

Thematic Research Paper

Biodiversity and modular vertical greening

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ABSTRACT

Many species that are dependent on buildings are beginning to appear as more and more species of nature learn to adapt to city life. In the same vein, the concurrent loss of biodiversity presents a problem for the planning of vertical greening. This article attempts to explore the combination of animal nesting and vertical greening to develop a more species-friendly environment. The end goal is to create a flexible, easy-to-maintain, demountable, modular vertical greening system that can respond to changes in the ecosystem.

KEYWORDS: *Biodiversity, Modular vertical greening, Nature inclusive design, Urban ecological system*

1. Background

Cities are growing as a result of population increase and the quick advancement of technology, which has also resulted in several issues like habitat loss for animals and environmental pollution, which has sparked a global catastrophe of species extinction. According to the United Nations Environment Programme (2010), human activity is 1,000 times more likely to cause a species to become extinct globally than it would be in the wild. Cities must have biodiversity to survive, and it is crucial for preserving natural balance and promoting sustainable development. Therefore, it is essential to incorporate biodiversity into urban and architectural planning.

Macro, meso, and micro scales are the three main ones used to study urban biodiversity planning. The creation of ecological network systems is the main focus of macro-scale biodiversity planning. A trans-European ecological network for biological conservation is suggested by the European Commission's "The Pan-European Biological and Landscape Diversity Strategy." (1992, European Commission). Meso-scale urban biodiversity planning, which is typically implemented as a specific macro-level planning strategy, is primarily concerned with the control and direction of biodiversity at the scale of urban populations. Design strategies are put forth at the micro-scale biodiversity design level to improve biodiversity at the scale of streets, buildings, and even walls, roofs, and individual parts. Islington in Greater London advises that biodiversity should be taken into account even if

there are no significant habitats or species to be protected on a site in the "Sustainable Design and Green Planning Good Practice Guide." The planning for biodiversity protection at the meso-micro scale, with one building as the major emphasis, is the main topic of this research. Vertical green walls, green roofs, and interior gardens make up the majority of the design.

The right habitat conditions for wildlife depend on their eating patterns, nesting preferences, reproductive preferences, territorial behavior, and natural adversaries. All wildlife has three basic needs: food, water, and shelter (cover), which are dictated by the laws of nature. (1993; Johnston et al.) A particular region of land, commonly referred to as the "Home Range," is required for wild animals to rest, move around, escape potential predators, locate mates, and receive food and water in order to survive. (Börger et al., 2008)

According to home range theory, the spatial configuration of an organism's daily functional needs for feeding, drinking, resting, wandering, courtship, and brood rearing must form a suitable and convergent order, i.e. nesting spatial ecotope, feeding spatial ecotope, and resting spatial ecotope resources must be located within a certain spatial range that enables the animal to move safely between these three types of spatial ecotone throughout the day. "Convergent demands of nesting, feeding and resting space ecotopes" (Jing, 2018).Information in Figure 1.

In natural ecosystems, the number of individuals, biomass, or energy of creatures at each trophic level, often known as the "ecological pyramid," is produced by food chain linkages. According to trophic levels, these might be placed in a diminishing pyramidal order. The decomposer is at the bottom of the "ecological pyramid," followed by the producer and the consumer. Earthworms, ants, bacteria, fungi, and other species that rely on decaying matter for nourishment are examples of decomposers, commonly referred to as soil organisms. The green plants that can absorb solar energy and make organic materials are the producers of it. There are three categories of consumers: primary, secondary, and tertiary.Beetles, butterflies, and other creatures that eat green plants directly are referred to as primary consumers. Birds and bats are considered secondary consumers, while raptors and foxes are the highest degree of eaters and are referred to as tertiary consumers. Information in Figure 2.

Urban planners and designers have developed techniques in recent years to incorporate biodiversity into urban development. For instance, nested bricks and bat boxes atop buildings are mentioned in Gemeente Amsterdam's "Twenty ideas for integrating biodiversity into urban planning and development," as well as installations in parks and forests such as rainwater pools and insect hotels. Their building of artificial habitats for urban animals including insects, hedgehogs, squirrels, bats, and birds, as well as their consideration of plant species as food sources, is what they all have in common.

The technology for vertical greening systems, such as green roofs, rooftop pools, and green walls, has been continuously evolving. These systems use a variety of modular architectural strategies and are more adaptable and durable than the original technology. Based on the hierarchy of biological chains and the "convergence of nesting, feeding and resting space ecological requirements" of animals, the vertical greening system of buildings and the habitat of invertebrates and secondary consumers are taken into account as a whole. The development of a modular vertical greening system that can be installed on any building surface, and is demountable, versatile, and responsive to the

demands of urban plants and animals.

Why modularity: The producer and decomposer modules (plants and microorganisms), the primary consumer part (invertebrates), the water part, and the secondary consumer part (birds and bats) are just a few examples of how the modular design method splits the entire system into smaller pieces. Each module can be separately built, and it can be put together with consideration for how its location within the structure will be affected by things like height, orientation, artificial light, and noise.

Demountable animal nests and vertical greening could allow for future changes to the location of nests in the building or changes in plant species that would be more beneficial to the urban ecosystem, as many of the animals discussed in the article have changed their hunting habits and nesting requirements to survive in the city. The nests' modular design permits a more adaptable form in addition. The modular design allows for recycling and maintenance easier.

Research question: How to use flexible modular vertical greening to enhance the biodiversity of the city and build an ecological system on the building scale?

Sub question:

- 1.What is local biodiversity?
- 2.What is modular vertical greening?
- 3.How to combine the needs of urban animals with modular vertical greening system?

2.Methods

Beginning with an animal ecology viewpoint, the study examines the spatial requirements of nesting sites for building-dependent species in urban contexts, including size, orientation, entry, height, and temperature. This is done through literature reviews and case studies. The impact of various vertical greening techniques on the diversity and abundance of insect species is then researched in the literature, with the modular living wall system serving as the primary system chosen for analysis. To define the various modular living wall systems in terms of substrate, materials, and irrigation systems as well as to determine the effects of each feature on the diversity of insect species and strategies to improve them, literature reviews and case studies were used.

3.Results

3.1 Target species and requirement

Based on the overall consideration of the Delft urban ecosystem, the target species were selected from three categories: plants (soils), primary consumers, and secondary consumers, with plants (soils) and primary consumers being selected mainly for the conservation of native species and the enhancement of species richness and abundance in the vertical greening system. Therefore, floral resources and host plants are included in the selection of plants (soils).

With increasing urbanization, some animals have adapted to share built structures with us to survive. We call them 'building-reliant species' (Gunnell et al., 2013). In this paper, the analysis will focus on 'building-reliant species'.

3.1.1 Birds

In the Netherlands, the birds that depend on cities for their survival fall into approximately the following categories:

Species living in buildings: House sparrow, Common swift, Black redstart, Eurasian Oystercatcher;

Species living in green areas: Common starling, Western jackdaw, House martin, sand martin and Barn swallow, Common Blackbird, Common wood pigeon and Eurasian collared dove;

Garden and Park birds: Water birds, Great crested grebe and Eurasian coot, Mallard and common moorhen;

Wintering species: Black-headed gull, Birds of prey, Tawny owl

3.1.1.1 House sparrow

Although the situation has improved, house sparrows in the Netherlands are still on the red list due to their severe population falls in urban areas since 1970. Being sedentary, house sparrows spend the winter on or near their breeding sites.

Aphids and other insects are used to feed their nestlings. The nests are preferably inside the building at the soffit/eaves level, although they can also be found as an external box. The preferred aspect is easterly, and the nests must be kept out of direct sunshine.

The nest is approximately 150mm (w) x 350mm (h) x 150mm (d) in size. (This size is based on a study of an existing bird brick built for a house sparrow. However, there are many alternative artificial nest sizes available.) At the same time, the box's base must be at least 150mm from the bottom of the entrance hole. The males of sparrows guard the entrance to their area as they build their nests in loose groups of 10 to 20 pairs. The male will guard the territory's entrance. Although there might be as little as 200–300 mm between nests, a meter gap lessens hostility. Sparrows typically build their nests close to dense deciduous shrubs in the wild for protection, roosting, and foraging. These places also offer food sources like insects and seeds. This shows that while nesting and foraging sites might be close to one other, sparrow nests must be hidden and cover their entrances. Information in Figure 3.

3.1.1.2 Black redstart

The Black Redstart is a migratory bird that only spends the summer in the Netherlands. Black redstarts typically arrive in the Netherlands in late March or early April, begin breeding in mid-April, and depart in most cases around the end of August; their migration seasons are in September and October. Black redstarts primarily consume spiders and insects they catch in the air and on the ground. They demand a variety of habitats.

Brown roofs and eco-roofs might make a location appealing to the Black redstart in cities with dense urban development. The nest is approximately 150mm (w) x 260mm (h) x 150mm (d) in size. It must be shielded from the sun's rays, wind, and rain. Because they naturally construct their nests on cliffs and hilltops, black redstarts like to nest on the walls of buildings and generally select more overgrown terrain with less flora but lots of insects. Information in Figure 4.

3.1.1.3 Common swift

Since 2007, there has been a sharp fall in the number of common swifts in the Netherlands, which has since sustained a modest annual decline. The Common Swift is a migratory bird that comes to the Netherlands every year in late April or early May,

begins breeding, and then starts to migrate out in August. It continues to migrate out until September or October. The Common Swift used to make its nests in cliffs and tree cavities, but because it has adapted to city life, most of its nests are now found in cracks in buildings, such as those found under tiles, in gaps in window sills, and under eaves.

Except when it is nesting, the common swift spends the most of its time in the air, where it feeds primarily on flying insects. In terms of nesting requirements, pick a location where the nest will face east, be out of direct sunshine, and be away from climbing plants, as these might give animals like rats access to the nest. At least five metres should separate the nest from the ground, and there should be multiple possible nesting sites for common swifts nearby. The nest's floor area must be at least 350 square centimetres, or 200 mm x 175 mm, with a minimum height of 75 mm; however, 150 mm or 200 mm are preferable but can be smaller. Oval or rectangular entrance, 65mm (w) x 33mm (h), should be no higher than 5 cm from the bottom. Additional details can be found in Figure 5.

3.1.1.4 Oyster catcher

Over the past three decades, there has been a steep drop in the number of oystercatchers found in the Netherlands. The oystercatcher was traditionally a bird that lived around the shore, but in recent years it has begun to travel inland and can now settle in fields and cities. When it does so, it typically nests on flat roofs and eats on neighbouring lawns and football pitches, its primary diet consisting of earthworms and the larvae of insects.

The breeding season for oystercatchers typically runs from February through July. An oystercatcher's nest is little more than a shallow scrape in the ground that is sometimes lined with vegetation and is located in an area that provides a suitable environment for the young. In addition, they require many nesting sites as well as safe havens in which to conceal their offspring once they have hatched. In order to ensure the young are protected from the elements, the nests should have as much protection from the wind as possible.

There is scant information available regarding the dimensions of oystercatcher nests. In the wild, oystercatchers build their nests near the water's edge and typically do so by rearranging a few stones and leaves. To get a better idea of the size of the nest, I referred to a temporary nest that was built by Robertson Construction during the construction of a road at the University. This nest had a wooden plank base, was filled with gravel and sand, and was designed to be moved. It measured approximately 800 mm(w) x 800 mm(d) x 500mm(h). Additional details can be found in Figure 6.

3.1.2 Bats

The common pipistrelle is a species of bat that can be found in the Netherlands and prefers hunting at the edges of woodlands. Its primary prey consists of insects, including flies, caddisflies, lacewings, and mayflies. Generally speaking, roosts for common pipistrelles can be broken down into three categories: summer roosts, winter roosts, and male roosts. This activity, which is carried out by male bats in the hopes of luring in females, continues from July to October, with its height occurring in September. Following copulation, the females will travel to their winter roosts, where they will remain dormant from the months of November through February. After that, the females will travel to the summer roosts, where dozens of females would congregate in a single roost in order to give birth to their young and nurse them.

The common pipistrelle does not have any specific criteria for the size of the roost, but it

does require particular components to have cracks that range from 20 to 30 millimetres in width. A total space of roughly one square metre or more is considered to be relatively high for summer roosts, and the interior of the roost must contain horizontal wooden beams in order to provide resting areas for the bats. Summer roosts are typically oriented towards the south or west to take advantage of solar heating; however, extreme caution must be exercised to prevent the roost from becoming too hot. Winter roosts and male roosts will normally be closer together, typically oriented towards the north, and the material will generally need to be a rougher surface for the bats to grip onto. Natural materials such as untreated wood, stone, or masonry will be chosen as the roosting material of choice.

In all roosts, it is important to steer clear of direct exposure to artificial lights. A flight space measuring 5 metres wide x 2.8 metres high x 5 metres deep may also be required in addition to the entry to the roost with dimensions of roughly 20-50 millimetres wide by 15-20 millimetres high. The height of the entrance to the roost will be approximately 2-7 metres above the ground. Summertime temperatures will be in the range of 30-40 degrees Celsius, while wintertime lows will hover around 0-6 degrees Celsius. Additional details can be found in Figure 7.

3.2 Biodiversity and vertical greening system

There are a variety of approaches that can be taken to alter the built environment of cities in order to raise their biodiversity. Due to the vast wall surface that is already available in cities (Darlington, 1981) and is predicted to be by 2030 (World Bank, 2009), vertical greening systems (VGS) have a tremendous potential to be one of the most effective solutions (World Bank, 2009). Vertical greening systems are divided into green facades, living walls and other categories such as moss cladding and 3D printing. Among these, living walls are divided into continuous and modular, and green facades are divided into direct and indirect, a detailed classification of which can be seen in Figure 9.

They compared the three different types of walls that can be found in European latitudes: bare walls (BW), green facades (GF), and living walls (LWS, both continuous and modular). The research was based on the work done by Flavie Mayrand and Philippe Clergeau. Figure 9 demonstrates that both green facades and living walls are preferable to bare walls from the perspective of birds and insects. However, from the perspective of the most common species of spiders and beetles, living walls are preferable to green facades. When comparing these two options, the modular LWS is superior to the continuous LWS.

In terms of structure and plant development, a substrate of soil is not necessary. Instead, the plants grow in screens that are lightweight and absorbent, such as a layer of fabric (such as felt) that has been sliced to form pockets. Modular living walls are distinguished by their pre-vegetated LWSated panels, each of which contains a unique set of supporting materials (vessels, trays, flexible bags, and planter tiles) in which the plants can grow. The medium for growing plants is made up of an organic and inorganic substrate that has a high capacity for water retention and provides a space for the roots to spread out and multiply. The Continuous LWS have a lower seeding depth, while the Modular LWS have a greater seeding depth than the Continuous LWS do. Additionally, the Modular LWS are easier to maintain in terms of substituting plant species. (Amorim et al., 2017) The green facade, on the other hand, has the benefits of not requiring a support structure and being inexpensive to create. However, it takes a long time to cover the wall, it is not sympathetic to the diversity of insect life, and it is not conducive to maintenance or disassembly. As a result, it is being contemplated for usage in part as a covered resting

spot for birds, and later studies will examine both continuous and modular LWS systems. It has been discovered through literature research that birds and invertebrates prefer to use vegetation that covers walls; however, this association may change depending on the resources available (Hinsley & Bellamy, 2000).

Some bird species use the flora along the wall as a place to nest, while others may merely use it as a haven or a source of food. The density of the surrounding habitat may affect the height of the perches used by birds for singing (Scherrer, 1972), and the fact that most birds prefer the cover of higher vegetation may be because taller structures offer larger refuge areas (Campbell, 2011) and better vantage points (Moller et al., 2006), reducing the risk of predation in some cases. In contrast to other times of the day, birds are also more active in the morning during vertical greening. According to Deslauriers and Francis (1991) and Trnka et al. (2006), this may be primarily due to nutrition, with insectivorous birds being most active in the morning and invertebrates being least active because of the chilly surroundings. Evergreen species are the most appealing choices for vertical greening plants, and Arnold (1983) showed that hedgerows serve as both a physical haven during the winter and a significant source of food for birds.

The height of the structure and the environment around it both significantly affect invertebrates. The percentage of green area surrounding a green wall has a substantial impact on the richness and abundance of populations with low dispersal abilities, according to research by Madre (2015). According to a recent study (Vergnes, 2017), the height of walls has an impact on how aerial plankton disperses in urban areas. Thus, it is important to look into the type, quality, and surroundings of VGS in order to establish connectivity. According to Madre et al. (2013), height can also have an impact on the diversity of species with limited movements, such as spiders and carabids. On the other hand, nearby green spaces and green roofs have an impact on the variety of species with high mobility (bees, weevils). Height has an impact on the number of highly migratory

3.3 Possible modular LWS and material

Planter/pot, textile bag and panel living walls are the three primary types of modular living walls. Textile materials are used to make textile bags, including deemed, adobe, burlap, tarpaulins and any other fabric robust enough to survive moisture, the elements and the weight of the system itself. The plant-growing media is often housed in textile pockets and can take the form of soil, coconut fibre substrate felts, expanded clay pellets, peat moss, or mineral wool. On the other hand, prefabricated panels are distinguished by structural waterproof box panels (such as polystyrene or HDPE), typically containing lightweight inorganic substrates (such as mineral wool, felt, or perlite) or organic substrates (such as soil, potting mix), wrapped in a geotextile and outfitted with an irrigation and fertilisation system. The planting box or pot used in the planter/pot system is fastened to a support structure. With the planter/pot system, a variety of shrubs, herbs, and food plants can be grown. Soil is typically used as the substrate, although lighter substrates like coconut fibre, expanded clay pellets, or peat moss can also be added to lighten the system overall and improve drainage. A planting substrate is fitted into a metal module or cage to create wire cage panels in the planting medium or cages. The majority of the substrate elements in planting mediums are either of mineral (rock wool or clay), plant (Chilean sphagnum peat moss or coconut fibre), or animal (microbial or bacterial) origin. In addition, there are developing technologies or materials that can be utilised as modules for modular LWS, such as the earthen building materials that Ehsan Baharlou and his team put seeds into before layering them to create walls. The purpose is to create "an active ecological system that might store emitted carbon in 3D-printed soil structures through the process

of photosynthesis."

Table 1 displays the effects of various substrates and irrigation on biodiversity and offers recommendations. Following a thorough examination, the support GF and living soil wall made using 3D printing, planter/pot modular LWS, panel modular LWS, and mesh were ultimately chosen from the perspectives of boosting biodiversity and not impacting building lighting. Planter and panel are the ones that have the biggest impact on how well-lit buildings are, but they can also improve the living conditions for invertebrates and vastly improve the variety and abundance of important insect species. Living soil walls created using 3D printing offer birds and bats a more comfortable place to rest when combined with nests. Other green walls, aside from planer/pipe modular LWS, offer improved wind protection and nest entrance concealment. More information in Figure 10.

Try to choose native species and evergreen plants when making your plant selection, and make sure to alter them for height and orientation. Try to increase the rooting area and employ the drip watering system in the design of the green wall.

4. Conclusion

Strategies for taking biodiversity into account in urban planning are diversifying as a result of the global reduction in biodiversity caused by rising urbanisation. By considering roofs, walls, other vertical greening elements like vertical green walls, green roofs, and indoor gardens, it is possible to design species-friendly streets and neighbourhoods. The nesting, eating, and resting areas of the target species must be situated within a specific spatial area, or the animals' "home range," in order to maintain a healthier, species-friendly ecology throughout the entire vegetation system. Second, the ecological pyramid consists of producers (plants), primary consumers (insects), and secondary consumers (birds and bats), and their demands for food, nesting, and breeding must be addressed as much as possible throughout the entire vegetative system. An attempt was made to investigate the spatial requirements of urban biological demands through literature and case studies in order to construct a modular vertical greening system after it was discovered from the case study that the existing design methods lacked flexibility, maintainability, and recyclability.

Based on studies into the ecosystem and biotope of the Delft campus and information on the birds and bats that depend on urban life in the Netherlands, the targets of the study were chosen to be the house sparrow, black redstart, common swift, oystercatcher, and common pipit. species. We looked at their preferences for nest dimensions, heights, temperatures, directions, materials, and times of use. Additionally, it is clear from the research and case studies that vertical greening can greatly boost biodiversity when compared to bare walls. In order to study and analyse the four various types of vertical green façade—direct green façade, indirect green façade, continuous living wall system, and modular living wall system—literature was reviewed because vertical green walls are typically connected with insects. The direct green façade, indirect green façade, continuous living wall system, and modular living wall system were the four different types of vertical greening that were examined and compared. It was discovered that the modular living wall system is more ecologically friendly to insects and can be modified to attract more birds. Insect survival is also influenced by the amount of greenery nearby and the height of the wall, with less mobile species better suited to lower walls and more mobile species better able to live in relation to connection and the amount of greenery nearby. Modular living wall systems come in a wide range of variations

based on structure, substrate, and irrigation technique. system of living walls. Following a thorough examination, the support GF and living soil wall made using 3D printing, planter/pot modular LWS, panel modular LWS, and mesh were ultimately chosen from the perspectives of boosting biodiversity and not impacting building lighting. Try to choose native species and evergreen plants when making your plant selection, and make sure to alter them for height and orientation. Try to increase the rooting area and employ the drip watering system in the design of the green wall.

How much provision do we require? This question will never have a "one size fits all" response. Every structure needs to be examined for potential roosting and nesting areas. As a general rule, each development should have about the same number of nesting or roosting areas built in as there are homes.

Throughout the essay, the advantages of including bird and bat roosts in the vegetative system in connection to urban biodiversity are emphasised. The next phase of the design will involve starting to think about how nesting areas and vertical greening spaces might be combined, as well as how the modular vertical greening system can be used to progressively build a community that is species-friendly.

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APPENDIX

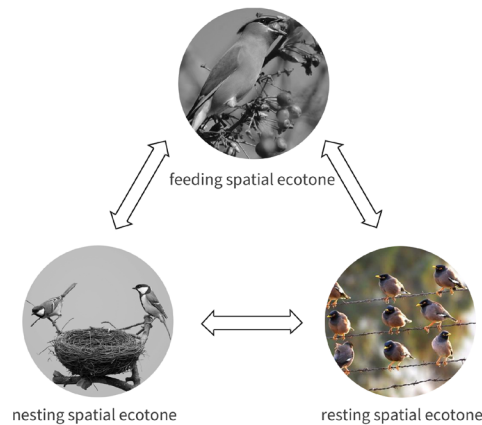
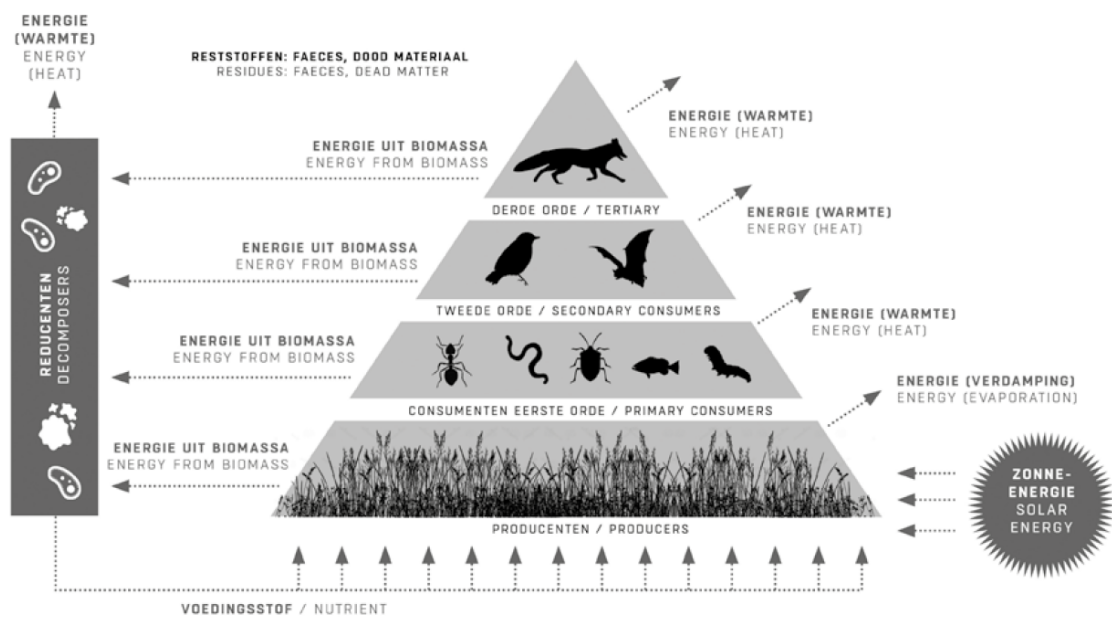


Figure1: Convergent demands of nesting,feeding and resting(Jing, 2018)



Voedselpiramide. Food pyramid.

Figure2: Food pyamid(Vink et al., 2017)

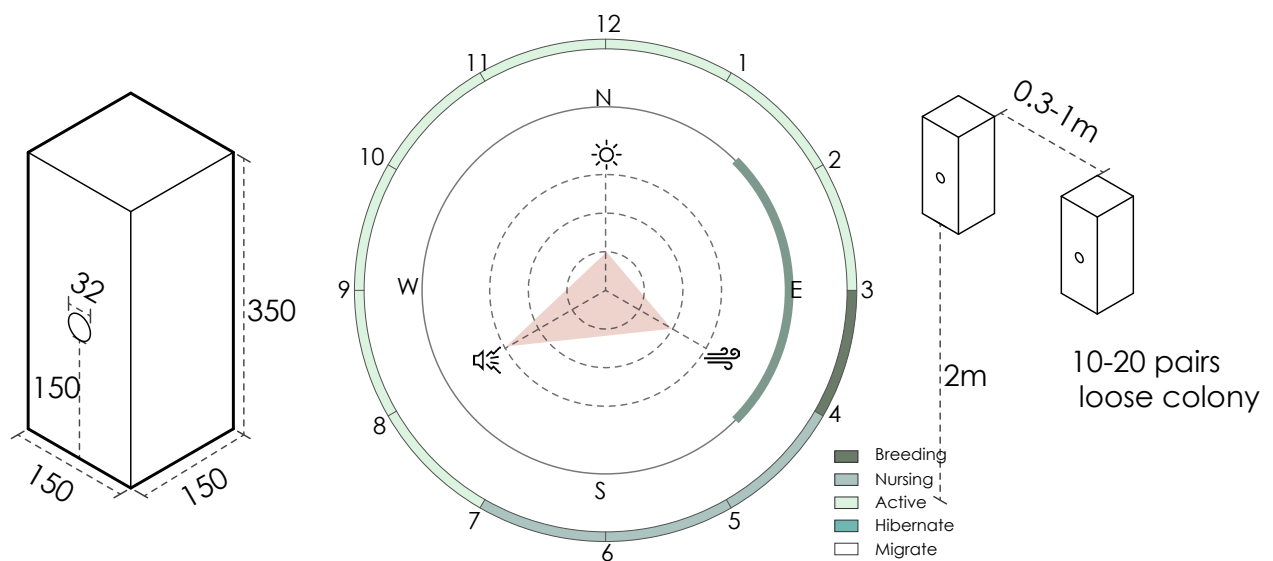


Figure3: House sparrow requirements

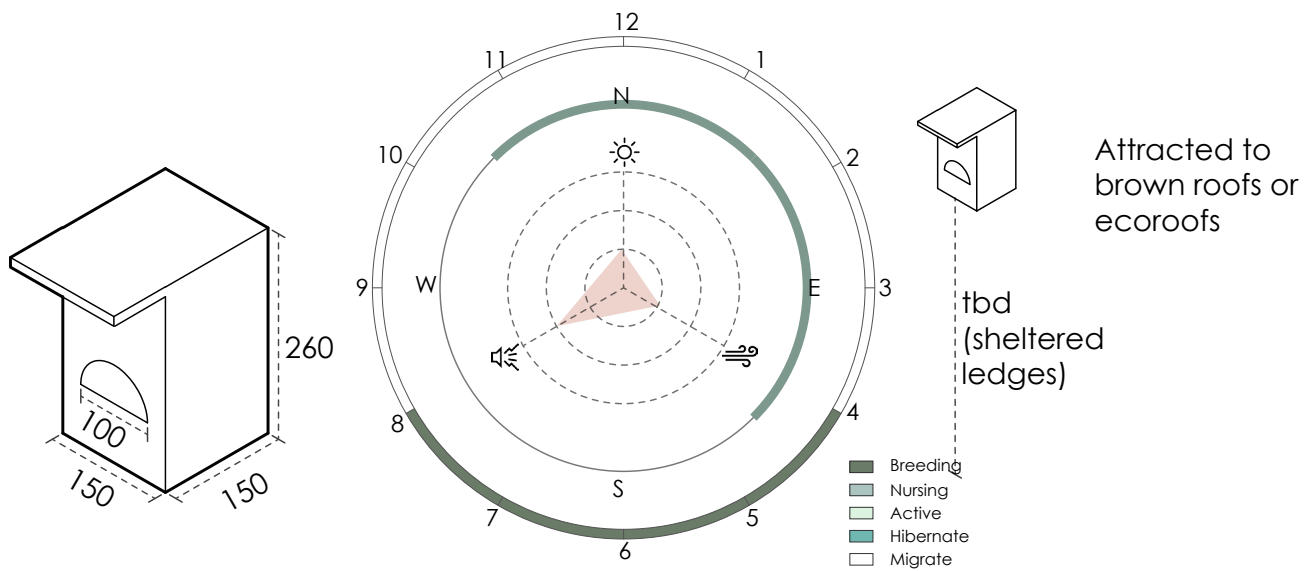


Figure4: Black redstarts requirements

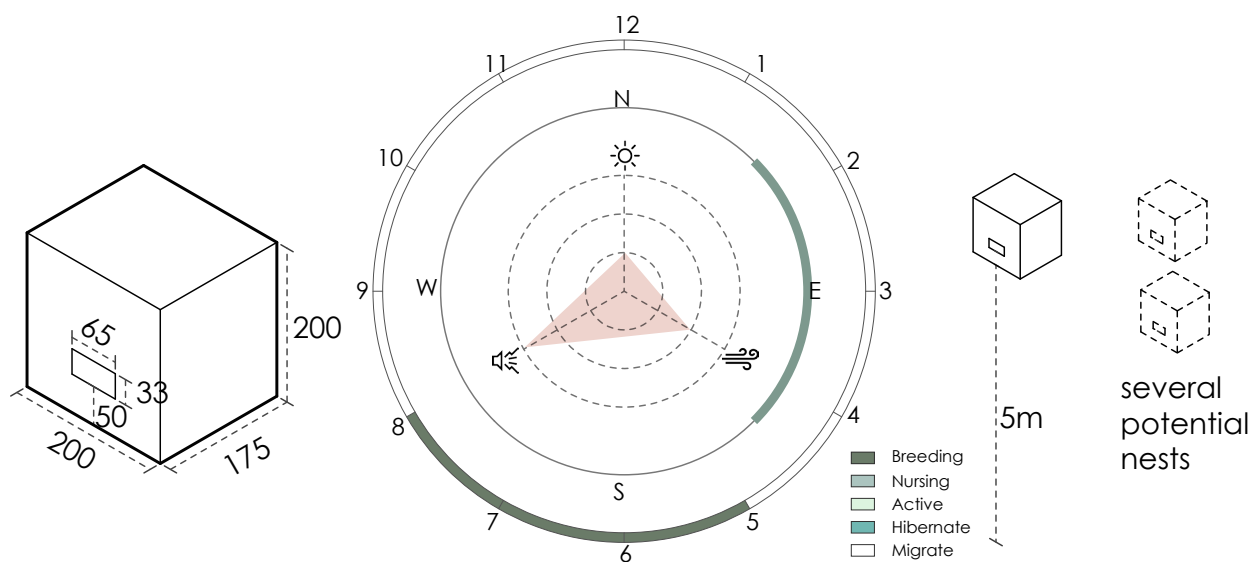


Figure5: Common swifts requirements

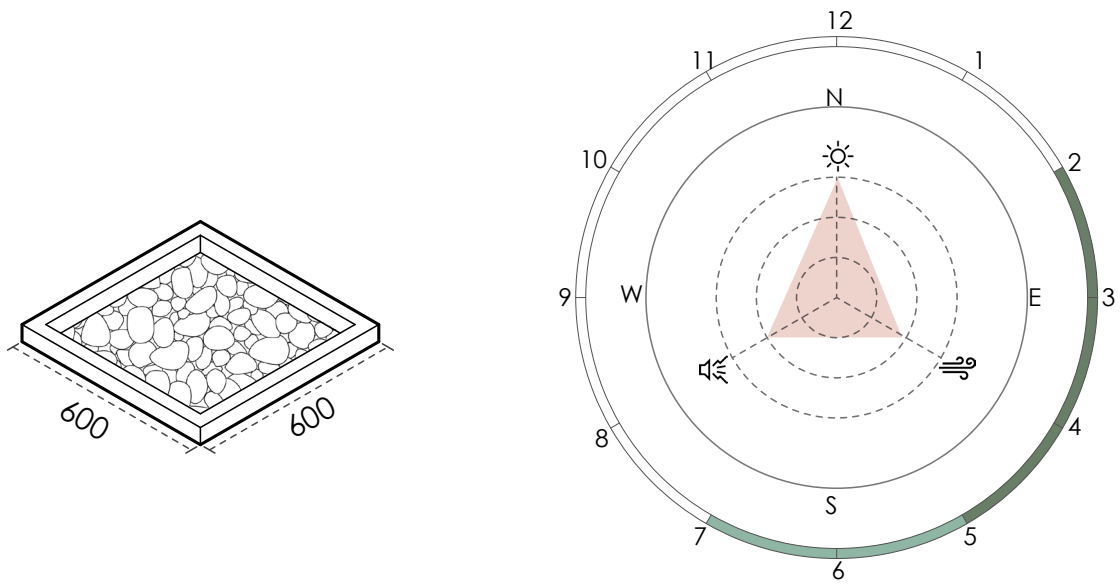


Figure6: Oystercatcher requirements

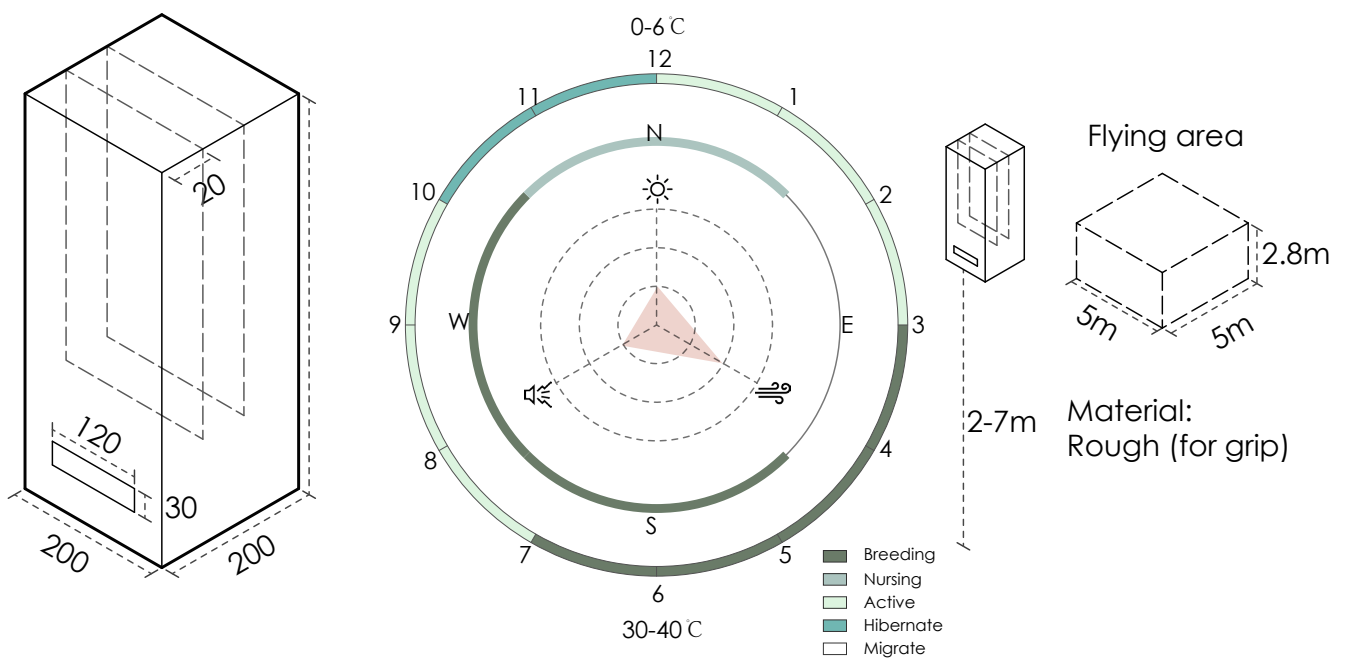


Figure7: Common pipistrelle requirements

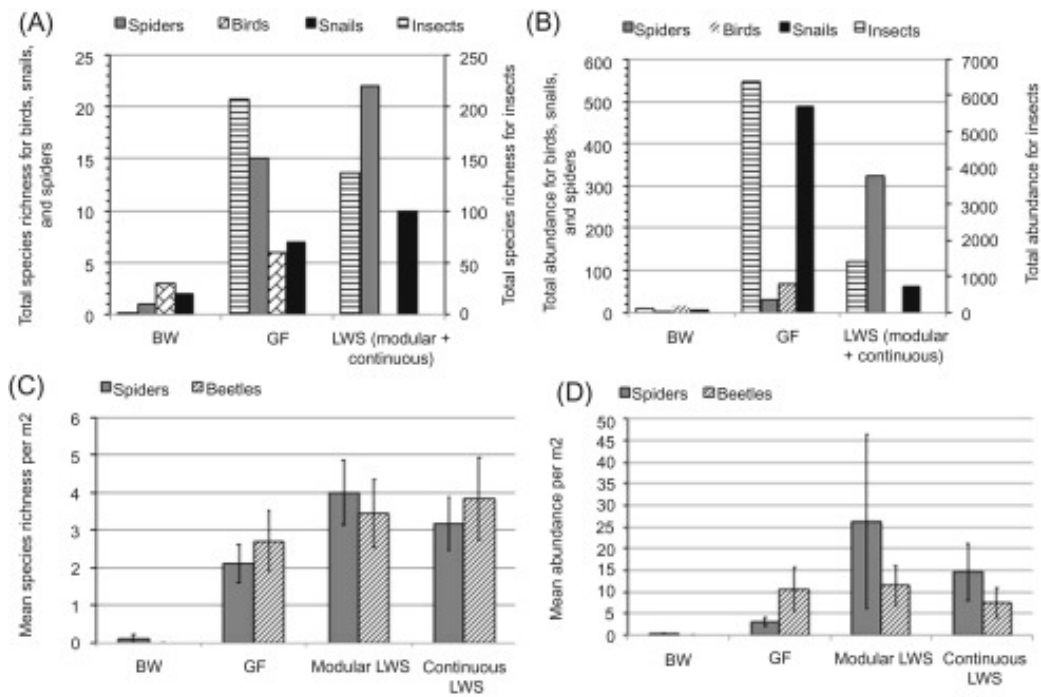


Figure8: Abundance and richness of species on wall(Mayrand et al., 2018)

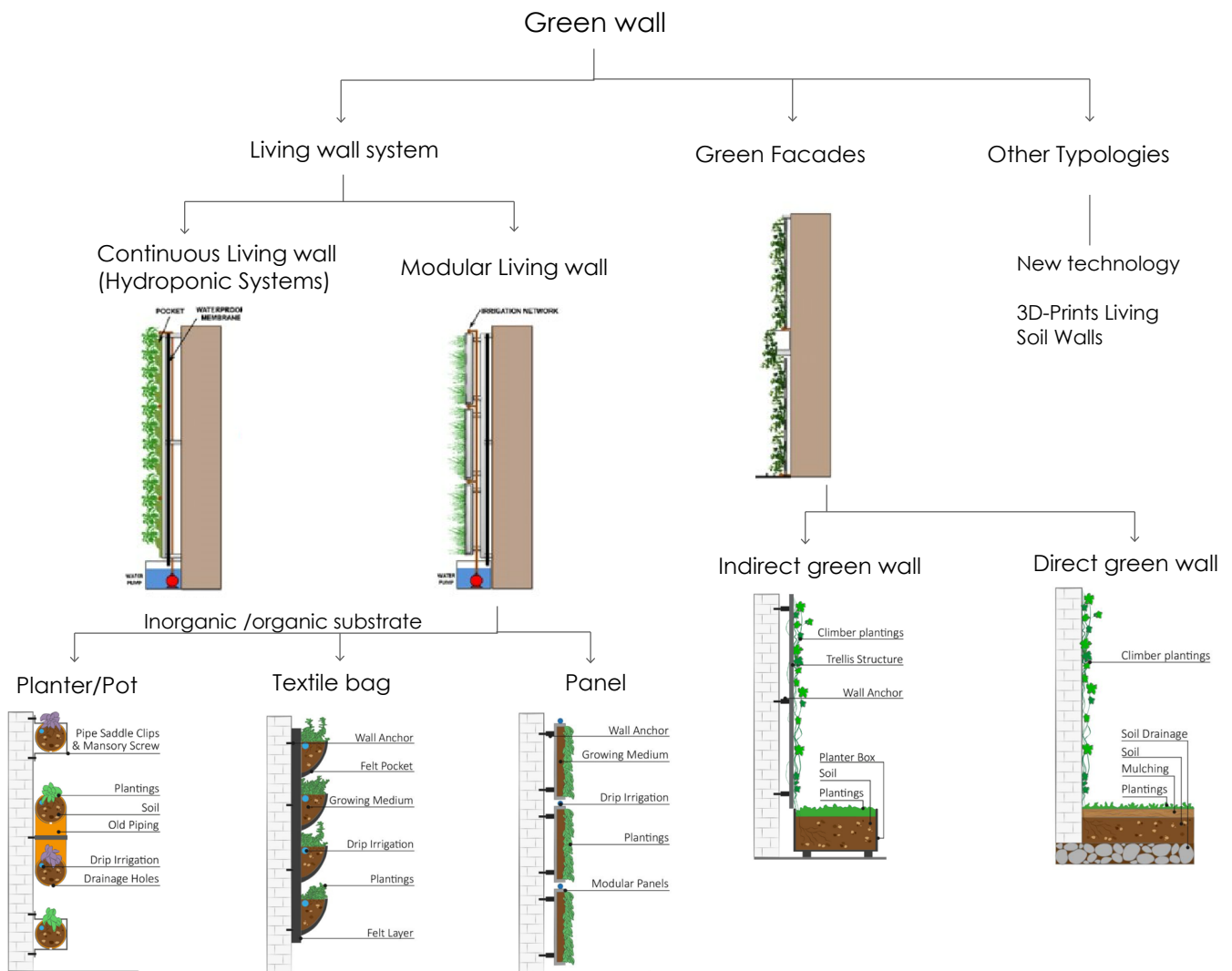
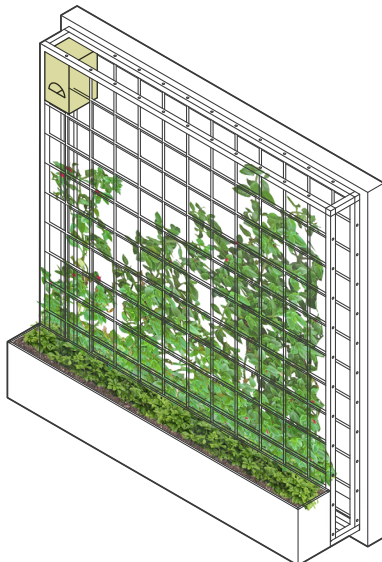


Figure9: Green wall classification

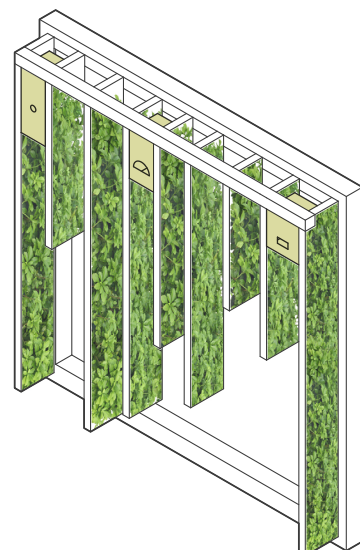
Feature	VGF	Disadvantages	Recommendations
Support	Modular LWS	Limited substrate volume for individual plants and limited chance for roots to extend and share substrates.	Enlarge rooting by proposing new containers
Growing media	Modular LWS	Frequent and difficult soil management operations.	Stimulate the microbiological activity in substrates instead of supplying fertilizers. Choose plants with lower nutrient requirements, eventually with symbiotic interaction capacity. Leave a part of the decayed plants materials to accumulate organic matter.
Green coverage	LWS	A large repertoire of exotic species.	Using native species and natural habitats as templates for assemblages.
	LWS	Disturbance of companion wildlife because of frequent maintenance.	Decrease the intensity of maintenance by tolerating few spontaneous species with no impact on the system safety, and the seasonal effect.
	LWS	High probability of poor performance and more need for replacement	Choose native plants adapted to constraint environment. Plant diverse assemblages of vegetation according to the wall height and the gradient of ecological conditions (e.g., exposure and wind). Seedlings rather than pregrown plants
Water	LWS	High consumption of irrigation water	Improve flows (e.g., water and nutrients) within the entire wall. Choose species with lower water requirements. Use rain water for irrigation.

Table 1: Recommendations to Design VGS to Function as a Habitat for Biodiversity(Mayrand et al., 2018)

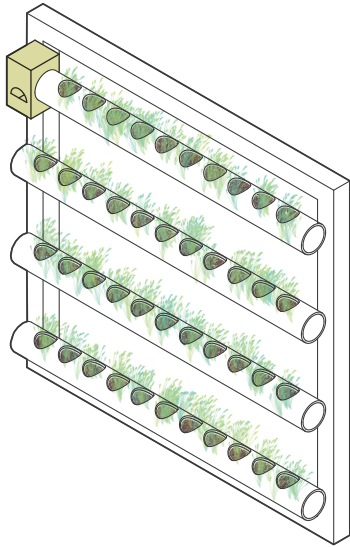
mesh support
living wall system



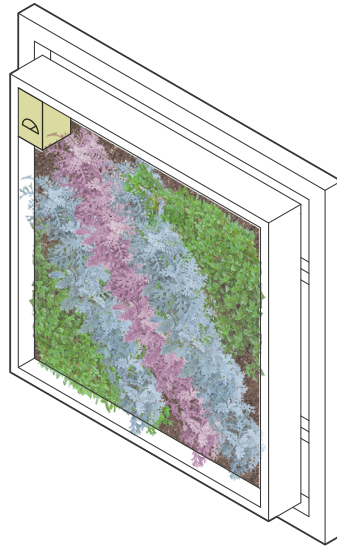
3D-prints living
soil wall



Pipe modular LWS



Panel modular LWS



Planter modular LWS

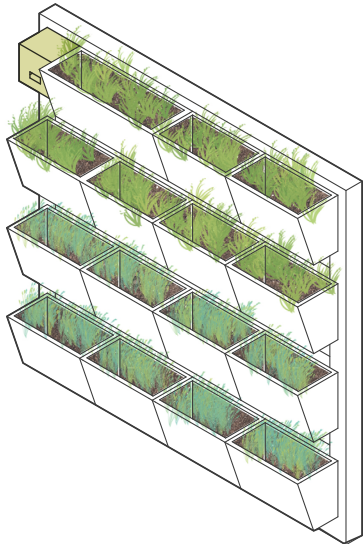


Figure10: Combintion of urban animal nests and modular vertical greening