NATURE INCLUSIVE DESIGN IN HIGH-DENSITY URBAN DEVELOPMENT TO SUPPORT URBAN BIODIVERSITY

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ABSTRACT

Biodiversity is declining, urbanization is increasing, and the pressure on urban nature is rising. Nature inclusive design can provide a solution. This paper researches the current trend of nature inclusive design, the architectural interventions that can be used in nature inclusive design and urban ecology in the Netherlands, to be able to answer the main research question: How does the integration of nature inclusive design interventions into the building envelope support local biodiversity in an urban environment? Connecting species to architectural interventions, this research provides an overview of the possibilities in nature inclusive design to support urban biodiversity.

KEYWORDS: *Nature inclusive design, Urban ecology, Design for biodiversity, Green architecture*

I. INTRODUCTION

Biological diversity in plant and animal species is declining worldwide. This is caused by human activities, land use change and urban densification (European Parliament, 2020). At least 75% of all land and 66% of the marine ecosystems have been altered by human influences. Currently, approximately 16 percent of all species worldwide - that is one million species - are threatened with extinction (UN, 2019). These do not only include rare species that can only be found in specific ecosystems that are under pressure, for example tropical rainforests or coral reefs, but also species that are considered ‘common’, such as the house sparrow in the Netherlands.

The process of urbanization brings rapid and dramatic changes in the environment (Dearborn & Kark, 2009). Many native species cannot thrive in urbanized areas and these changes can make it a real challenge to protect or reintroduce certain native ecosystems to support the species.

It is important to conserve the natural environment because of the ecosystem services. Nature provides our oxygen, regulates weather patterns, pollinates our crops, produces our food, feed and fibre (UN, n.d.). Sustaining ecosystem services that humans benefit from is just one of seven motivations for conservation of urban biodiversity formulated by Dearborn and Kark (Figure 1, 2009).

Figure 1. Reasons why it is important to conserve urban nature (adapted from Dearborn & Kark, 2009)

1.1. Urbanization

Today, 55% of the world population lives in urban areas. With the continuous shift of people from rural areas to urban areas and the general growth of the world population, the United Nations predicts that in 2050 this will increase to 68% (UN, 2018). This trend creates a large necessity for residential development in and around cities all over the world.

Amsterdam is the capital and the largest city of the Netherlands, with a population of 872.757 within city borders and a total population of 1.392.695 in the region of Groot Amsterdam (CBS, 2020). With a current annual population growth of 11.000 people, the city faces increasing pressure on housing development. There is already a housing shortage and the municipality wants to build 50.000 homes before 2025 (Gemeente Amsterdam, n.d.c).

1.2. The relation between city and nature

The city of Amsterdam grew rapidly in the course of the twentieth century. Over time, the city expanded towards smaller towns surrounding the city with large-scale development projects, which created urban 'fingers' (Figure 2). Between these urban fingers - stretching outwards from the city centre - remained larger unbuilt areas that function as green fingers reaching into the city (Figure 3). The green fingers are now an active part of the urban green vision of the municipality of Amsterdam, because they play a significant role in the conservation of the quality of life for the inhabitants of the city (Gemeente Amsterdam, 2020). The municipality's ambition is to densify the city instead of expanding it. This means there will be more inhabitants per square kilometre, which will increase the pressure on natural areas in the urban context. It also increases the demand for green spaces from the inhabitants.

Figure 2. Urban development of Amsterdam

Figure 3. Green fingers

To densify within the city borders and at the same time sustain the quality and quantity of nature in the urban context, nature inclusive design in architecture provides a solution. In the Green vision for 2050, the municipality of Amsterdam (2020) states that they want "nature inclusive design to be the new standard for future (re)development". The municipality formulated a point system based on types of interventions, to check whether tenders meet this new standard - to ensure the quality of nature in the built environment (Gemeente Amsterdam, 2019).

1.3. In this research paper

The objective of the research is to formulate a definition of nature inclusive design, investigate the development of nature inclusive design in the Netherlands, and make inventory of the architectural interventions that are currently available for nature inclusive design. Then the research covers urban ecology, which information in combination with the gathered information about nature inclusive design will answer the main research question: *How does the integration of nature inclusive design interventions into the building envelope support local biodiversity in an urban environment?*

In the part: *Nature Inclusive Design*, the state of the art is considered a basis to define what nature inclusive design means for this research and the graduation project. It is also a part of the research that shows what nature inclusive precedents there are in the Netherlands in general, and internationally specifically urban high-rise buildings. The precedents provide inspiration, and a way to relate both the design intentions and the graduation project to the state of the art.

In the part: *Urban ecology*, the research covers species that are present in Dutch urban environments. Since the site for the graduation project is in Sloterdijk-Centrum, Amsterdam, some of the information gathered for this part of the research is specific for the Netherlands and the municipality of Amsterdam.

The part: *Architectural interventions*, consists of two parts: the investigation of (1) interventions to accommodate fauna in a building and (2) interventions to integrate flora into a building envelope. For the integration of fauna into the building, the investigation of architectural design interventions will focus on housing of animals, since other aspects of the life of the animals are mostly related to plants. For the integration of flora into the building envelope, the research investigates a variety of techniques available to place vegetation on the façade or on the roof of a building.

II. NATURE INCLUSIVE DESIGN

Figure 4 shows Hundertwasser Haus (1985) in Vienna, a design from Austrian artist Friedensreich Hundertwasser and architect Joseph Krawina, based on the former's ideas about tree tenants and a forested roof, which started the development of a movement in architecture that combines the natural with the built environment: 'nature inclusive design'.

Figure 4. Hundertwasser Haus, Vienna

2.1. Defining nature inclusive design

To formulate a definition of nature inclusive design that is fitting for the graduation project, the research first considers the definitions formulated by persons, platforms and organizations that play a significant role in the development of the (architectural) trend in the Netherlands and in the context of the project.

Maike van Stiphout is the author of the First Guide to Nature Inclusive Design (2019) and director of DS Landscape Architects. According to the book, landscape architecture has been the sole profession to design with urban ecology. Now it is time for architects *"to engage into design that purposefully accommodates man, flora and fauna in an adequate way in order to maximise and popularize ecosystem services and the synergy evolving between them."* (Van Stiphout, 2019, p. 23)

Bouwnatuurinclusief.nl is an informative website concerning different aspects and scales of nature inclusive design for residents, architects, and housing corporations. On the website, an initiative of Bird Protection Netherlands, the Dutch Mammal Association, and local and national government, nature inclusive design is formulated as: *"A well-executed nature inclusive design is capable of creating a strong bond between a building and the surrounding natural environment, without having to compromise on architectural quality."* (bouwnatuurinclusief.nl, n.d.-a)

The definition of nature inclusive design by the team of Green Deal Groene Daken (GDGD) in Handreiking Natuurdaken (2019) is unspecific in terms of the relation between the building and the surrounding environment: *"Nature inclusive design is to integrate nature in the building of houses, offices and other architectural objects."* (GDGD, 2019, p. 5)

The Award Nature Inclusive Building and Design is an award for inspirational nature inclusive building projects in the Netherlands. Projects that can be nominated for this award are *"[projects] that demonstrably [take] into account all users of the urban environment: both humans and animals."* (bouwnatuurinclusief.nl, n.d.-b)

Municipality of Amsterdam (2018) and the Netherlands Enterprise Agency (RVO) (2020) cover possible interventions in their explanation of nature inclusive design: *"Relatively simple and inexpensive interventions - such as nesting spaces for birds and bats, green roofs or facades - can improve the role of a building within the urban ecosystem. Nature inclusive design creates a healthy, future-proof living environment for both humans and animals."* The RVO sees an opportunity to include the improvement of the natural environment in the 1.000.000 homes housing task the Netherlands are facing.

Many definitions are broad and non-specific about the requirements for a project to be labeled 'nature inclusive'. What can be concluded is that to develop nature inclusive architecture, there should be attention for the relation between the building and the natural environment and the function the building can have in the urban ecosystem, to create a healthy living environment for humans and animals, where both can thrive. In the design process, therefore, architects and planners need to take into account the needs of animals and investigate how to incorporate those needs in a building that also functions properly for humans.

In the traditional way of building animals such as birds and bats could find open spaces in houses that they use for nesting - for example in cavity walls and under roof tiles. With the new way of building, where the goal is to minimize the environmental impact of building houses, these spaces are filled up with insulation materials, or other solutions are found in construction without cavities or left-over spaces. Therefore, there will be another criteria added to the definition of 'nature inclusive design' in this research: A nature inclusive design incorporates architectural interventions for both flora and fauna. This way the selection of precedents can be more specific and thus of greater value for the project.

2.1.1. Greenwashing

After Friedensreich Hundertwasser and the Hundertwasser Haus, green architecture began to take rapid strides. Many architects have incorporated natural elements into their designs since then. For example: Stefano Boeri Architects' Bosco Verticale in Milan (2014, Italy) or Emilio Ambasz & Associates, Inc.'s ACROS in Fukuoka (1995, Japan). The buildings are covered in lush vegetation, they are iconic and very inspirational examples of green architecture. However, the incorporation of natural elements does not necessarily imply that the building is designed in a nature inclusive manner. Although the integration of vegetation in the building (envelope) can be beneficial for the natural context and biodiversity in the area, these designs are based on the benefits of the green for human life, and the aesthetic or "wow-factor" of the building. It is very important to clearly state that in the context of this research paper these kinds of buildings are not to be considered nature inclusive designs, in this context they are examples of "greenwashing". "Greenwashing", in this case, is not defined as "making unwarranted or overblown claims of sustainability or environmental friendliness in an attempt to gain market share" (Dahl, 2010), but it means that the projects are not meeting the requirements for the label 'nature inclusive design' in the way that it is defined in this research.

2.2. Development of nature inclusive design in the Netherlands

To better understand the architectural context of nature inclusive design that the graduation project will build upon, there are some projects analysed and elaborated below. These precedents include realised projects from the last three decades, for nature inclusive design is relatively new (Van Stiphout, 2019) and the term 'nature inclusive design' has not often been explicitly used. There is no other particular selection criterium, because this part of the research is an inventory of what nature inclusive projects have been realised in the Netherlands, independent of size, location and program.

2.2.1. Medina

Medina is a residential building complex in the city centre of Eindhoven. It is a design by Neave Brown & Van Aken Architecten (VAA) completed in 1999 (VvE Medina Eindhoven, n.d.). The building has seven floors and contains 73 apartments. The gardens of the complex are designed to make the city more attractive to animals. The larger plants provide shelter and nesting opportunities for birds, and specific host plants and plants that produce nectar provide place for insects. Because of the diversity of the plants, there is a large diversity of birds and butterflies to be found.

Figures 5, 6. Medina

2.2.2. NIOO-KNAW

The research institute NIOO-KNAW in Wageningen is designed by Claus & Kaan Architecten and completed in 2011. The main challenge in the design was to combine ecological requirements and challenges, and architectural ambitions. The building has four floors and a planted roof to compensate for the ground floor area it takes up in its natural environment. The roof is a space for (re)introduction of threatened plant species, but also functions as a laboratory, in collaboration with Wageningen University, to study how to sustain the variety of species of plants and animals. The whole building is a testing ground for ecotechnology and cradle to cradle principles (NIOO-KNAW, n.d.); The roof is an experimental green roof and there are experiments with solar energy, reuse of waste water, and sustainable materials and energy use in the building as well.

Figure 7. NIOO-KNAW, Wageningen

2.2.3. Campus Triodos Bank

The office campus of the Triodos Bank in Driebergen-Zeist is a circular building designed by RAU architecten & Arcadis Landscape Architects, completed in 2019. The building has a structure that is made 100% of timber. The building won the Award for Nature Inclusive Design in 2019 (bouwnatuurinclusief.nl, n.d.). The (landscape) architecture focuses on humans, but also follows function, nature and culture. Key aspects are sustainability, transparency, excellence and entrepreneurship.

Figures 8, 9. Campus Triodos Bank, Driebergen-Zeist

It must be noted that realised nature inclusive projects in the Netherlands mostly focus on vegetation and using this vegetation as a means to attract fauna to the site. Only in recent projects did the architect introduce architectural interventions for fauna, such as nesting stones. Also, the majority of the projects is located in peri-urban areas or natural environments.

2.3. Development of nature inclusive design in high-rise buildings

A specific type of project of which analysis might prove to be useful input for the design phase of the graduation studio is the nature inclusive high-rise building. Based on the dwelling density ambitions and urban vision of the municipality (Gemeente Amsterdam, n.d.b) it can be assumed that the graduation project will result in a high-rise building. High-rise in the Netherlands is defined as a building of at least five floors high. However, in this research high-rise will be defined as a building with a building height over 30 meters.

As stated before, not every building with natural elements meets the requirements for the label of ‘nature inclusive design’ as formulated in this research. To select precedents that can be considered valuable for the research, some criteria need to be met:

- The building should be a high-rise building
- The building should be detached from other buildings
- The building has to be part of an urban context
- The building should include interventions for both flora and fauna
- The project has to be realised

2.3.1. Stadskantoor Venlo

The design of Stadskantoor in Venlo is of Kraaijvanger Architecten and completed construction in 2016. The 45 meter high building contains 11 floors of flexible office spaces for the municipality of Venlo. The building is constructed following cradle to cradle principles: All materials can be reused, without comprising quality. The green wall on the façade (Figure 10) is one of the largest green walls in the world and cleans the air both inside and outside of the building. The design also includes a helophyte filter to filter water, and solar panels in the sun protective overhangs.

Stadskantoor is located very close to the river Meuse and its floodplains, which provides a possible natural connection and extension of the natural environment of the river bank onto the building. The design principle, however, was to bring inside as much greenery as possible (Kraaijvanger, n.d.), and not explicitly to create this link using the façade greenery.

Figures 10, 11. Stadskantoor, Venlo

The intention of this analysis was to find projects worldwide and not only limit the research to the Netherlands for this specific type of building. There are countless high-rise projects that include vegetation and regard for the natural environment; Buildings with green facades, green roofs, sustainable design and materials, alternative construction methods, or buildings that produce their own energy using solar panels. Inspiring examples of what is possible in the field of architecture today.

However, as was the case with the projects of the overview of nature inclusive design in the Netherlands, the realised high-rise projects focus on the aesthetic and value of the vegetation for the human living environment. This vegetation might as a result attract more animals than buildings without the vegetation, but there are few to no projects that include both vegetation and interventions for animals. This leads to an assumption that nature inclusive interventions for animals are new and not yet properly researchable in realised projects.

This also means that following the definition of nature inclusive design as formulated in the first part: *Defining nature inclusive design*, there are very few precedents that meet all expectations of a nature inclusive building in the context of this research. Nevertheless, in nature inclusive projects that are yet to be realised, such as Vertical in Amsterdam (Figure 12) and SAWA in Rotterdam (Figure 13), the architects explicitly focus on creating an environment that functions for both humans and fauna. Both projects can be inspirational in the design phase, but because they are not realized yet, they have not been included in this analysis.

Figure 12. Vertical, Amsterdam

Figure 13. SAWA, Rotterdam

III. URBAN ECOLOGY

The field of urban ecology is young and pioneering. Focus in urban ecology lies on making inventory of the urban natural environment and promoting natural maintenance of urban greenery. American biologist Donna Haraway (Vink et al., 2017) pleads for introduction of *refugia*: open spaces in the urban fabric that function as refuge for species that cannot survive in the surrounding urban environment. Nature inclusive design can contribute to this, when ecosystem and species' requirements are considered in early stages of the design process.

Animals need food, shelter and a place to reproduce in close proximity (Kooijmans, 2009). Specific requirements vary per species. Because there are many different species that can live in the urban environment, this research will focus on:

- Birds – more specifically species that are building-related, such as House sparrow, Common swift, and Black redstart
- Bats – Common Pipistrelle
- Insects – Wild bees, Butterflies

The research will not cover interventions for waterbirds, amphibians, or fish, because there are no water bodies in the direct context of the site and the final design will probably not include large water bodies that meet the environmental requirements for aquatic fauna. Furthermore, the research will not cover reptiles, for the context is a dense and dynamic one and reptiles that do live in Dutch cities prefer calmer environments (Vink et al., 2017, p. 110). Another reason is the (limited) availability of information from the municipality of Amsterdam (Gemeente Amsterdam, 2018; 2019).

3.1. Birds

3.1.1. House sparrow

The house sparrow was a very common bird in the Netherlands, but is now an endangered Red list species. In Sloterdijk, Amsterdam, the house sparrow is a protected species (Gemeente Amsterdam, n.d.a).

The house sparrow is a small bird, that needs a lot of green in its surroundings. It thrives in messy, human environments, like older sub-urban neighbourhoods with a combination of open and more dense green patches (Vogelbescherming, n.d.b). If there are too many tall trees, the bird will migrate to a more fit environment.

House sparrows nest in spring and summer, in colonies. They are very social birds; Most nests are in close proximity of another. For a fit environment for house sparrows, a complete habitat – food, shelter, nesting space – should be created on a small surface. Providing just nesting places is not sufficient.

3.1.2. Common swift

The built environment is like a mountainous landscape for the common swift: a rocky environment with crevices to nest in. For the larger part of their life, swifts live in the air, except when breeding. Swifts are dependent on crevices to nest in to survive. Most important to provide is a place for nesting (Vogelbescherming, n.d.a).

3.1.3. Black Redstart

As for the common swift, the black redstart perceives the city as a rocky landscape, which confreres with its natural habitat. Warm and dry shelters in buildings are alternatives for crevices to breed in. The black redstart thrives in industrial areas or new construction and will migrate to a more fit location if the surrounding environment gets too green (Vogelbescherming, n.d.c).

3.2. Bats

3.2.1. Common Pipistrelle

The common pipistrelle is the most frequently occurring species of bat that lives in the Netherlands. It is a nocturnal animal that seeks shelter in dark crevices in rocks, trees, caves or buildings during the day. After sundown, the common pipistrelle starts hunting. It prefers the cover from trees or greenery, but also the openness of water bodies where it flies along protected shores, and forest edges.

Table 1. Animal species details: Birds and bats

Species	Endangered	Migration	Food	Lives in	Breeding / gestation
House sparrow	Yes, Red List species in the Netherlands	No	Insects, seeds, grain, flowers, bread, berries, peanuts	Colonies, socially, nesting boxes	March-August 4-6 eggs 11-12 days
Common swift	No	Yes, spends winter in Africa	Flying insects	Colonies, nesting boxes	May-June 2-3 eggs 18-22 days
Black redstart	Yes, protected indigenous species in the Netherlands	Yes, spends winter in Southern Europe / Africa	Insects, seeds, berries, fruit	Solitary, territorial, nesting boxes	From April 4-7 eggs 12-14 days
Common pipistrelle	No, although existing roosts in buildings are protected by law	No, max. 25 kilometres from summer roost	Insects, mosquitos, moths, beetles	Colonies or solitary	From June 1-2 babies 4 months

These natural environments do not necessarily have to be in close proximity to the roosts, maximum 5 kilometres away (Zoogdiervereniging, n.d.). The bat eats what is available: mosquitos, moths, flies, butterflies or beetles, up to around 300 insects per night. They live solitary as well as in colonies. An example of when bats live together in a larger group is when the females are breeding. The males spend more time living individually. Although it is known that bats hibernate, a precise hibernation period is not definable for the common pipistrelle.

3.3. Insects

3.3.1. Wild Bees

In the Netherlands, one species of bees, the honey bee, is cultivated by humans. Other species that survive without human interference are considered "wild bees". There are various types that can be subdivided in multiple species. This research elaborates on four types (Table 2) that are vulnerable or endangered (Koel, n.d.).

Table 2. Animal species details: Bees

Type (species, in NL)	Endangered	Hibernation	Flying time	Lives in	Gestation
Bumblebee (29, 21)	63% of species is Red List species	Yes, and after hibernation the queen bees migrate to form new colonies	February-October	Ground / existing holes; Colonies, caste system	Spring-summer Queen lays eggs 5 days: larvae 24 days: bees
Andrena (78, 70)	Approximately half of the species (53%) is Red List species	Yes, and most species are only active with sunny weather	March-October	Sandy ground; Solitary	Nest cells for single egg
Megachile (17, 13)	77% (10) of species is Red List species	No, a leaf-cutting bee lives only 6 weeks	May-August	Holes, possibly insect hotels; Solitary	Multiple eggs in a cylinder, sealed with leaves
Hoplitis / Osmia (20, 20)	Very vulnerable, 74% (6 / 8) of species is Red List species	Yes, before winter the bees develop, after winter they will work their way out of the nest	March-July	Holes, possibly insect hotels; Solitary	Multiple eggs in a shaft, sealed with mortar

3.3.1.1. Bombus

Bombus (bumblebees) live in colonies that are founded by a queen bee. The queen is the only one in the caste system that hibernates. After hibernation, in march, she eats nectar and pollen, finds a suitable nest place, and lays eggs that evolve from larvae into worker bees: females that cannot lay fertile eggs (EIS Kenniscentrum Insecten, n.d.a). The worker bees then tend to finding food and building the nest, while the queen bee only focusses on laying eggs. At the end of summer, the nest is crowded. Unfertilized eggs from the queen bee or worker bees form male bees; Larvae that are over-fed form new queen bees (Meijers, 2021). The queen bees leave the nest to find nectar and pollen and mate with males, before finding a place for hibernation. The other worker bees and males will die before winter.

3.3.1.2. Andrena

Andrenas are bees that nest in sandy soil, depending on the species 5 to 60 cm deep into the ground. They create nest cell for a single egg, that is provided with pollen before being sealed off. Some Andrena species choose pollen from one specific host plant, others have a more diverse floral diet (EIS Kenniscentrum Insecten, n.d.b).

3.3.1.3. Megachile

Long hairs on the back of the body 'capture' pollen, which is characteristic for the megachile. Megachile are better known as leaf-cutting bees (Van Breugel, 2014a). They use their jaws to cut pieces out of leaves and create a cylinder in the nest where they put nectar, pollen and an egg. The cylinder consists of several cells with single eggs that are sealed of with perfectly round pieces of leaf.

3.3.1.4. Hoplitis / Osmia

Hoplitis and Osmia are bees characterized by their nesting habits. Females collect nectar and pollen which they place in a hole, usually a horizontal shaft. When there is sufficient food, the female places and egg and seals off a small cell with mortar. This is a mixture of the saliva of the bee and clay or sand. The bee repeats this process until the shaft is full. The last wall is extra thick to protect the eggs in the shaft (Van Breugel, 2014b).

3.3.2. Butterflies

Because of intensive agriculture, the countryside does not provide a safe environment for butterflies. The urban environment, and specifically the type of maintenance of urban greenery, offers possibilities to improve the living conditions for butterflies in the Netherlands (Vlinderstichting, 2019). There are relatively easy alterations that can create significant opportunities, such as changing lawns to herbaceous or flowery grassland, or changing maintenance programs for roadside greenery for the creation of the before mentioned types of grassland.

Butterflies eat nectar from flowers, but they need other plants, and in fall also fruits. Caterpillars are very picky when it comes to food. Most butterflies place their eggs on species-specific host plants, that the caterpillars can eat when they hatch (Vlinderstichting, n.d.). Examples of host plants are nettle, sorrel and thistle.

The warmer the weather, the better the butterflies can move. They need a body temperature of at least 20 degrees centigrade. On colder days the butterflies will stay in shelters, other days they prefer to find a secluded spot where they can absorb warmth of the sun. Butterflies start their hibernation around September.

IV. Architectural interventions

As mentioned before, because of development in construction and renovation, the possibilities for fauna to spontaneously settle in buildings are decreasing. For plants, because of urbanization, space in the urban environment to grow and thrive is decreasing. Therefore humans can benefit less from the ecosystem services flora and fauna can provide. Architects can contribute to the solution and help to sustain the natural environment and ecosystem services by incorporating space and elements for flora and fauna in their designs.

4.1. Interventions for fauna

Animals need food, shelter, and a place to reproduce in close proximity. If one of the three is missing, animals will not stay in the area (Kooijmans, 2009). Food can be provided by plants or smaller animals such as insects and rodents. Shelter can be provided by different types of plants and organic landscape elements, depending on the size of the animal. Architecture can also provide shelter in the form of eaves or cantilevers. To provide a place to reproduce, again, the natural environment can play a role but there are also architectural interventions that can provide a nesting place.

4.1.1. Ground-bound fauna

Approximately 80 percent of biodiversity lives underground. The soil fauna consists of microfauna (bacteria, fungi, nematodes), mesofauna (mites, springtails), and macrofauna (insects, spiders, millipedes, worms) (Vink et al., 2017, p. 132). They work the soil and play a significant role in the nutrient cycle. Important for their living environment is the absence of chemicals and pesticides, and protection from drought and frost. In a building, a well-constructed vegetated roof design can provide a steady environment for these species. This is an example of how the architectural interventions for plants can provide a place to live for (soil) fauna. These interventions will be elaborated in the part: *Interventions for plant species*.

4.1.2. Flying fauna

4.1.2.1. Insects

The most important resources to improve the living conditions for insects are flowering plants and trees (Vink et al., 2017). Insects like to seek shelter in walls that are made up of loose stones, horizontally stacked hollow reeds or bamboo, or so called insect hotels. This is perhaps part of a landscape design or a sculptural design more than an architectural design. However, there are architectural elements, such as bricks (Figure 14), that are perforated to accommodate insects in the same way as the insect hotel would. The placement and orientation of the architectural element is very important. It needs to be providing shelter from rain and wind, located close to flowering plants, and facing south or south-west where the element can be in full sun. This can also be on the roof of a building (Gemeente Amsterdam, 2018, p. 14).

Figure 14. Bee brick

Nevertheless, the majority of architectural nature inclusive interventions that currently exist – that are not related to the implementation of flora – focus on either birds or bats.

4.1.2.2. Birds

There are nesting stones that can be fitted in with masonry or added onto a building. Per species the distance between and the height of the implementations of these stones varies. Also the size of the entrance of the nesting stone varies per species.

There are specially designed roof tiles that include nesting places. On slanted roofs, these tiles can provide a shelter in a place that is a traditional nesting place for birds such as the house sparrow (Figure 15). This influences just the edge of the roof, which allows the remainder of the tiled roof to be constructed in a modern way.

Nesting stones for birds on or in walls (Figures 16, 17) should be orientated towards the north or north-east. This prevents over heating in the summer. The flight to the entrance of the stone should not be obstructed by trees or roadside ornaments. The stones should not be placed above windows, to prevent collisions with windows caused by confusion of the birds.

Figure 15. Traditional shelter or nesting place for birds in houses

Figure 16. Bird box added on the facade

Figure 17. Nesting stone embedded in the masonry

4.1.2.3. Bats

There are twenty species of bats in the Netherlands, half of which live in cities. Bats are nocturnal animals, which means they are active during the night. During the day they are dependent on existing hollow spaces in the built environment, such as attics, cavity walls and cavities under roof tiles. For their presence in cavity walls, the cavity needs to be at least 3 centimetres wide. Bats will enter via open butt-joints of at least 1.7 centimetres (Vink et al., 2017, p. 67). In buildings without cavity walls bat boxes can be integrated into the masonry, in a similar way as the nesting stones for birds (Figures 18, 19). There are several shapes and sizes of bat boxes, for bats need four different types of roosts: one for shelter during the day, one for mating, one for nesting, and one for hibernation (Vink et al., 2017, p. 65). Bat boxes for nesting are larger, because bats nest in breeding colonies of hundreds of females (Figure 20).

Figure 18. Bat boxes in masonry

Figure 19. Bat box placed in masonry. Smaller size

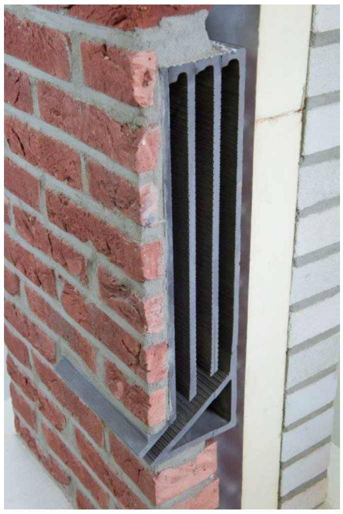

Figure 20. Bat box embedded in masonry. Larger size

An overview of the orientation (N, E, S, W) and positioning (height) of architectural interventions for the specific animals can be found in Appendix 1.

4.2. Interventions for flora

Generally, plants need soil or substrate, water and sunlight to grow. Plants have requirements that are species specific, such as orientation to the sun and moisture levels. To include plants in the building envelope these specifications need to be taken into account. Nevertheless, this part focuses on a more general level on implementation of vegetation onto the building envelope: the different techniques and interventions for the roof and the facade.

4.2.1. Roof

Traditionally, roofs are covered with tiles when they are sloping, and with a material like bitumen when they are flat. Such roofs are considered grey roofs (GDGD, 2019). Green roofs are designed to benefit the local natural environment and biodiversity. There are different types of green roofs, based on their function:

- Natural roofs
- Sedum roofs
- Mixed-use or utility roofs
- Green-blue roofs

There is another type of vegetational roof - the brown roof - which is a literal transplant of the local soil onto the roof (Biodivercity.nl, 2011). There is no extra vegetation added to this roof type. Vegetation will come and grow naturally with the dispersion of seeds from surrounding natural areas through wind flow or animals.

Even roofs without vegetation, that covered with pebbles or shells, can be beneficial for the natural environment, for example for coastal bird species - such as the oystercatcher and the common tern - because it resembles their natural nesting place (Checklistgroenbouwen.nl, n.d.).

The green roof types are the most complex, but also the most beneficial for and most contributing to the urban and the natural environment. These are elaborated hereafter.

4.2.1.1. Natural roofs

The natural roof is intensively vegetated and thus requires a thick layer of soil or substrate for the vegetation to grow in. This layer should be at least 150 mm thick (not including the vegetation). To sustain the natural roof, frequent maintenance is needed. Therefore the roof should be accessible for people. To support the natural roof and maintenance work, the building's structure should be of sufficient strength. In the layered construction of the natural roof, there are possibilities for water storage. Because of the thick layer of substrate, there are opportunities for more diverse vegetation.

4.2.1.2. Sedum roofs

Sedum roofs are extensively vegetated, which means the vegetation can sustain itself without frequent maintenance. The layer of soil or substrate is thinner than the substrate layer of the natural roofs. The substrate layer of a sedum roof is maximum 150 mm thick (not including the vegetation). These roofs are usually planted with sedum, hence the name. However, grass and herb species are extensive species as well. The vast surfaces covered in one type of vegetation are not as appealing to animals as diverse natural roofs.

4.2.1.3. Multifunctional roofs

Multifunctional roofs, also known as utility roofs and referred to as red roofs in Handreiking Groene Daken (GDGD, 2019), are roofs of which design focuses on utilitarian function for humans. These roofs are partly planted, but the majority of space is usable by humans. The flora and fauna in this environment will most likely be disturbed by human presence, which can lead to less biodiversity because larger animal species will not settle here. However, for humans, the presence of vegetation on this type of roof is very beneficial (De Dakdokters, n.d.). Plants provide ecosystem services such as improving human health, cooling the climate, mitigating peak precipitation and urban heat island effect, filtering CO2 and particulate matter from air, and plants can have a noise cancelling function.

4.2.1.4. Green-blue roofs

Green roofs have a system that slows the water drainage, because the water is first intercepted by the vegetation and layer of substrate before it is discharged. With green-blue roofs an additional system is integrated where water can be stored temporarily or for longer periods, and where the discharge of water can be regulated.

Figure 21. Natural roof

Figure 22. Sedum roof

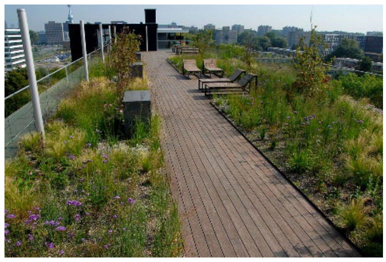

Figure 23. Multifunctional roof

The principle of a vegetated roof is based on a construction with a layer of substrate in which vegetation can grow roots. The basis of the system is a (building-) structure with a carrying capacity that is sufficient to carry the load of the construction. In the case of a renovation project, the possibilities for a green roof very much depend on the existing carrying capacity. With new construction, there are more possibilities and the structure can be designed to meet the technical requirements for the desired green roof type.

4.2.2. Facade

Recent interest in 'green architecture' and 'ecological urbanism' has increased the amount of greenery in facades in architectural design significantly (Gandy, 2010). Vegetation on a facade is an efficient way to contribute to greening the urban context, because it does not occupy extra ground area. Vegetation on walls also has greater potential than green roofs, especially in urban centres where the surface of the facade usually exceeds the footprint of the building (Manso & Castro-Gomes, 2015). There are several types of facades with vegetation. The types that will be discussed are the green wall, the facade garden, and balconies with planters.

4.2.2.1. Green wall

Traditional green wall methods were used in warm and dry climates. Vegetation was used to cover pergolas or exterior walls to provide shade and cool the building envelope. Over time, the covering of surfaces with climbing plants became more common in Europe and North America, as ornamental elements in the building envelope (Manso & Castro-Gomes, 2015). Today, green walls are not just exterior surfaces covered with vegetation. There are different types of systems and techniques developed in green wall technology that can be subdivided in two main systems: green facades and living walls (Figure 24).

A green wall is a green facade when the plant grows on a horizontal surface and is attaching to or growing along the facade panel. Living Wall Systems (LWS) consist of a supporting structure that makes it possible for plants to grow from the facade panel. This allows rapid and higher covering, and uniform growth on the facade.

The French botanist Patrick Blanc is a leading figure in the greening of architecture (Gandy, 2010). He created an LWS - le mur végetal - that was patented in 1988. This system consists of a steel frame covered in PVC and felt with an automated watering and fertilizing system.

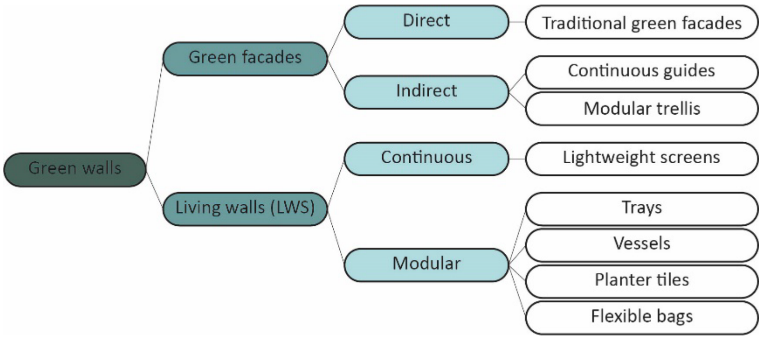

Figure 24. Types of green walls (adapted from Manso & Castro-Gomes, 2015)

There are other types of living wall systems: modular systems such as trays, vessels, bags and tiles (Manso & Castro-Gomes, 2015). Modulogreen® by Mostert De Winter (Figure 25) is an example of a tray LWS. This has been used in the facade of Stadskantoor Venlo (Figure 10, page 7). SemperGreenwall by Sempergreen Group is an example of a tile LWS (Figures 26, 27).

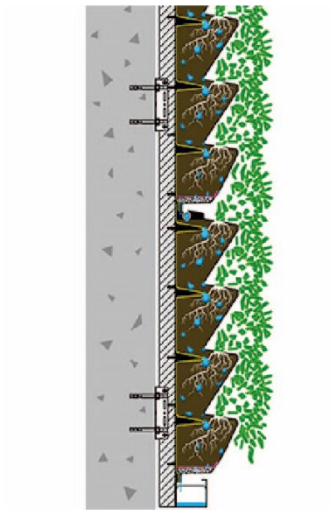

Figure 25. Modulogreen system

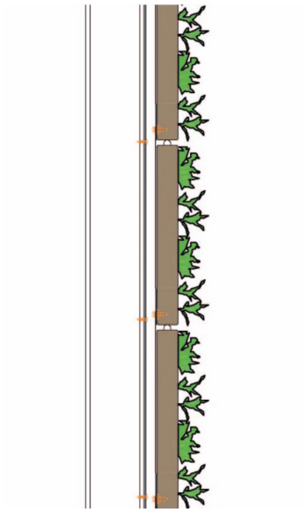

Figure 26. Sempergreenwall system

Figure 27. Bus stop Willemsplein, Arnhem

4.2.2.2. Facade garden

The facade garden is a narrow strip of greenery - usually on the sidewalk - along the facade (Kooijmans, 2009) where the plants are directly rooted in the ground (Figure 28). Facade gardens can also be a form of green facades (Manso & Castro-Gomes, 2015). The climbing plants grow directly on the facade or they are supported by structures to guide them to higher elevations.

4.2.2.3. Balcony with planters

A balcony is a horizontal surface in or sticking out of the facade. It can be considered a small roof with a utility function. On a balcony, an individual resident can create space for greenery by putting down plants in pots. Architects can also already integrate planters on balconies in the design, as did Stefano

Boeri in Trudo Tower (Figure 29), to create possibilities for natural interaction between vegetation over the whole facade.

Figure 28. Facade garden

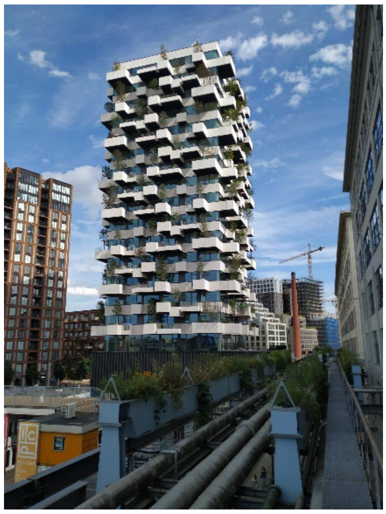

Figure 29. Trudo tower, Eindhoven

V. CONCLUSIONS

Biodiversity is declining worldwide. One of the causes is urbanization. To tackle the loss of natural area in the urban context, architects can play a significant role by introducing nature inclusive design in their projects. Nature inclusive design is relatively new and there is not yet one specific definition in the architectural field that can guide all designs. Because the definitions can be quite vague, I have formulated nature inclusive design in a way that is relevant for my graduation project. Nature inclusive design means that there is significant attention to the natural world in the early stages of the design process. What do animals and plants need to survive in a dense urban context and how can we as architects provide the right circumstances for humans and animals to coexist in this space? Focus in nature inclusive design until now lies on how greenery can benefit humans; How to optimize the benefits for humans from ecosystem services provided by the natural environment. Attracting or supporting animals such as birds or bats has been a nice side issue. In the case of this research, nature inclusive design would mean that in the design of a building also the possible benefits of the built environment for the animals and plants are taken into account, and which architectural elements can be added to improve the living conditions for animals and plants in the building. The research tried to find precedents that met this more specific definition of nature inclusive design. However, it proved difficult to find precedents that explicitly met the requirements.

The architectural features discussed in this research support the basic needs of birds, bats and insects. Animals need three things: food, shelter and a place to reproduce. With new construction methods, depriving the building envelope of left-over spaces, bats and birds have less opportunities to find shelter or a nesting place. Integrating nature inclusive design interventions such as nesting stones into the facade, provides a new opportunity for them. Integration of plants - specifically plants with nectar and pollen - in facades or roofs can attract smaller animals such as insects, which in turn attract larger animals such as bats and birds. Thus, nature inclusive architectural interventions can provide all three requirements for animal species to settle. The interventions will improve the quality of their living environment and the resilience of the species in the urban environment.

While there are specifications for the implementation of nesting stones, these are simple, such as orientation or height. The integration of plant species into the building envelope requires a more technical approach. Based on the type of plant that is desired, there is a certain type of soil with density and weight. There is a need for an irrigation system, sufficient strength in the supporting structure, and a maintenance plan for the preservation of the ecosystem on the building.

These are details that will need extra attention in the design process, because there needs to be specific plant species that attract certain insects. There needs to be attention for the relation between humans and the animals in the shared spaces such as multifunctional roof gardens. There could be a balance between humans and nature where both can thrive and benefit from each other, because of nature inclusive design.

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FIGURES

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APPENDIX 1.

Orientation and positioning of nature inclusive architectural interventions on a building's façade (adapted from Gemeente Amsterdam, 2019).