub layer, 3) a layer of small trees and tall shrubs, 4) a canopy layer. In addition, climbers could be added, which are not necessarily bound to any of the layers. The amount of vegetation layers that can be added to each green space depends on its functionality and size. A maximised vegetation composition is created by maximally diversifying the species that are implemented in the neighbourhood, as well as replacing current vegetation compositions by maximally diversified ones.

In addition to the opportunities to maximise habitat quality and quantity, target species have been identified. Three species that reside and/or forage in Rivierenwijk are also focussed on in the municipality's policy have been selected: common pipistrelle, common swift, and house sparrow. As all these species forage on insects, pollinators have been selected as a fourth target species group.

7.1.3 How can these principles and guidelines be employed to maximise the biodiversity potential of Rivierenwijk and similar urban areas?

In order to maximise the biodiversity potential of Rivierenwijk the theoretical perspective has been combined with the outcomes of the case study. This has resulted in a biodiverse design in which the needs of the target species are weighed against the functionality of the neighbourhood.

In order to come to this design, first an exploration of different models took place. At the scale and design level of models, the landscape factors of habitat area and connectivity held the most relevance. Subsequently, design principles were formulated. Both landscape and local factors were employed in combination with target species' habitat and foraging requirements to formulate them.

The design principles have accordingly been applied to the preferred model to create a biodiverse design for Rivierenwijk. The section of Rivierenwijk for which the design has been elaborated obtained approximately 16000m2 new and/or qualitatively improved habitat area, divided between three habitat typologies: the streetscape; parks, playgrounds; and schoolyards; and water banks. Within these habitat typologies additional habitat diversity has been created by variances in habitat structure and composition. These variances were based on habitat size and functionality. Additionally, new functionality was integrated based on habitat size.

To finalise the design, vegetation was selected, and a maintenance scheme has been drafted.

7.1.4 How can the biodiversity of urban areas, such as Rivierenwijk, be maximised by landscape architecture design?

So how can the biodiversity of urban areas be maximised by landscape architecture design? This thesis illustrated that maximising the biodiversity of any given area requires maximising habitat quantity as well as quality, and creating habitat diversity. Habitat quantity will determine the layout of the design and thereby forms a framework for further design elaboration. Maximising habitat area and connectivity therefore requires altering the urban configuration. Within existing urban layouts, the possibilities are limited. By making several alterations, such as conjoining green space into the largest possible areas and reducing parking spaces, higher levels of potential biodiversity can be reached. To what extent habitat area can be increased and the urban configuration can be altered depends of course on the project area at hand.

Further design elaboration of the framework that is established by maximising habitat quantity, is based on local factors. Maximising habitat quality and creating habitat diversity determine the elaboration of this framework. How to maximise quality and create diversity is highly dependent on the selected target species. Both are also reliant on the size of an area and its assigned function. It is easier to create higher quality habitats in larger areas. A higher habitat diversity can also be created in larger habitats.

In addition, it is important to adjust the design strategy to the scale level of the project. Habitat quantity is more significant on higher scale levels, while quality becomes more relevant in small scale projects.

Also select the right target species. Target species give direction to the design. While it is interesting to create a design for a species that does not occur in an area, it is recommended to focus on improving the conditions for species that already reside near or in the project area.

Another important factor is maintenance. Appropriate or inappropriate maintenance can determine the success of failure of a project. It is important to establish a maintenance scheme based on target species' habitat and foraging requirements, and on the biodiversity target to be reached.

Lastly, especially in urban areas, the human factor should be acknowledged. While it may seem attractive to completely focus on biodiversity and override the preferences of users, this is not the way to go. Urban areas are first and foremost designed for humans. This fact should be recognised and considered in any design.

7.2 Discussion

The discussion reflects critically on the results and limitations of this thesis' research and design process. The research, the case, and the design are reflected on separately. The discussion is finalised with a reflection on the significance of this thesis.

7.2.1 Research

Biodiverse design is a developing field and therefore existing literature resources are limited. To generate the theoretical underpinning for the design, an extensive literature review was performed on urban biodiversity. This research accordingly led to the formulation of biodiversity principles and design guidelines. A few critical notes are to be made regarding the outcomes of this research.

Many factors are mentioned to influence biodiversity levels. Of these, habitat area, connectivity, structure and composition seemed to hold the greatest influence, complemented by habitat diversity. Therefore, they were also assigned the greatest significance in this thesis. However, it is of course possible that other important factors were overlooked.

There is still debate on which factors are of most influence (Goddard et al, 2010; Lepczyck et al, 2017; Werner & Zahner, 2010). Landscape factors (area and connectivity) are often seen as the largest predictors for species richness. However, Werner & Zahner (2010) emphasise that the area factor often conceals numerous other factors that influence biodiversity levels. One of which, as mentioned in 4.1 is habitat diversity. Which in turn is established by variations in local factors (habitat structure and composition). It is also known that local factors can be more determinant for the presence of specific fauna (Nielsen et al, 2014; Shwartz et al, 2013). And that small patches with a high habitat quality can hold significant biodiversity value (Lepczyck et al, 2017; Miller, 2008). So, it might just be that after establishing a certain amount of habitat area and connectivity, local factors completely surpass landscape factors (Lizée et al, 2010; Shwartz et al, 2013). However, it is still unknown what amount of area and connectivity is required. A number that will likely also vary between species (Beninde et al, 2015; Lepczyck et al, 2017). As such, the threshold value is unknown for when habitat quality becomes more significant than quantity. And therefore, it is very uncertain to say when what biodiversity principle gains more influence on biodiversity levels.

As the field of biodiverse design is still in its early stages of development, there is not yet a clear framework that tells landscape architects how to design for biodiversity. This thesis design guidelines that could be the basis for such a framework. These guidelines were based upon different guidelines that were presented in literature on biodiverse design. The design guidelines for biodiverse design that can be found in literature are varied, but there are not many. Some only included an ordering of design interventions (e.g. Bennett, 1999). Other also included a basis for analysis (e.g. Gagné et al, 2015). And even others proposed a comprehensive framework (e.g. Garrard et al, 2017; Weisser & Hauck, 2017). The common factors of these approaches were distilled and simultaneously employed in the design process. Accordingly, they were adjusted based upon the experiences of the design process. As such, the guidelines that are presented in section 4.2. are only based upon one project. A different approach might have been taken in different projects, and therefore different guidelines might have been formulated. The guidelines also might not work for other people, just like the approaches that were presented in the literature did not completely work for this thesis and had to be amended. Repeated application is required to further develop these guidelines and eventually come to a comprehensive framework for biodiverse design.

Ideally, both the knowledge that was generated to formulate the biodiversity principles and design guidelines would have been supplemented with knowledge from experts and practitioners. The original proposal for this thesis included conducting expert interviews with both ecologists and landscape architects that have experience with biodiverse design. Due to time constraints, and as sufficient knowledge was obtained from the literature review, the decision was made to not conduct the interviews. However, these interviews might have provided interesting additional insights into the required knowledge and tools, and perhaps even inspiration for design interventions.

7.2.2 Case study

The choice was made for a worst-case scenario in the form of Rivierenwijk, instead of a representative case for the average Dutch neighbourhood. Choosing an average case might have made the results more generalisable and perhaps even directly transferable to other instances. However, as Hannington & Martin (2012) emphasise: "*the case study method ... welcomes extraordinary cases and outliers*" (p.28). It was reasoned that if creating a biodiverse design in a worst-case scenario would be possible, it will be possible everywhere. Besides that, Rivierenwijk is a very diverse neighbourhood in its configuration due to multiple redevelopments. While not the whole of the neighbourhood was elaborated further in the creation of a design, the model study illustrated that the general approach would have significant impact in all of the neighbourhood's differently configured subsections. However, of course, the design outcomes for this case should be cross-verified in other cases to enhance reliability and validity. And of course, to prove the claim that creating a biodiverse design is possible everywhere, since it has proven to be possible in this worst-case scenario.

In the case study, the choice was made to focus more on the biodiversity analysis than on the regular analysis. In doing so, an attempt was made of an in-depth biodiversity analysis. However, in the process, it became clear that neither the time or the expertise was there to perform a completely comprehensive biodiversity analysis. As such, the choice was made to first generalise the neighbourhood's green spaces into three typologies and then highlight the most significant characteristics and distinctive green spaces. As of this, still a decent overview of the biodiversity of Rivierenwijk

is presented.
Only a few sources could be relied on to establish the current biodiversity of Rivierenwijk. The first was www.waarneming.nl, which is a website that collects observations of nature (flora, fauna). These observations can be submitted by anyone. The observations that have been made for Rivierenwijk might not include all natural flora and fauna that occurs in the neighbourhood. And the data might also not be completely accurate. However, the website does provide a decent overview of especially the present fauna. The second source was first person observation. There are no (freely available) complete overviews of all the vegetation that is employed in the neighbourhood's parks and other green spaces, let alone for the whole neighbourhood. This only exists for the municipal trees. As such, all data about the presence of flora, other than trees, was obtained by first person observations during site visits. Of course, to gain a complete overview of the flora of Rivierenwijk, many visits should have been made throughout at least a whole year. Due to time and monetary constraints, this was not possible. In addition, due to a limited floristic knowledge, a complete overview of all the flora would have never been achieved anyway.

The biodiversity analysis resulted in selecting three species that are already present in Rivierenwijk and under protection of the municipality. Supplemented by a fourth species group that forms a prey for these three species. Though other species have been observed in the neighbourhood, the three species are among the few species that are certain to be breeding and/or foraging in Rivierenwijk. Other species could have been selected. Some literature even suggests the selection of species that do not occur at the site or in its surroundings (e.g. Rosenzweig, 2003; Weisser & Hauck, 2017). For example, Rosenzweig (2003) proposes that it would be interesting to focus on species that normally avoid a certain landscape. Thereby he reflects on the differences between urban avoider and urban adapter species and suggests that it could be well possible to turn the first into the latter through thorough habitat design. However, too little knowledge was available to realistically consider other species. In addition, in practice it is more relevant to choose species that are already present (M. van Aar, personal communication, 11-04-2018). And since the municipality already works on protecting and promoting these species, it seemed logical to join that effort.

In addition to the research that was performed for the case study, it could have been helpful to discuss the biodiversity and ecology of Rivierenwijk with someone that possesses in-depth knowledge of it. This might have provided insights that are now missing. The interview that was conducted with ecologist of the municipality of Utrecht, Mies van Aar did not provide this in-depth knowledge, as she did not possess it.

7.2.3 Design

The creation of a biodiverse design was an emergent and cyclical process. In different stages of the thesis, the design process took place either subsequent or parallel to the research process. As such, the research informed the design, but also went hand-in-hand with the design process. At certain times, the design process even inspired further research. Different stages of the design process and design decisions are discussed below.

The models showed a good range of the possibilities of a biodiverse transformation of Rivierenwijk. More extreme models could have also been drafted. For example, in the early stages of the design process, the possibility of demolishing buildings was considered to create more green space. However, this idea was discarded as it was deemed to be very ambiguous. The remaining models proved to be more valid for the purpose of this thesis.

Despite the literature review having resulted into very clear biodiversity principles, it proved difficult to clearly formulate general design principles. The lack of available knowledge on how much area, connectivity, structure and diversity in composition is required, resulted into the formulation of principles that simply stated: "as much as possible". A phrase that was subsequently supplemented by stating the constraints and/or conditions to which it should uphold. A separate design principle for area and connectivity became clear to be redundant for this specific design. Taking connectivity as being the distance between patches (Beninde et al, 2015), it sufficed to combine both area and connectivity into one general principle. The principle of connectivity, in terms of the creation of corridors or stepping stones, did not hold enough relevance for this biodiverse design to be included separately. This can be attributed to two things. First, perhaps connectivity, in these terms, is not a significant influencing factor on a neighbourhood scale and/or smaller scale levels. While it might have been a quite significant factor if this thesis included a city or district scale approach. Or second, the relevance of connectivity depends on the selected target species. While the first is an educated guess resulting from the design experience, the second possibility is supported in literature. The species that have been selected for this thesis are all highly mobile. Highly mobile species do not require an ongoing connected habitat for dispersal (Bennett, 1999). While, for example, small mammals such as rabbits and squirrels do in fact require this (Gao et al, 2011).

In contrast to the general design principles, design principles for the different habitat typologies were easily formulated. This can be attributed to the combination of target species requirements with the biodiversity principles, as well as assigning functionality to each typology. Without the habitat and foraging requirements of the target species, the design could have become very ambiguous. Their inclusion gave clear direction to the design. For example: where to locate the new habitat areas; what vegetation structure to create; and what vegetation composition to include. Accordingly, green space functionality and area gave direction to the creation of habitat diversity.

The design principles were developed parallel to the design for a section of Rivierenwijk. The biodiverse design for Rivierenwijk balances biodiversity with functionality. Initially, this thesis did not include the constraint of preserving the functionality of the neighbourhood. However, it was added as it was noticed that this constraint was required to avert some dubious design decisions that this thesis would not benefit from. For example, without this limitation it would have been a very valid option to demolish the whole neighbourhood and let nature develop in its place. Though this constraint limited the design possibilities, it also facilitated the development of a more realistic design. A design that clearly shows that biodiversity is perfectly combinable with functionality. As such, perhaps functionality should not be seen as a limitation to biodiverse design, but even a supplementation. Multiple researches support this notion. Supplementing biodiversity with functionality creates opportunities for people to interact with urban nature (Ikin et al, 2015; Savard et al, 2000). This interaction can promote successful conservation schemes, as well as take away safety concerns (Garrard et al, 2018). In addition, multifunctionality increases sustainability (Lovell & Johnston, 2009). So, expanding the focus from solely biodiversity to also include recreation and aesthetics, for example, is preferable (Rosenzweig, 2003; Weisser & Hauck, 2017).

Additionally, it has proven quite possible to combine the promotion of biodiversity with the resolution of other urban challenges, such as water retention and the urban climate. These urban challenges were not considered elaborately, but during the design process it became clear that some solutions for them were naturally incorporated into the design. For example, the new habitat areas were placed to the south- and westside of the buildings blocks to provide free flying access for both house sparrows and common swifts to their nests. This simultaneously proved beneficial to the microclimate, as the vegetation in these areas provide shade on the warmest side of the street. Interventions to mitigate urban challenges can reversely also be beneficial to biodiversity. For example, the provision of wadi's for water retention simultaneously provides new habitat opportunities.

As mentioned, the design has mainly been drafted based on the requirements of the four target species in addition to the biodiversity principles. The design also identified benefits for other species, such as amphibians and fish (e.g. floating gardens), other birds (e.g. through vegetation selection), and other insects that also use pollinator habitat. In addition, circumstances have been created that could also benefit other species that have not been directly or indirectly considered. Bräuniger et al (2010) describe the surrogate taxa concept. This concepts states that *"the species richness of one taxon can be representative for the richness of other single taxa and the biodiversity of a given area"* (p.284). As such, this concept can provide an idea of the ability of an area to also accommodate other species. For example, vascular plant richness can be taken as a surrogate for the richness of several other taxa, such as butterflies, lichens and carabids. And a large structural diversity can explain for a larger species richness of highly mobile fauna, such as birds, butterflies and carabids (Bräuniger et al, 2010). Angold et al (2006), Beninde et al (2015), and Cornelis & Hermy (2004) Have found similar relations. Both structural diversity and a large vascular plant richness are provided in the biodiverse design for Rivierenwijk, and therefore the beforementioned species groups can be expected to inhabit the new habitat areas. While the structural diversity that has been created in the design in theory also supports the presence of small mammals (Gao et al, 2011; Mahan & O'Connell, 2005), their presence is less likely. As Gao et al (2011) describe, small mammals depend on well-connected habitat area for their dispersal. So, for Rivierenwijk to also accommodate small mammals, a well-connected habitat should additionally be created throughout Utrecht in order to connect the neighbourhood to areas in which these species are already present.

It is of course highly uncertain if the design will actually promote these species in addition to those that the design was drafted for. In order to make any assumptions, more knowledge is required about these species' presence in Utrecht and Zuidwest, as well as the presence and functioning of corridors and connected habitats that might lead these species to Rivierenwijk.

Additionally, any assumptions about the soundness of this design are highly uncertain until the design is executed and monitored over a longer time period. Even though all measures are included that should maximise Rivierenwijk's biodiversity potential and accommodate the target species, no certainty can be derived from this.

7.2.4 Significance

This thesis has significance in different respects. Firstly, it has landscape architectonic significance. As mentioned in the introduction, landscape architects can make a difference when it comes to the preservation and development of biodiversity in urban areas (Ahern et al, 2006; Beatley, 2000; Felson et al, 2013; Ignatieva, 2010; Müller et al, 2010). However, landscape architects as of yet do not possess the means to fulfil this role (Johnson & Hill, 2002; Nassauer, 2002). With this thesis, landscape architects are provided with the knowledge and tools that enable them to maximise the biodiversity potential of their designs. Thereby, landscape architects are provided with the means to make a change with their designs and establish biodiversity by design.

Secondly, from an academic point of view, this research is significant as it makes a start at bridging the extensive knowledge gap between the fields of landscape architecture and ecology, thereby working towards an integrated approach. As such, this research will hopefully be the starting point that sparks an academic conversation and a close collaboration between ecologists and landscape architects, from which further research into the interface of the two fields develops. In turn, continued research can further inform the professional practice.

Finally, a thorough integration of ecology in the design practice will have societal significance, as biodiversity has many societal benefits (see section 1.3). While society benefits most from productive services that provide food and building materials, biodiversity also has great cultural significance, and underlies many important ecological processes (CBD, 2000; Harrison et al, 2014; Miller, 2008).

7.3 Recommendations

To conclude this thesis, several recommendations are made for further research based on the research and design experiences of this thesis.

A first recommendation is to always collaborate with ecologists when working on a design for biodiversity. A landscape architect does not possess as much in-depth knowledge as an ecologist. It is impossible to try and appropriate the same amount of knowledge in a single research and design project. It might even be interesting to perform a thesis with a similar topic as this one in close collaboration with an ecology student. The design that has been drafted for Rivierenwijk only takes public space into account. Large parts of urban areas also constitute of privately-owned areas (e.g. front- and backyards, roofs, walls). These areas can all contribute to biodiversity conservation and promotion as well (Farinha-Marques et al, 2011; Goddard et al, 2010; Müller et al, 2013). It would therefore also be interesting to create a biodiverse design for privately owned areas based on the same biodiversity principles. Of course, this includes a new challenge that does not have to be considered in public areas: how to stimulate people to promote biodiversity on their privately-owned properties. This likely includes a form of participatory design (Beumer & Martens, 2015; Farinha-Marques et al, 2011; Goddard et al, 2010).

Participatory design is also recommended for biodiverse design of public space. It is exemplified that participation builds support for biodiversity (Alvey, 2006). It would be very interesting to see in what way the outcomes of the design process would be affected by this. Would the end result suffer from it or would participation stimulate more extreme interventions?

Another recommendation is to integrate biodiversity into other (urban) landscape architecture projects. For example, projects concerning the urban climate. Climate change has been indicated to become one of the main threats to biodiversity next to urbanisation and agriculture (CBD, 2000; PBL, n.d.; Solecki & Marcotullio, 2013). This thesis already showed that the urban climate can also benefit from biodiverse design. This notion is also supported by research (CBD, 2013; Elmqvist et al, 2013; Farinha-Marques et al, 2011). Fully integrating the two subjects could lead to innovative urban designs.

Lastly, it would be interesting to further research the idea of creating actual urban wilderness. While some research is already investigating this (e.g. Garrard et al, 2018; Müller et al, 2018), it has become clear during the thesis process that it is currently unimaginable to even coin the idea of letting go of the maintenance of urban green space (Nassauer, 1995; M. van Aar, personal communication, 11-04-2018). So, would it at all be possible to do so and establish self-regulating urban nature? And what would it take to make this acceptable for people?

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Appendices

Appendix A:
Vegetation selection

				House sparrow		Food source bee / butterfly		Host plant butterfly	Birds in general
Scientific name	Dutch name	Flowering period	Flowering colour	Food source	Shelter	Nectar	Pollen		
TREES									
Acer campestre	Veldesdoorn	april-may	green			6	2		x
Betula pendula	Ruw berk	april-may	yellow/green	x		0	2	x	x
Crataegus laevigata	Tweestijlige maydoorn	may-june	white			2	2	x	x
Crataegus monogyna	Eenstijlige maydoorn	may-june	white	x	x	2	2	x	x
Malus domestica	Appel	april-may	white	x		3	3	x	x
Malus sylvestris	Wilde appel	april-may	white/pink	x		4	4	x	x
Mespilus germanica	Mispel	may-june	white			2	2		
Populus tremula	Ratelpopulier	february-march	catkin	x		0	3	x	
Prunus avium	Zoete kers	may-june	white			4	4	x	x
Prunus cerasifera	Kerspruim	april-may	pink			4	4		
Pyrus communis	Peer	april-may	white	x		2	3	x	
Robinia pseudoacacia	Robinia	june-july	white			6	3	x	
Salix alba	Schietwilg	april-may	light yellow			4	4	x	
Salix caprea	Boswilg	march-april	light yellow	x		5	5	x	
Sorbus aucuparia	Wilde lijsterbes	may-june	white	x		2	1	x	x
Tilia cordata	Winterlinde	june-july	green			5	3		
Tilia x europaea	Hollandse linde	june-july	green			5	3		
SHRUBS									
Amelanchier lamarckii	Krentenboompje	may-june	white	x		4	2		x
Buddleja davidii	Vlinderstruik	july-october	purple			2	0	x	
Cornus mas	Gele kornoelje	february-march	yellow	x	x	3	5		
Cornus sanguinea	Rode kornoelje	june	white			2	2	x	x
Corylus avellana	Hazelaar	january-march	green/yellow			0	4	x	x
Hedera helix 'Arborescens'	Struikklimop	september-november	green			5	4	x	x
Ilex aquifolium	Hulst	may-june	white	x		3	2	x	x
Ligustrum vulgare	Liguster	june-july	white	x	x	4	4	x	x
Prunus spinosa	Sleedoorn	april-may	white	x	x	2	3	x	x
Rhamnus frangula	vuilboom	may-september	green			5	5	x	x
Ribes rubrum	Aalbes	april-may	yellow/green			4	1	x	x
Rosa canina	Hondsroos	june-july	pink	x	x	0	5		x
Rosa rubiginosa	Egelantier	june-august	pink	x	x	0	5		x
Rosa rugosa	Rimpelroos	june-july	pink	x	x	5	5		x
Rubus caesius	Dauwbraam	may-august	white	x		4	4	x	x
Rubus fructicosus	Gewone braam	june-september	white/pink	x		5	5	x	x
Rubus idaeus	framboos	may-july	white			4	3	x	x
Salix cinerea	Grauwe wilg	march-april	yellow/green			5	4	x	
Salix repens	Kruipwilg	april-may	yellow/green			3	3	x	
Salix viminalis	Katwilg	april-may	gray/green			3	2	x	
Sambucus nigra	Zwarte vlier	may-july	white	x		0	2		x
HEDGES									
Acer campestre	Veldesdoorn	april-may	green		x	6	2		x
Cornus mas	Gele kornoelje	february-march	yellow	x	x	3	5		
Crataegus monogyna	Eenstijlige maydoorn	may-june	white	x	x	2	2	x	x
Ligustrum vulgare	Liguster	june-july	white	x	x	4	4	x	x
Rosa canina	Hondsroos	june-july	pink	x	x	0	5		x
Rosa rubiginosa	Egelantier	june-august	pink	x	x	0	5		x
Rosa rugosa	Rimpelroos	june-july	pink	x	x	5	5		x

PERENNIALS										
Achillea millefolium	Gewoon duizendblad	june-october	white				1	1	x	x
Agrostis stolonifera	Fioringras	june-september			?				x	
Anthoxanthum odoratum	Gewoon reukgras	april-june			?					
Anthriscus sylvestris	Fluitenkruid	may-june	white				2	2		
Aruncus dioicus	geitenbaard	june-august	white				5	5	x	
Arrhenatherum elatius	Glanshaver	may-september			?					
Aster novi-belgii	Aster	september-october	purple				3	3		x
Campanula latifolia	Breedbladig klokje	june-july	purple/white				3	3		
Campanula rotundifolia	Grasklokje	june-october	purple				3	3		
Centaurea jacea	Knoopkruid	june-september	purple	x			3	3	x	x
Centaurea scabiosa	Grote centaurie	june-august	purple	x			3	3	x	x
Echinacea purpurea	Zonnehoed	july-october	pink				3	2		
Echinops sphaerocephalus	Kogeldistel	july-september	blue	x			3	2		x
Euphorbia cyparissias	Cipreswolfsmelk	may-june	yellow/green				1	1		
Galium verum	Geel walstro	june-september	yellow							
Geranium pratense	Beemdooievaarsbek	june-july	purple/blue				3	3	x	
Geranium sylvaticum	Bosooievaarsbek	june-august	purple				3	3	x	
Holcus lanatus	Gestreepte whitebol	may-september								
Knautia arvensis	Beemdkroon	june-september	purple/pink				3	1	x	
Lamium album	witte dovenetel	april-october	white				4	0		
Lavandula angustifolia	Echte lavendel	june-july	blue/purple				4	0	x	x
Oenothera biennis	Middelste teunisbloem	june-september	yellow	x			3	3		x
Origanum vulgare	Wilde marjolein	june-september	pink/purple				4	2	x	
Pimpinella saxifraga	Kleine bevernel	july-september	white				3	0	x	
Prunella vulgaris	Gewone brunel	may-september	purple				5	0		
Salvia pratensis	Veldsalie	may-july	purple/blue	x			5	3		x
Sanguisorba minor	Kleine pimpernel	may-july	red/green	x			3	3	x	
Sanguisorba officinalis	Pimpernel	june-september	red/brown	x			3	3	x	
Saxifraga granulata	knolsteenbreek	may-june	white				1	1		
Scabiosa columbaria	Duifkruid	july-september	lilac				2	1	x	
Sedum telephium	Hemelsleutel	july-september	pink				2	2	x	x
Thymus pulegiodes	Grote tijm	june-september	purple				3	3	x	
Thymus serpyllum	Wilde tijm	june-august	purple				4	1	x	x
Verbena bonariensis	Ijzerhard	july-october	purple				3	0		x
WADI's										
Agrostis stolinifera	Fioringras	june-september							x	
Angelica sylvestris	Gewone engelwortel	july-september	white				3	3	x	
Cardamine pratensis	Pinksterbloem	april-june	pink/white				3	3	x	
Cirsium palustre	Kale jonker	june-september	purple				3	3	x	
Cynosurus cristatus	Kamgras	june-october							x	
Eupatorium cannabium	Koninginnenkruid	july-september	pink				3	3	x	x
Filipendula ulmaria	Moerasspirea	june-september	white/pink				0	3	x	
Galium palustre	Moeraswalstro	may-september	white							
Glyceria fluitans	Mannagras	may-august								
Glyceria maxima	Liesgras	july-august								
Lotus pendunculatus	Moerasrolklaver	june-august	yellow				3	3	x	
Lycopus europaeus	Wolfspoot	june-august	white				3	1		
Lysimachia vulgaris	Grote wederik	june-august	yellow			?	?			x
Lythrum salicaria	Grote kattenstaart	june-september	purple/red				5	5	x	x
Persicaria bistorta	Adderwortel	may-july	pink				3	3	x	x
Petasites hybridus	Groot hoefblad	march-april	purple/pink				3	3		
Saxifraga granulata	knolsteenbreek	may-june	white				1	1		

Silene diocia	Dagkoekoeksbloem	april-october	pink		1	1		
Stachys palustris	Moerasandoorn	july-august	pink		5	0		
Symphytum officinale	Gewone smeerwortel	april-september	purple		3	3		
Thalictrum flavum	Poelruit	june-july	white		0	3		
Valeriana officinalis	Echte valeriaan	june-july	white/pink		3	3	x	
CLIMBERS								
Clematis vitalba	Bosrank	june-august	white	x	0	2	x	x
Hedera helix	Klimop	september-november	green/yellow	x	5	4	x	x
Hydrangea anomala	klimhortensia	may-july	white		3	3		x
Lonicera periclymenum	wilde kamperfoelie	june-september	white/red	x	1	0	x	x
Parthenocissus tricuspidata cv. 'Veitchii'	Driebladige wingerd	june-august	white		5	0		x
Wisteria sinensis	blauwee regen	may-july	blue		3	0		x
Humulus lupulus	Hop	july-september	bunch		0	1	x	x

				House sparrow		Food source bee / butterfly		Host plant butterfly	Birds in general
Scientific name	Dutch name	Flowering period	Flowering colour	Food source	Shelter	Nectar	Pollen		
(FOREST) PARKS									
TREES									
Acer campestre	Veldesdoorn	april-may	green			6	2		x
Alnus glutinosa	Zwarte els	february-march	yellow/brown			0	3	x	x
Betula pendula	Ruw berk	april-may	yellow/green	x		0	2	x	x
Crataegus laevigata	Tweestijlige meidoorn	may-june	white			2	2	x	x
Crataegus monogyna	Eenstijlige meidoorn	may-june	white	x	x	2	2	x	x
Malus domestica	Appel	april-may	white			3	3	x	x
Malus sylvestris	Wilde appel	april-may	white/pink			4	4	x	x
Mespilus germanica	Mispel	may-june	white			2	2		
Populus tremula	Ratelpopulier	february-march	catkin	x		0	3	x	
Prunus avium	Zoete kers	may-june	white			4	4	x	x
Prunus cerasifera	Kerspruim	april-may	pink			4	4		
Prunus padus	Gewone vogelkers	may	white	x		2	2	x	
Pyrus communis	Peer	april-may	white			2	3	x	
Robinia pseudoacacia	Robinia	june-july	white			6	3	x	
Salix alba	Schietwilg	april-may	light yellow			4	4	x	
Salix caprea	Boswilg	march-april	light yellow	x		5	5	x	
Sorbus aucuparia	Wilde lijsterbes	may-june	white	x		2	1	x	x
Tilia cordata	Winterlinde	june-july	green			5	3		
Tilia x europaea	Hollandse linde	june-july	green			5	3		
SHRUBS									
Amelanchier lamarckii	Krentenboompje	may-june	white	x		4	2	x	x
Cornus mas	Gele kornoelje	february-march	yellow	x	x	3	5		
Cornus sanguinea	Rode kornoelje	june	white			2	2	x	x
Corylus avellana	Hazelaar	january-march	green/yellow			0	4	x	x
Euonymus europaeus	Kardinaalsmuts	may-june	green			4	0	x	x
Ilex aquifolium	Hulst	may-june	white	x		3	2	x	x
Prunus spinosa	Sleedoorn	april-may	white	x	x	2	3	x	x
Rhamnus frangula	vuilboom	may-september	green			5	5	x	x
Ribes rubrum	Aalbes	april-may	yellow/green			4	1	x	x
Rosa canina	Hondsroos	june-july	pink	x	x	0	5		x
Rubus caesius	Dauwbraam	may-august	white			4	4	x	x
Rubus idaeus	framboos	may-july	white			4	3	x	x
Sambucus nigra	Zwarte vlier	may-july	white	x		0	2		x
CLIMBERS									
Clematis vitalba	Bosrank	june-august	white		x	0	2	x	x
Hedera helix	Klimop	september-november	green/yellow		x	5	4	x	x
Humulus lupulus	Hop	july-september	bunch			0	1	x	x
Lonicera periclymenum	wilde kamperfoelie	june-september	white/red			1	0	x	x
PERENNIALS									
Aegopodium podagraria	Zevenblad	june-july	white/pink			2	1	x	
Alliaria petiolata	Look zonder look	april-june	white			3	3	x	
Anemone nemorosa	Bosanemoon	march-may	white			2	2		
Arum maculatum	Gevlekte aronskelk	april-may	green/yellow/red						
Campanula persicifolia	Prachtklokje	may-august	blue			2	3		
Campanula trachelium	Ruig klokje	july-august	blue			4	4		
Chamerion angustifolium	Wilgenroosje	july-september	pink/purple			5	5		
Deschampsia flexuosa	Bochtige smele	june-august	brown					x	

Digitalis purpurea	Vingerhoedskruid	may-august	purple			Hommels			x	x
Dryopteris carthusiana	Smalle stekelvaren	july-september								x
Dryopteris dilatata	Brede stekelvaren	july-september								x
Dryopteris filix-mas	Mannetjesvaren	june-october								x
Geranium phaeum	Donkere ooievaarsbek	may-september	dark purple				3	3	x	
Geranium robertianum	Robertskruid	may-october	pink				3	3	x	x
Geranium sanguineum	Bloedooievaarsbek	may-august	red/purple				3	3	x	
Geum urbanum	Geel nagelkruid	may-september	yellow				1	1		
Hesperis matronalis	damastbloem	may-august	lilac				3	3	x	
Holcus mollis	Gladde whitebol	june-august	white						x	
Lamiastrum galeobdolon	Gele dovenetel	april-june	yellow				1	1		
Polygonatum multiflorum	Gewone salomonszegel	may-june	white				1	1		
Pteridium aquilinium	Adelaarsvaren	july-august					1	0		x
Silene diocia	Dagkoekoeksbloem	april-october	pink				1	1		
FLOWERING BULBS										
Allium ursinum	Daslook	april-may	white				2	1		
Colchicum autumnale	Herfsttijloos	september-october	pink				3	3		
Corydalis cava	Holwortel	march-may	purple/red	x			1	1		
Corydalis solida	Vingerhelmbloem	march-april	pink	x			2	3		
Crocus vernus	Bonte krokus	february-april	purple or white	x			0	2		
Eranthis hyemalis	Winterakoniet	february-march	yellow				2	3		
Galanthus nivalis	Gewoon sneeuwklokje	february-march	white				1	2		
Hyacinthoides non-scripta	Wild hyacint	april-may	blue				2	2		
Hyacinthus orientalis	Hyacint	march-april	blue				1	2		
Muscari botryoides	blauwe druifjes	april-may	blue				3	1		
Ornithogalum umbellatum	Gewone vogelmelk	may-june	white				1	1		
Scilla bifolia	Vroege sterhysacint	march-april	blue	x			3	3		
Scilla non-scripta	Wilde hyacint	april-may	blue	x			3	3		
Scilla siberica	Wilde hyacint	march-april	blue	x			2	2		
Tulipa sylvestris	Bostulp	april-may	yellow				1	1		
BUTTERFLY GARDENS										
PERENNIALS										
Achillea millefolium	Gewoon duizendblad	june-october	white				1	1	x	x
Agrostis stolonifera	Fioringras	june-september			?				x	
Anthoxanthum odoratum	Gewoon reukgras	april-june			?					
Anthriscus sylvestris	Fluitenkruid	may-june	white				2	2		
Aruncus dioicus	geitenbaard	june-august	white				5	5	x	
Arrhenatherum elatius	Glanshaver	may-september			?					
Aster novi-belgii	Aster	september-october	purple				3	3		x
Campanula latifolia	Breedbladig klokje	june-july	purple/white				3	3		
Campanula rotundifolia	Grasklokje	june-october	purple				3	3		
Centaurea jacea	Knoopkruid	june-september	purple	x			3	3	x	x
Centaurea scabiosa	Grote centaurie	june-august	purple	x			3	3	x	x
Echinacea purpurea	Zonnehoed	july-october	pink				3	2		
Echinops sphaerocephalus	Kogeldistel	july-september	blue	x			3	2		x
Euphorbia cyparissias	Cipreswolfsmelk	may-june	yellow/green				1	1		
Galium verum	Geel walstro	june-september	yellow							
Geranium pratense	Beemdooievaarsbek	june-july	purple/blue				3	3	x	
Geranium sylvaticum	Bosooievaarsbek	june-august	purple				3	3	x	
Holcus lanatus	Gestreepte whitebol	may-september								
Knautia arvensis	Beemdkroon	june-september	purple/pink				3	1	x	

Lamium album	Witte dovenetel	april-october	white			4	0		
Lavandula angustifolia	Echte lavendel	june-july	blue/purple			4	0	x	x
Oenothera biennis	Middelste teunisbloem	june-september	yellow	x		3	3		x
Origanum vulgare	Wilde marjolein	june-september	pink/purple			4	2	x	
Pimpinella saxifraga	Kleine bevernel	july-september	white			3	0	x	
Prunella vulgaris	Gewone brunel	may-september	purple			5	0		
Salvia pratensis	Veldsalie	may-july	purple/blue	x		5	3		x
Sanguisorba minor	Kleine pimpernel	may-july	red/green	x		3	3	x	
Sanguisorba officinalis	Pimpernel	june-september	red/brown	x		3	3	x	
Saxifraga granulata	knolsteenbreek	may-june	white			1	1		
Scabiosa columbaria	Duifkruid	july-september	lilac			2	1	x	
Sedum telephium	Hemelsleutel	july-september	pink			2	2	x	x
Thymus pulegiodes	Grote tijm	june-september	purple			3	3	x	
Thymus serpyllum	Wilde tijm	june-august	purple			4	1	x	x
Verbena bonariensis	Ijzerhard	july-october	purple			3	0		x
SHRUBS									
Buddleja davidii	Vlinderstruik	july-october	purple			2	0	x	
Hedera helix 'Arborescens'	Struikklimop	september-november	green			5	4	x	x
Prunus spinosa	Sleedoorn	april-may	white	x	x	2	3	x	x
Ribes rubrum	Aalbes	april-may	yellow/green			4	1	x	x
Rosa canina	Hondsroos	june-july	pink	x	x	0	5		x
Rosa rubiginosa	Egelantier	june-august	pink	x	x	0	5		x
Rosa rugosa	Rimpelroos	june-july	pink			5	5		x
Rubus caesius	Dauwbraam	may-august	white			4	4	x	x
Rubus fructicosus	Gewone braam	june-september	white/pink			5	5	x	x
Rubus idaeus	framboos	may-july	white			4	3	x	x
Sambucus nigra	Zwarte vlier	may-july	white	x		0	2		x
TREES									
Crataegus laevigata	Tweestijlige meidoorn	may-june	white			2	2	x	x
Crataegus monogyna	Eenstijlige meidoorn	may-june	white	x	x	2	2	x	x
Malus domestica	Appel	april-may	white			3	3	x	x
Malus sylvestris	Wilde appel	april-may	white/pink			4	4	x	x
Mespilus germanica	Mispel	may-june	white			2	2		
Prunus avium	Zoete kers	may-june	white			4	4	x	x
Prunus cerasifera	Kerspruim	april-may	pink			4	4		
Prunus padus	Gewone vogelkers			x					x
Pyrus communis	Peer	april-may	white			2	3	x	
Sorbus aucuparia	Wilde lijsterbes	may-june	white	x		2	1	x	x

				House sparrow		Food source bee / butterfly		Host plant butterfly	Birds in general	Dragonfly
Scientific name	Dutch name	Flowering period	Flowering colour	Food source	Shelter	Nectar	Pollen			
WATER BANKS										
Agrostis stolinifera	Fioringras	june-september						x		
Angelica sylvestris	Gewone engelwortel	july-september	white			3	3	x		
Butomus umbellatus	Zwanenbloem	june-september	white/pink			3	3			x
Caltha palustris	Dotterbloem	april-may	yellow			3	3			x
Cardamine pratensis	Pinksterbloem	april-june	pink/white			3	3	x		x
Cirsium palustre	Kale jonker	june-september	purple			3	3	x		
Eupatorium cannabium	Koninginnenkruid	july-september	pink			3	3	x		x
Filipendula ulmaria	Moerasspirea	june-september	white/pink			0	3	x		x
Galium palustre	Moeraswalstro	may-september	white							
Glyceria fluitans	Mannagras	may-august								
Glyceria maxima	Liesgras	july-august								
Iris pseudacorus	Gele lis	may-july	yellow			1	1			x
Lotus pendunculatus	Moerasrolklaver	june-august	yellow			3	3	x		x
Lycopus europaeus	Wolfspoot	june-august	white			3	1			
Lysimachia vulgaris	Grote wederik	june-august	yellow			?	?			
Lythrum salicaria	Grote kattenstaart	june-september	purple/red			5	5	x		x
Mentha aqautica	Watermunt	july-september	lilac			3	3	x		x
Myosotis scorpioides	Moerasvergeet-mij-nietje	may-august	blue			1	0	x		x
Nymphoides peltata	Watergentiaan	july-september	yellow			3	3			x
Persicaria amphibia	Veenwortel	june-october	pink			1	1			
Persicaria bistorta	Adderwortel	may-july	pink			3	3	x		x
Petasites hybridus	Groot hoefblad	march-april	purple/pink			3	3			x
Phragmites australis	Riet	july-october	cream					x		
Silene flos-cuculi	Echte koekoeksbloem	may-june	pink			3	3			x
Stachys palustris	Moerasandoorn	july-august	pink			5	0			x
Symphytum officinale	Gewone smeerwortel	april-september	purple			3	3			x
Thalictrum flavum	Poelruit	june-july	white			0	3			x
Valeriana officinalis	Echte valeriaan	june-july	white/pink			3	3	x		x
FLOATING GARDENS										
Acorus calamus	Kalmoes	july-august	green/yellow							
Alisma plantago-aquatica	Grote waterweegbree	july-september	white			1	1			
Carex pseudocyperus	Hoge cyperzegge	may-july	brown							
Cicuta virosa	Waterscheerling	june-august	white							
Epilobium hirsutum	Harig wilgenroosje	july-september	pink/red			5	2			
Glyceria maxima	Liesgras	july-august								
Iris pseudacorus	Gele lis	may-july	yellow			1	1			x
Lycopus europaeus	Wolfspoot	june-august	white			3	1			
Lythrum salicaria	Grote kattenstaart	june-september	purple/red			5	5	x		x
Mentha aqautica	Watermunt	july-september	lilac			3	3	x		x
Myosotis scorpioides	Moerasvergeet-mij-nietje	may-august	blue			1	0	x		x
Phalaris arundinacea	Rietgras	june-july				5	5	x		
Phragmites australis	Riet	july-october	cream					x		
Rumex hydrolapathum	Waterzuring	july-august	red					x		
Scutellaria galericulata	Blauw glidkruid	june-september	purple/blue							
Solanum dulcamara	Bitterzoet	june-september	purple/red			5	5			
Stachys palustris	Moerasandoorn	july-august	pink			5	0			x
Typha latifolia	Grote lisdodde	june-july	brown							

SHRUBS / TREES NEAR NESTING FACILITIES KINGFISHER BIRD										
Alnus glutinosa	Zwarte els							x		
Salix alba	Schietwilg	april-may	lightyellow		4	4	x			
Salix caprea	Boswilg	march-april	lightyellow	x	5	5	x			
Salix cinerea	Grauwe wilg	march-april	yellow/green		5	4	x			
Salix repens	Kruipwilg	april-may	yellow/green		3	3	x			
Salix viminalis	Katwilg	april-may	gray/green		3	2	x			

Appendix B:
Interview M. van Aar

The trranscript of the interview with Mies van Aar, city ecologist of the municipality of Utrecht can be accessed online via the following link:

https://drive.google.com/
open?id=1viWd6SA9ZIbnPi49wIIN47Y6HocF3Otx