MYCELIUM FOR THE CREATION OF ANIMAL HABITATS IN UTRECHT'S SCIENCE PARK

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ABSTRACT

Urban habitats on building's facades are needed to be included in the design as more and more species lose their natural habitat and turn to the built environment. Utrecht's Science Park is a place where many buildings' reliant species are found since it combines different biotopes for habitat and foraging. The rock biotope is being studied and the different needs for habitat of different building reliant animal species, to produce universal needs of these species in the faҫade design. Mycelium molding techniques are being studied for the experimentation of sustainable ways to produce mycelium habitats for these animals. Nature inclusive design considers the process as well as the ending product, that's why MDF and massif wood are being studied for the creation of the molds for common pipistrelle bat, swift and solidary bee nesting boxes.

KEYWORDS: *Nature inclusive design, Biodiversity, Urban habitat, Facade design, Mycelium, Conservation, Urban Ecosystem, prefabrication*

I. INTRODUCTION

1.1 Urbanism & biodiversity loss

Looking at the sustainable goals from 2015, we can understand that some of them are more fundamental than others. Life on land and water and climate change are those that architects must deal with first. The deprivation and loss of biodiversity is one of the most alarming environmental problems of today's, threatening precious ecosystem services, animal, and plant existence, as well as human welfare. As the built environment may threaten the existence of various animals, at the same time creates habitat and living conditions for some other species to thrive, such as swallows, bats, and falcons.

1.2 Building reliant species

Throughout the years of human development there are animals that have coevolved along with humans and have learned to coexist with us, and even sometimes depend on us for their survival. There are foraging opportunities for finding food and shelter within the built environment. These building reliant species do not necessarily cause harm. Yet, frequently other organisms found in the urban areas than that of human are considered negative. Such organisms can be cockroaches, pigeons, racoons, weedy plants, and bats. The adaptation of these organism co-existence in the urban environment, has occurred due to adjustments of their activity patterns. For instance, nocturnality, or the alteration of their settlement from a tree to an attic (Clucas & Marzluff,2011). Domestication should be viewed as a form of coevolution, in which both species benefit from the phenotypic qualities of the other creating coupled relationships (Clucas & Marzluff,2011). Animals can cause material damages on buildings and several times can nest or defecating in undesirable areas, but human can cause even worse damage on the animals themselves.

1.3 Role of faҫade in biodiversity and nature inclusive design

Faҫade is the most prominent part of every building, is the first indicator of whether a building is beautiful or not and it can come in different styles. Nowadays the buildings are constructed as high as possible creating a glass wall on the exterior that interrupts the natural movement of urban animals and thus the continuity of valuable ecological processes like that of pollination. Tall buildings and structures cause many window-strike victims in bird populations during their migration (Adams & Lindsey, 2011).

The establishment of meaningful connections between human and nature is unachievable just by looking at the urban environment in 2D. Green corridors are read in 3D and a green roof cannot enhance biodiversity in the city on its own. Most of the times the square meters of the façade of a building far exceeds the ones of the roofs, thus by introducing nature inclusivity on it, there can be better results. How can nature be given a fully-fledged place in the façade design for the transformation of the urban environment, which is currently out of balance, to a healthy, future-proof, and attractive place that humans, animals, plants, micro-organisms, and minerals would love to live and co-exist.

1.4 Problems of current nesting facilities

The current nesting facilities are mainly constructed out of woodcrete and clay when placed in the façade of the building. The second most common material is wood with nails and screws, usually when the boxes are in the extension of the façade. The nesting boxes that are on the market for built-in façade, are usually designed for brick façade. That makes it difficult in the maintenance as it is not removable, and incase the conditions are not good for the nesting to be activated it cannot be removed and placed somewhere else. In the end of their lifetime these elements will end up in the landfill contaminating nature. This practice is controversial as one shouldn't design for nature against nature. Finally, nature is unpredictable. Climate change has a great impact on biodiversity. Thus, permanent solutions and materials are not always the answer. Is it possible that mycelium-based solutions could potentially solve these issues? In this research paper I will investigate how biodegradable material like that of mycelium can be used for the creation of the nesting facilities to promote biodiversity, nature inclusivity and flexibility to the design.

Main research question:

How to design nature inclusive façade elements out of mycelium with organic/agricultural waste, to increase the biodiversity in Hugo R. Kruyt building in Utrecht Science Park?

Sub questions:

1. What are the urban habitats of local species, and its spatial and ecological needs?

2. What are some of the existing case-studies of nature-inclusive building elements?

3. How can mycelium with organic/agricultural waste, be used and shaped for the materialization of prefab nature inclusive façade elements?

I. METHODS

The research methods that are going to be utilized in my research paper are both quantitative and qualitative. The different sub-questions require different methods due to their distinct character. Literature review, scientific research, data collection, research by design, reports, and case studies. The findings will be used as guidelines, evidence, and inspiration for the redesign of Hugo R. Kruyt in Utrecht University. The research will be realized within the specific geographic location of Utrecht for the mapping of the local biodiversity, as it is essential for my understanding of the local situation and the local needs in terms of biodiversity.

I. RESULTS

3.1 Selecting target species in Utrecht Science Park

The Utrecht Science Park comprises natural as well as domesticated ecosystems. The site largely consists of an intensive urban area of high human activity, highrise buildings and commuting, interspersed with open areas, as that of parks and small scale agriculture character areas. Moreover, a large part of the sourounding area comprises semi-open to open areas of agricultural landscape, mostly grasslands and meadows with waterways such as ditches and canals. Forests and estate areas are situated on the edges of the Uithof. These different ecosystems result to different types of biotopes. The rock biotope is the one created by the buildings and resembles a baren mountain that provides cavities for animals to nest. Other biotopes are that of woodland, agriculture, grassland/meadow and garden. All of these biotopes connect to each other and share fauna and flora species. Animals move through the biotopes for habitat and foraging opportunities. Pollinators act as the vessel for the movement of seeds and pollen to different areas. In Figure 1 in the appendix the different biotopes in the area, in and arround the Utrecht's Schience Park, are depicted. All the biotopes together can create a balanced ecosystem for animals and plats. Many animals have their nests in one biotope and forage in others. Specifically in Figure 2 of the appendix, the birds, bats, bees and butterflyes that already exist in the area and potentially could habitate the façade of a building are depicted and their territories. As animals nest and migrate in different periods the map is not complete and extra information could be added or removed as time changes. The biotopes (Figure 3) and the building reliant animals of Kruytgebouw (Figure 4) respectivelly.

The biotope that will be examined in this research paper is the rock biotope due to its resemblance to the built environment and specifically I will be focusing on species that habitate or potantionally can habitate the façade of buildings. The fauna species that usually habitate facades are birds, bats, insects like butterflies, and wild bees. In the area of De Uithof some birds of pray have registered territory. A pair of Pelegrine falcon birds nests on the bird box on the top of the Van Unnik building and a Kestrel (red list) on the bird box on De Bisshoppen building as seen in Figure 2 of the appendix. On the develolped land biotope house sparrows (red list) have been observed having multiple territories. The Migratory birds such as Swifts have been seen in the the study area, buildings act as a rocky landscape full of cavieties where swifts can nest. Other bird species like Great tit, Blue tit, Finch, Starling, wood pigeon, wren, Black redstart and Robin have habitats in the urban area biotope, yet they will not be examined in this research paper. Bat species are common in the urban area, as like swifts they don't create their own habitat but nest in cavities in the trees and some species on buildings.

In the site common pipistrelli bat habitates at least four university buildings, that of H.R. Kruytgebouw, the Sjoerd Groenmangebouw, Bestuursgebouw and Martinus J. Langeveldgebouw. Utrecht has more than 100 species of bees, the Red mason bee will be examined because as the above species creates its nests in holes in cliffs and in the mortar of old buildings. In Table 1 of the appendix the choosen species are studied according to their breeding season, natural breeding habitat, urban habitat in the netherlands, whether they built their nest, foreging areas, food, predation and interaction with humans. The table shows that these animals even though they share the same biotope they have many differences. Bees and butterflies may spend their whole lifetime in one place while other like Swifts may occur in the Netherlands only for three months. In Figure 5 the full life in a year of the selected animals is being depicted with differences and similarities. The last years with the climate change many animals, as that of the butterfly Red admiral, that prevously would migrate due to the harch winter, now choose to stay in the Netherlands since the winters are milder. Climate change affects the hibernation period of the local bats. More and more bats go through lighter hibernation periods.

3.2 Case studies of habitats in the built environment

3.2.1 Peregrine falcon

Peregrine falcon does not construct its own nest and naturally nests in cliff edges. It can nest as low as 10 meters height and have been witnessed to nest on more than 150 meters height in natural environment. In the city they usually nest in nest boxes that are placed on tall buildings, with optimum height from 61 meters to 150 meters. In the first case study depicted in Table 2, the dimensions of the vivara pro nest box are 64(b) x 80(h) x 62(d) cm and a 7.6 cm diameter entrance hole, and its materials are concrete plex and metal. Peregrine falcon naturally nests on cliff edges or hollow trees, where it forms a scrape or swallow depression on the existing debris, gravel or nesting material from previous species nests, to lay down its eggs. 10 to 15 cm of gravel as substrate is the optimum as less can cause damages to the eggs and more can cause drainage problems, holes on the bottom of the nesting box are recommended. Nest boxes with wide opening are many times putting in danger the Youngs from predators. The natural nesting habitat of these birds of prey are usually deeper than a nest box and narrow in some parts of its length, thus making it harder for predators to attack the young's. The nesting box maintenance takes place in the winter with all remains being removed. Yet, in nature the droppings in combination to the prey remains create the perfect conditions for low vegetation to thrive.

3.2.2 Common pipistrelle

Common pipistrelle as all bat species has different habitats for summer, winter, mating and nursing. The dimensions of the roost must provide an entrance of 15–20mm high (h) by 20–50mm wide (w) and should maintain a crevice of this approximate size so that the bats can roost. The height of the entry can be from 3 to 10 meters above existing trees and should be 6 to 9 meters away from trees and tree lines so that it can be found but at the same time leave enough space for the bats to fly. To allow flight in the case of a larger roost, it is important to keep 2.8 m height and at least 5 by 5 m length and width. The materials of the roost must be rough for the bats to grip, non-toxic or corrosive and with no risk of the bats to be entangled. In addition, the materials should minimize fluctuations in the temperature but allow maximum thermal gain for the summer and maternity roosts. Females can create small summer colonies of 25 to 50 individuals in a nursing roost. Warm and dry places are ideal for maternity roosts, with the temperature between 30 to 40 degrees Celsius. The orientation is usually to the south or to the west. The area of a nursery roost should be at least 1 m^2. Hibernation, mating and male summer roost needs to be cool with a constant temperature, usually they are underground sites like caves since the bats are not disturbed with light, noise and predators. The temperature in this type of roost is usually 0 ^{o} to 6 ^{o} Celsius with a north orientation.

The first case study is a nest box made from woodcrete with the dimensions mentioned on Table 2 Row 2. The specific solution is placed in a brick façade. The fact that it goes deeper than the bricks create a problem in the placement of the insulation, resulting to wider walls and thus more material use. It is a fixed solution so incase bats don’t use is as a roost, it will have to remain on the wall without being used. The second case study and third in row of Table 2, the bat cellar by MOONWALKLOCAL architects in Bordeaux is promoting biodiversity through the installation of 11 bat nesting boxes in the cladding of a wine cellar. The nesting boxes have a south orientation with the entrance placed 3 meters above ground. No information was found on whether bats live in the cladding.

3.2.3 House sparrow

The 4th case study in Table 2 is the Integrated bird box that is being placed in existing facades made from brick. The box is made from bricks and stainless still, with removable front lid for maintenance. Interesting is the fact that it can be placed in existing walls by removing some of the bricks of the facade it will be placed. The materials used in this case study may affect the maintenance of desirable temperature and may require specific conditions so that it does not overheat or freeze during summer and winter. The fifth case study in Table 2 is The Animal wall in Cardiff Bay, which is 50 meters long, has a southwest orientation and is along a water way, is made from woodcrete and has 1000 nest boxes for bats and four types of birds. Sparrow is one of them. Currently is being occupied by Sparrows along with other birds and bats. House sparrows are colony brothers so the fact that many boxes are provided together, makes the project desirable for nesting. Moreover, small busses are placed under the boxes making it a safe place for Sparrows to hide against predators. Interesting is the fact that Sparrows build their nest with sticks, wool, feathers and other materials and in this solution the maintenance is being done by placing worms in the nest boxes since they are fixed and can’t be opened.

3.2.4 Common Swift

In the case study of Table 2 row 6 the entrance of the nest box is happening through holes in tiles, this type of nesting for swifts is usually used in roofs. The tiles have an extruded blob that allows the swift to fly in but at the same time as the tiles are exposed to the natural phenomena, protect the nest box as well as the construction. The way these tiles are design also offer protection against predators. This example shows us that even curved surfaces can become habitats for animals. Swifts only come to the Netherlands for some months and their nest are usually occupied by other small birds, so it is important to cover the entrance till the time the swifts migrate again. The orientation of the nests is southeast, and maintenance is not required as swifts, as many other birds, look after themselves in order not to attract predators close to the nests.

3.2.5 Red mason bee

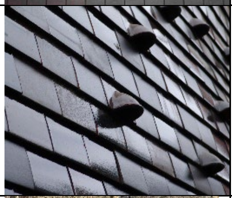
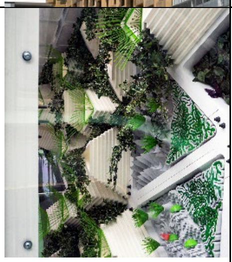
In the case study the bee brick's depth is 6.5 that means it can only host some species of bees. Red mason bee requires deeper length cavities where she will store her babies with pollen. In order to give the opportunity to Red mason bees and other solitary bee species to nest the nesting tunnels must be minimum 15 cm deep. Red mason bees require tunnel with 0.8 to 1 cm cavity hole. The bricks need periodic maintenance. The 8th case study of Table 2 shows a structure that is attached on the west facade of a building in France and includes 61 shelters for bees, butterflies and beetles, as well as space for plants between these habitats. It is lifted three meters from the ground and has six meters height. The insect boxes are rotated, thus have a southeast orientation. The structure today has little vegetation. The habitats for bees comprise reed sticks and drilled logs. Both require occasional maintenance and are not the best habitat for bees since wood is home for many other insects that are predators for bees. The structure provides enough space for the shelters to have enough length to host many species of bees, as well as Red mason bee.

3.2.6 Red admiral

In Figure 3 is depicted the life of a red admiral, that is like most butterfly species, in a year. Butterflies don't live for very long, usually 10 months, but many species migrate during the winter in warmer climates. The climate change has caused many species as butterflies to over winter in countries where the winters have become milder. The last case study in Table 2 deals with habitat for Monarch butterfly species. The double skin façade creates a vertical meadow for the butterflies to colonize. Between the two layers of the façade the terrarium (habitat) takes place. The idea of this solution is to create not only the butterfly boxes, but a holistic approach for the creation of specific conditions all year around for butterflies. ETFE cushions provide the necessary humidity while algae bags purify the air. Fly-ash impregnated 3D printed concrete forms the terrarium for butterflies to hide and rest. The building is not yet completed so there is no information on how the specific solution performs.

Table 2. Façade Nest Box Case studies.

Num	Image	Project name	Dimensions (wxhxd)(cm)	Weight	Materials	Maintenance	Orientation	Human-nature interaction
1		Peregrine Falcon Nest Box Vivara pro	W 80 x H 62 x D64 cm	Heavy	Concrete Plywood/ Metal/pebbles	Winter months – removal of prey remains	Recommended: North, east, southwest	Visual on the exterior. The minimum disturbance from humans will lead to the birds leaving the nest.
2		IB VL 06 Building block Bats Vivara pro	Outer 21x50x15 Inner 16x42.5x2.2	Heavy	Woodstone/Eco-board	Sloped bottom does not require maintenance.	Recommended: All four cardinals	Visual on the exterior.
3		The bat cellar by MOONWALKLOCAL	Outer 50x65x7.5 Inner 50x32x2	Light	Wood-clad sheds	Sloped bottom does not require maintenance.	South	Visual on the exterior, guano droppings in front of the main door.

4		Integrated bird box by Bird Brick Houses	3.4 cm diameter	Heavy	Brick, stainless steel	Yes, every year after the youngs have fled.	East	Visual on the exterior.
5		Animal Wall by Gitta Gschwendtner	50 meters by approximately 6 meters. 4 different sizes for birds and bats.	Heavy	Woodcrete	The boxes cannot be removed but maintenance is done with placement of worms.	Southwest	Humans can walk along the wall and may experience birds fly away and to their nests.
6		World Nature Fund by RAU architects	Tile dim: 27 x 17 x 1.2	Light	Glazed clay roof tiles	Not required	Southeast	Above entrance, visual on the exterior
7		Bee brick	21.5 x 10.5 x 6.5 0.6 cm cavity holes	Heavy	Concrete with wood fiber	Periodic maintenance must be made by hand.	Recommended: Southwest, southeast, west	Visual on the exterior
8		La Bourdonnerie insect hotel façade by Atelier Calc	Unknown	Light	Local wood, clay panels	Periodic maintenance	West	Visual on the exterior. Accessible from the balconies.
9		Monarch Sanctuary, Terreform ONE	Unknown	Heavy	Carbon concrete, glass, ETFE cushions, algae bags, fly-ash impregnated 3D printed concrete	Not required	Southwest	Visual on the exterior. Accessible from the interior.

3.2.7 Rules for building the chosen animal's habitats

Combining the information from Table 1 and 2 with the existing research of the First guide to nature inclusive design and Natuurinclusief bouwen en ontwerpen in twintig ideeën, in combination to information of global solutions on habitats the Table 3 in the Appendix is created to include all the necessary known rules for the design of Nature inclusive façade elements and are also depicted in Figures 6, 7, 8, 9, and 10 of the appendix.

3.3 Mycelium as building material

All the above solutions for habitat in the built environment are mainly done by woodcrete, concrete and wood. Designing for animals requires experimentation for each different area and building, which is better to do with biodegradable materials (Figure 11). Climate change is another reason why habitats should be made by naturally decomposable materials, as the conditions of an area can change. Mycelium is a biodegradable material that can be combined with natural fibers as well as human waste to produce deferent products, like clothes, shoes, boards, insulation, bricks, tiles, packaging and furniture. The most common techniques for production are by using molds and 3D printing. For the purpose of this research, one basic solution of its kind is going to be tested as a prototype for the molding possibilities of mycelium.

3.3.1 Molding techniques

The most typical molding materials are 3D printed molds out of bendable plastic materials and aluminum or any other non-porous material. The first type of mold gives the opportunity of seeing the mycelium growing while in the mold and provide stable conditions of moisture. The production of the molds can be also with CNC milling for the creation of the negative of the mold and then the casting of the plastic material to take the final form (Figure 12 in the appendix) by thermoform. In this research I am going to investigate whether it's possible to recreate the chosen habitat boxes out of cupboard, MDF and wooden molds with plastic film so that to minimize the CO2 footprint in the production processes. Basically, take one less step in the construction process of the molds by creating the negative of the desired shape and then casting the mycelium.

3.3.2 Research by design-constrains of the design

As the prototypes are created in a non-laboratory environment, there are some constraints that affect the design of the molds and the production process. The area of the Utrecht Science Park can contribute with agricultural and food waste from the campus to produce substrate for the mycelium. Yet, for financial and time limitation reasons already inoculated bags of mycelium are going to be used. The substrate of the mycelium used is saw dust produced by Mycelium Products Europe that comes in an inoculated bag with the substrate already sterilized. The process of the production of the mycelium habitat boxes is depicted in Figure 10 in the Appendix. The sizes of the molds are designed so that can fit inside a small house oven. Mycelium companies use ovens in the size of rooms so that larger components can be dried. Creating smaller parts of a mycelium product and later combining them is possible adding an extra step in the production process while the mycelium is still alive. Another constrain is the temperature factor, as the process is taking place in my apartment, the temperature cannot be monitored with a fluctuation of 17° to 26 ° degrees Celsius, with the optimum temperature being between 20 °-25 ° degrees Celsius. Finally, humidity levels were not controlled so that may have affected the result.

3.3.3 Research by design-Molds and production process

A common pipistrelle bat (Table 2, solution 2), a swift (Figure 13 in appendix) and a solidary bee box (Table 2, solution 7) are re-created that could be used in a typical brick façade. The prototypes of mycelium differ in dimensions due to the constrains of the material. Mycelium composites must be at least 2cm thick and not more than 12cm deep as the temperature inside the mycelium can rise so high that the growth stops. The composites that will be created are those depicted in Figure 14 in the appendix. Along these, molds made from cupboard and plastic kitchen foil were used for the creation of simpler shapes as that of bricks and part of the swift box.

The working environment was dark and sterile (kitchen clean). I had to wear a mask and disinfect my hands regularly for the prevention of the mycelium to be contaminated. The whole process from shaking the mycelium till putting it in the molds lasted approximately 6 hours. The final molds are being created with 9mm and 6mm MDF and massif wood (Figure 15 & 16 in the appendix). The process of growing the mycelium can be seen in Figure 17 in the appendix. For easier de-molding the molds are created in two parts, the bottom and the sides are separated letting the mycelium product easily removed. In the end the molds are covered with plastic tape. Then the mycelium is being shaken till it is homogenous and later its being placed in the sterilized, with 70% alcohol, molds. Then it is covered with a plastic film that is being punctuated for the mycelium to breath and is let to grow for 9 days. After it is grown it is going to be removed from the molds and dried for two days with a fan. In the end it will be baked in 90° Celsius till it is 35% percent of its weight. The ending product can be sprayed with wood resin in order to be placed in the exterior giving the product a lifetime of 20 years.

3.3.3 Research by design-Results

The harvested component from the cupboard molds with plastic foil were fully grown, but since cupboard is a bendable material, the result was random (Figure 18 & 19 in the appendix). The harvested composite was not fully grown, maybe since the temperature of the apartment is affected by many factors and during this time it could have reached lower or higher temperatures. The use of plastic tape also may have affected the humidity levels, as were the two pieces of the mold met there was left an open crack, that in the case of using plastic kitchen foil the harvested composite was well shaped. The molds that were made from 9mm Mdf and massif wood were rigid, thus making the unmolding difficult and while taking them apart resulted in the breakage of the harvested composite (Figure 20 in the appendix). Yet the molds made of 6mm Mdf provided a soft bending while unmolding, that left the mycelium composite in better condition (Figure 21 & 22 in the appendix). All the composites showed shrinkage after dried.

VII. CONCLUSION

Animals as humans require a variety of biotopes for their survival. Facades that combine different biotopes and habitat choices may have better results in them being used and promote biodiversity. When creating habitats for animals we must consider that animals don't always come in pairs, thus an abundance of nesting sites must exist. When it comes to temperature, it is good to provide bats of different choices, as 1.5^{o} Celsius is enough for bats to leave the nest and many times mothers move their young among different roosts in the nursing period. Thus, placing different size and color nest boxes can give bats different choices during colder or hotter days, especially now with climate change, weather conditions are different than what we would normally expect. The created Table 3 can be used globally for nature inclusive design as the animals that are being studied exist in all continents and some rules apply to species of the same family. There are still many things to learn on the animals' living requirements and have in mind that one solution is not future proof as climate change affects the living conditions. Thus, next boxes designed with demountable and eco-friendly materials can provide flexibility in testing the living conditions without creating waste and providing a futureproof solution.

Bee bricks require maintenance, which is difficult to be done on the façade, thus either the bricks should be removable or removable plastic/wooden tubes could be placed in the holes. Overall, a nature inclusive building requires periodic maintenance all year round, since animals have different nesting periods. A system for making this process easier should be applied in the cases of bigger scale projects like the façade of Hugo R. Kruyt building.

Although further study is needed, mycelium composites are hard enough to provide grasp without them getting crumbled when used by small birds, insects, and bats, but would significantly lower their lifespan. Large birds would require heat pressed mycelium for the design of their habitat. I believe that with professional equipment and experienced makers it can be that the composites would have been fully grown under specific growing conditions. Also, the different habitats could be created with less and larger molds. Since the shape is a closed box, larger than 12cm deep, it would require the extra step in the process where two pieces of mycelium are being connected in one composite. Also, mycelium can be used in combination with heat pressed mycelium as the glue to create even stronger habitats minimizing the use of nails and screws in the construction.

Regarding the molds, thinner MDF boards could be used that provide better flexibility and the design of the mold could be designed in such a way that it can be taken apart, letting the harvested composite intact. The interior parts of the mold should be design with a flexible material as silicon or in a way that they can be removed first and then the rest of mold to be taken apart. Further research on the molds is needed to have a clear idea of whether it is possible to create these types of forms only by using MDF. The created molds can be used as the negative form that can be used for creating thermoform plastic molds. In that case under the optimum conditions the mycelium components could be fully grown. Finally, the molds should be bigger than the original dimensions of the composite due to the shrinkage of the material after it is dried.

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APPENDIX

Glossary

Indicator species educate on the generic condition of a habitat (Ahern et al, 2007).

Target species are chosen for their worth in preservation (Ahern et al, 2007).

Ecological indicator species are extremely sensitive to changes regarding their ecosystem's environment.

Keystone species indicate the conditions of a whole ecosystem, and they are closely linked to landscape procedures and disruptions (Ahern et al, 2007).

Umbrella species live in large biotopes and affect numerous species living in the same habitat (Ahern et al, 2007).

Flagship species act as popular symbols and ambassadors for conservation efforts (Ahern et al, 2007).

Vulnerable species require peculiar conditions of habitat and are either atypical or under extinction (Ahern et al, 2007).

Economically valuable species are either raised or hunted for consumption or have financial worth.

Ecological guilds delineate a class of species, which exploit a discrete resource in an analogous manner (Ahern et al, 2007).

Table 1. Target species of the developed/rock biotope.

Type	Name	Breeding season	Natural breeding habitat	Urban habitat in the Utrecht/Netherlands	Built their nest	Foraging areas	Food	Predation	Interaction with Human
Bird of prey	Peregrine falcon *(Falco peregrinus)*	February - April	Mountain walls, grassy or earthen cliff-ledge, hollow tree bark, earth scrape	Nest boxes in office buildings & towers, high voltage pylons in open farmlands	No	Open landscapes (farmland) with a variety of birds	**Avivorous** Large size birds: geese Medium size birds: waders, ducks, pigeons, starlings Small size birds: swallows bats	Great Horned owls, and other Peregrines	Peregrines are used at airports to scare away other birds to avoid plane accidents, only aggressive if human get close to their nest during breeding season
Bat	Common pipistrelle *(Pipistrellus hesperus)*	May - July	Trees, caves	Maternity colonies, winter roosts, summer roosts, mating roosts: Cavity walls, in the roof, behind paneling and roof moldings, bat boxes and tree cavities.	No	Canals, waterways, ponds, forest streetlamps, rows of trees, and hedgerows	**Insectivorous** Flies, midges, mosquitoes, gnats, beetles, lay wings, mayflies, moths, and caddisflies	Domestic cats and birds of prey	Pollinator, natural pest control for humans, low risk of transmitting bacteria and viruses, passive, gentle creatures.
City bird - red list	House sparrow *(Passer domesticus)*	March – August (can be all seasons)	Forests, meadows, grasslands, deserts, desert edges, woodlands, urban areas	Any manmade habitat. Under roof tiles, in building cavities, sparrow boxes	Yes, by adding twigs, straw, feathers, and dog hair	On air	Flexitarian Seeds, grains, insects, flower buds, bread, berries, peanut, and fat balls	Feral cats, hawks, falcons, owls, foxes, squirrels	Friendly behavior towards human, they eat human cultivated food and have coevolved with humans
City /Migratory bird: July to April	Common Swift *(Apus Apus)*	May and June	Mountains, cliffs, and trees	In buildings, under the gutter, behind a drainpipe, dormer, roof tile, or in a hole in the wall and in nest stones.	No	Diverse habitats in towns and cities	Insectivorous Flying insects like mosquitoes, flies, butterflies, and moths.	Falcons, hobbies, rats, weasels, kestrels, and few species of owls	Wild birds, but they often nest on buildings, not aggressive
Common bee	Red mason bee	March to July	hollow plant stems, in holes in cliffs, beetles' borings in dead wood	In the crumbling mortar of old buildings, soft materials, bee hotels	Yes, the female lines each 'cell' with mud and pollen and lays a single egg in each until the cavity is full	Meadows, forests	Herbivores Nectar and pollen	Robins, crows, starlings, and woodpeckers	Gentle, solitary pollinator. The male has no sting, the female rarely stings
Butterfly	Red admiral *(Vanessa atalanta)*	April to July	Wetlands in forest ecosystems, yards, parks, marshes, seeps, and fields	Tree barks, under leaves, butterfly nest boxes are used for hibernation or sheltering during inclement weather and from predators	No	Yards, parks, marshes, forests, seeps, and fields	Herbivores Sap of rotting fruits, nectar	Wasps, birds, spiders, lizards, small mammals, and insects	People-friendly (may land on humans)

Table 3. Requirements of habitat for case study animals.

Type of animal and nest	Minimum dimensions	Minimum-optimum-maximum height placement	Materials	Maintenance	Orientation	Temperature	Color	Flying and landing area	Points of attention	Proximity to areas
Common pipistrelle summer roost	60 (h) x 20 (w) x 2 (d) cm (2cm opening is the optimum since wasps can't create their habitat)	Min 3m Opt 3.6 – 6 m Max 10 m* * 10 meters above high vegetation	Rough wood, fiberglass insect screen, aged wood, timber, woodcrete filling the inside of a house with slightly damp earth or a rich humus to attract bats.	Woodcrete: no maintenance required. Wood, timber, aged wood: Periodic maintenance. If tilted periodic maintenance.	South, east, west	30^{o} C < Insulation minimizes temperature fluctuations	Medium	6 – 9 m distance from trees for flight space. 3 – 4 m minimum above any limitation (trees, balconies) 10 cm landing area	Proximity to trees so that they can be found by the bats. Tilting at about a 10-degree angle reduces the frequency with which babies fall out. May need periodic cleaning.	Orchards, other agriculture, and woodlands, less than ¼ mile away from water
Common pipistrelle maternity roost	60 (h) x 60 (w) x 6 (d) cm					30^{o} - 40^{o} C 6 hours sun exposure Insulation minimizes temperature fluctuations	dark			
Common pipistrelle hibernation roost	60 (h) x 20 (w) x 2 (d) cm				North, east	0^{0} – 6^{o} C Insulation minimizes temperature fluctuations	light			
Common pipistrelle mating roost	60 (h) x 20 (w) x2 (d) cm				South, east, west	30^{o} C < Insulation minimizes temperature fluctuations	Medium			
Peregrine falcon	64 (w) x 80 (d) x 62 (h) cm Scrap: 17-22 cm diameter entrance hole, 3-5 cm deep	Min 10 m Opt 61 m -150 m	Pea gravel, wood chips, sticks, small amounts of vegetation,	Periodic maintenance	North or East, not with opening direction southwest	Shade is required for over 32^{o} C	Unknown	Unknown	Large overhanging can protect from elements and predators	Woodland ,meadows
House sparrow	15 (w) x 8 (d) x 20 (h) cm 3.2 cm hole	2 – 15 m	Woodcrete, wood, stone, clay	Periodic maintenance from September - January	East, North, South (under shadow) or west (under shadow).	33^{o} – 37^{o} C Temperature is monitored by the parents' building materials of the nest. Warm wet climates: sticks, grass. Cold climates: Fur, wool	Light color if placed in the South.	Not required.	Colony brother requires many boxes placed together with 20 – 30 cm distance. 10 – 20 pairs. Birds nesting on the ground are subjected to extremes of temperature	Diverse habitats in towns and cities.
Common Swift *(Apus Apus)*	43 x 17.5 x 17.5 cm, entrance near the bottom of the nesting box 3 x 6,5 cm. Swifts prefer entrances on the bottom of the nest.	4 – 40 m Opt: above 5 m	Woodcrete, wood, stone, clay	No maintenance required; small birds clean after themselves.	North or east or in the shade of the gutter/ overhang of 30 cm	Unknown	Light color if placed in the South.	1.5 meters minimum height distance from bottom obstacles. Open way without obstacles like trees.	Colony brother requires many boxes placed together with 20 – 30 cm distance. 10 – 20 pairs. Darker interior attracts swifts. Nest moulds can be used for the prevention of the eggs rolling out.	Diverse habitats in towns and cities.
Red mason bee	15 (depth) cm Various diameter cavities. (0.7 – 1 cm)	Variable. Better 1m off the ground.	Wood, woodcrete, clay, cork	Periodic maintenance during winter.	Southwest , east, north	Unknown	Not required.	Not required.	Mud stocks must be near the nest.	Plants high on nectar.
Red admiral *(Vanessa atalanta)*	15 (h) x 13 (w) x 23 (d) cm 1.27 x 7.62 – 8.89 cm entrance.	3 m min	Wood, woodcrete, clay, mycelium	No maintenance required.	Southwest , north, east	Unknown	Not required.	Not required.	Butterfly plants must be near nest boxes as butterflies give birth on plants and not on cavities.	Fruity trees and plants high on nectar. Mud puddle.

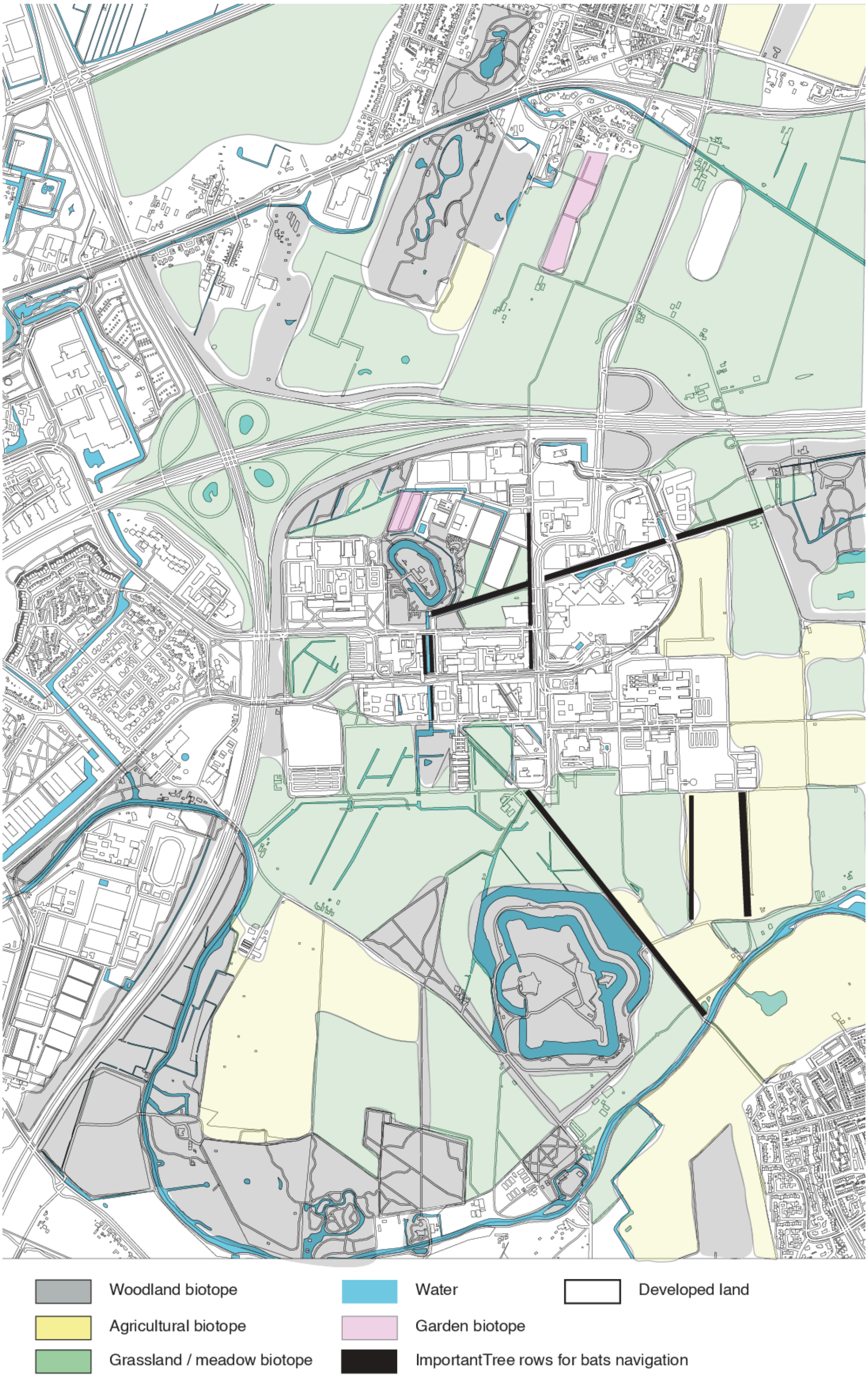


Figure 1. Biotopes in and around Utrecht’s Science Park.

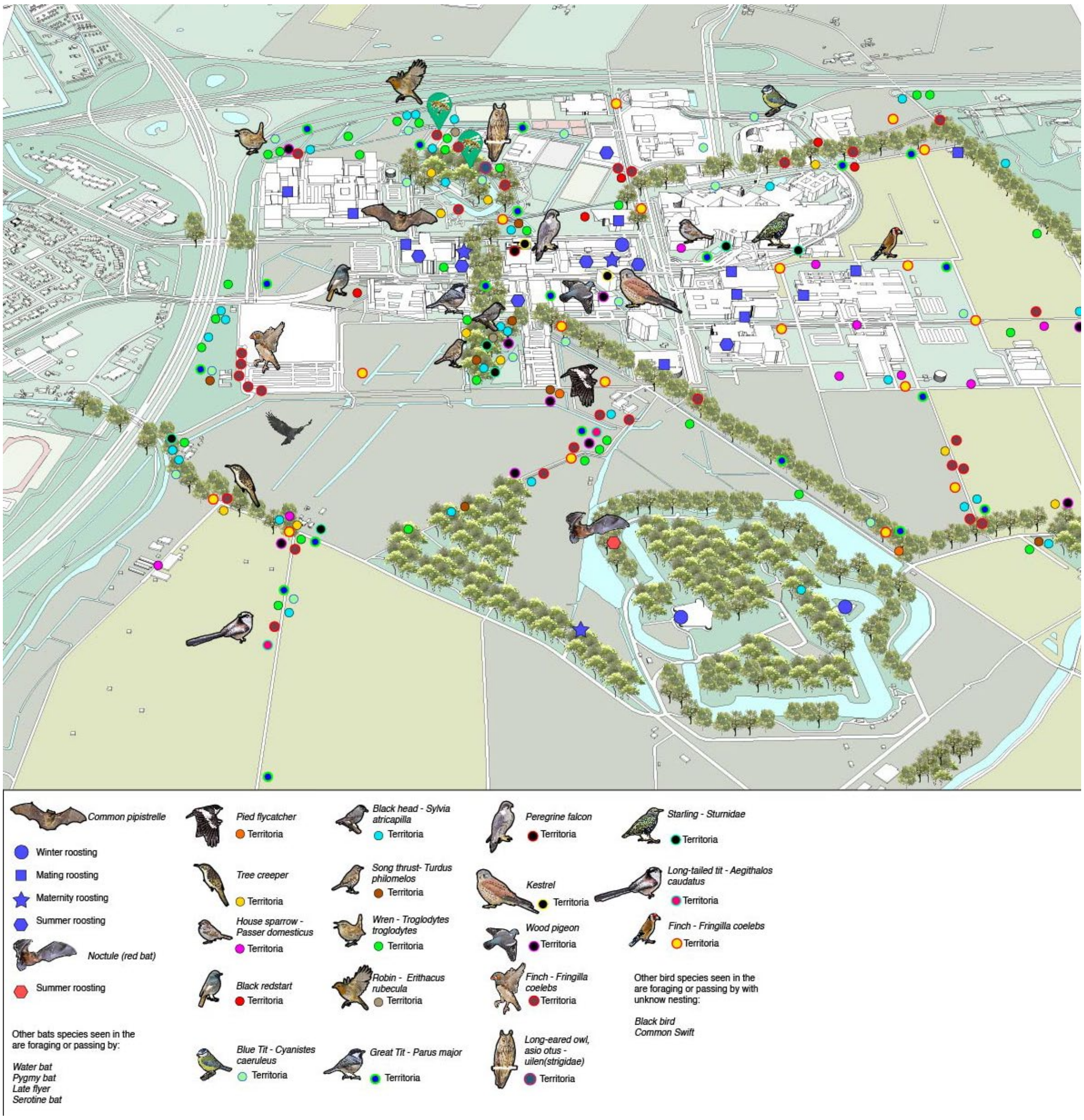


Figure 2. Birds and bats in the Utrecht Science Park and important green corridors for bats.

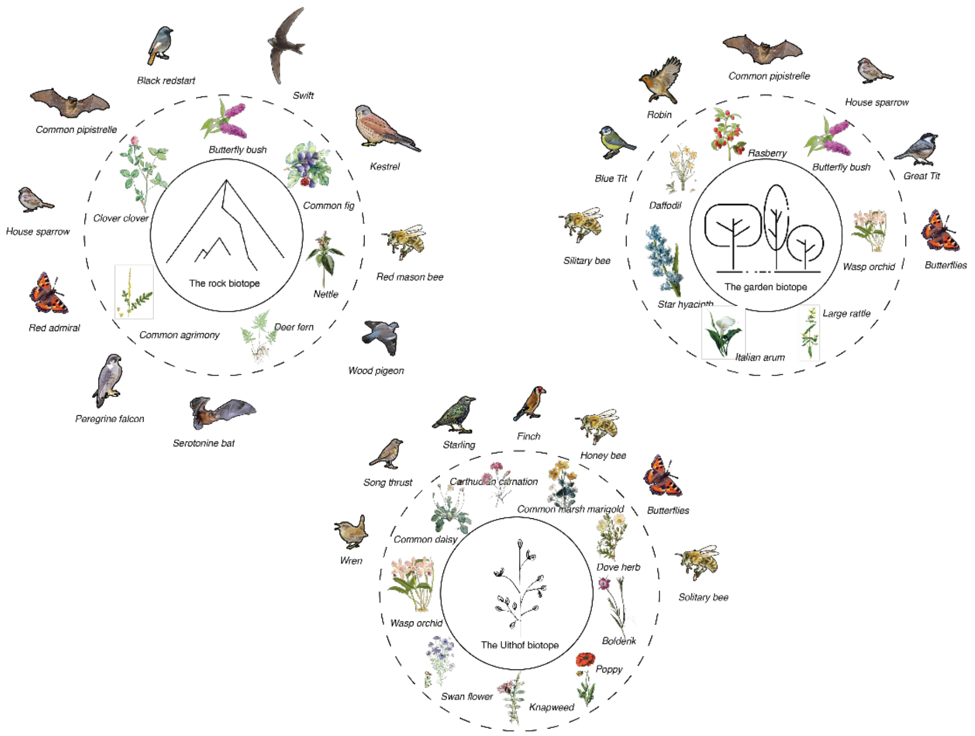


Figure 3. Biotopes of Utrecht Science Park that can be implemented to the Hugo R. Kruyt building.

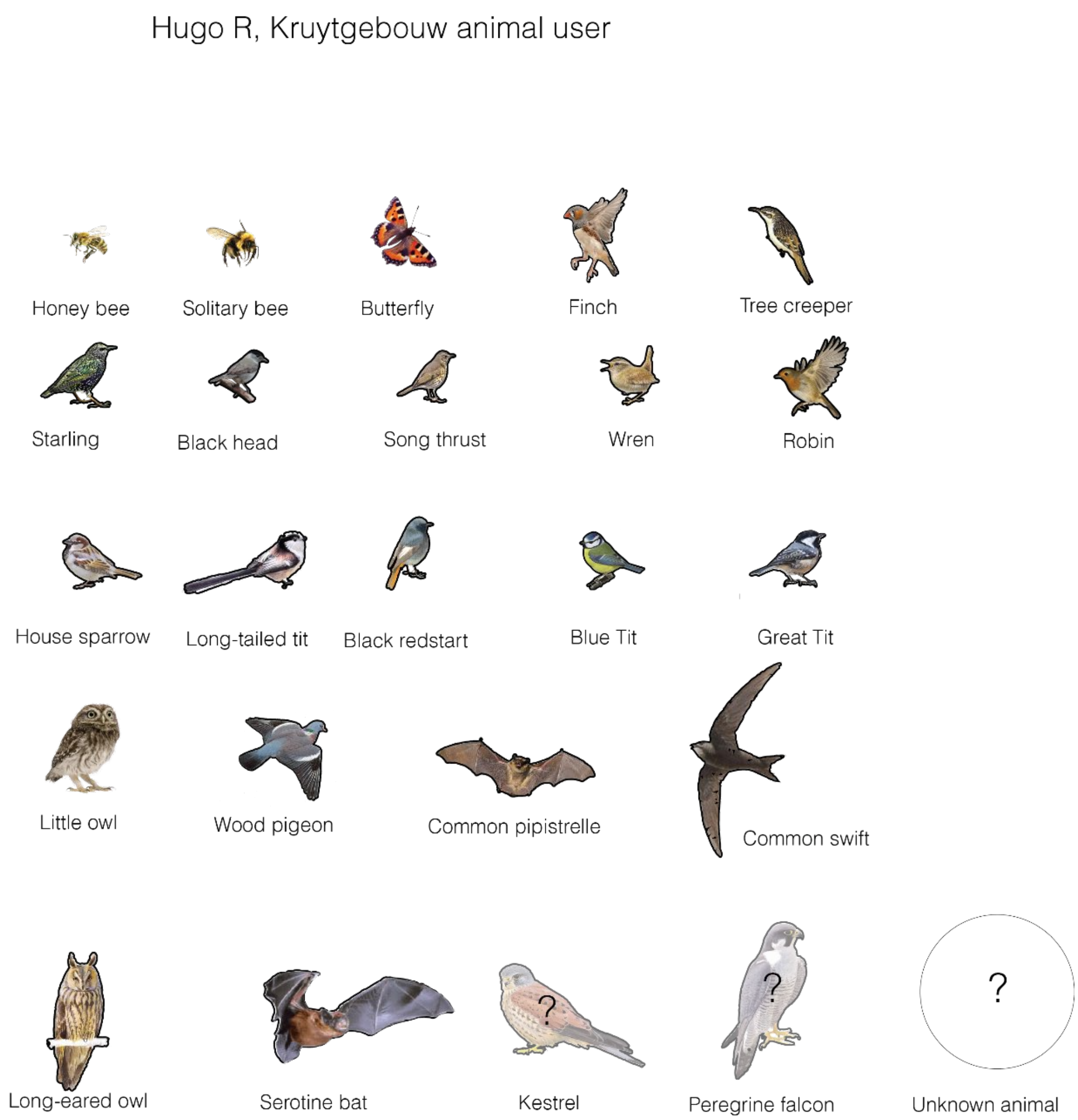


Figure 4. Building reliant animals that can occupy the facade.

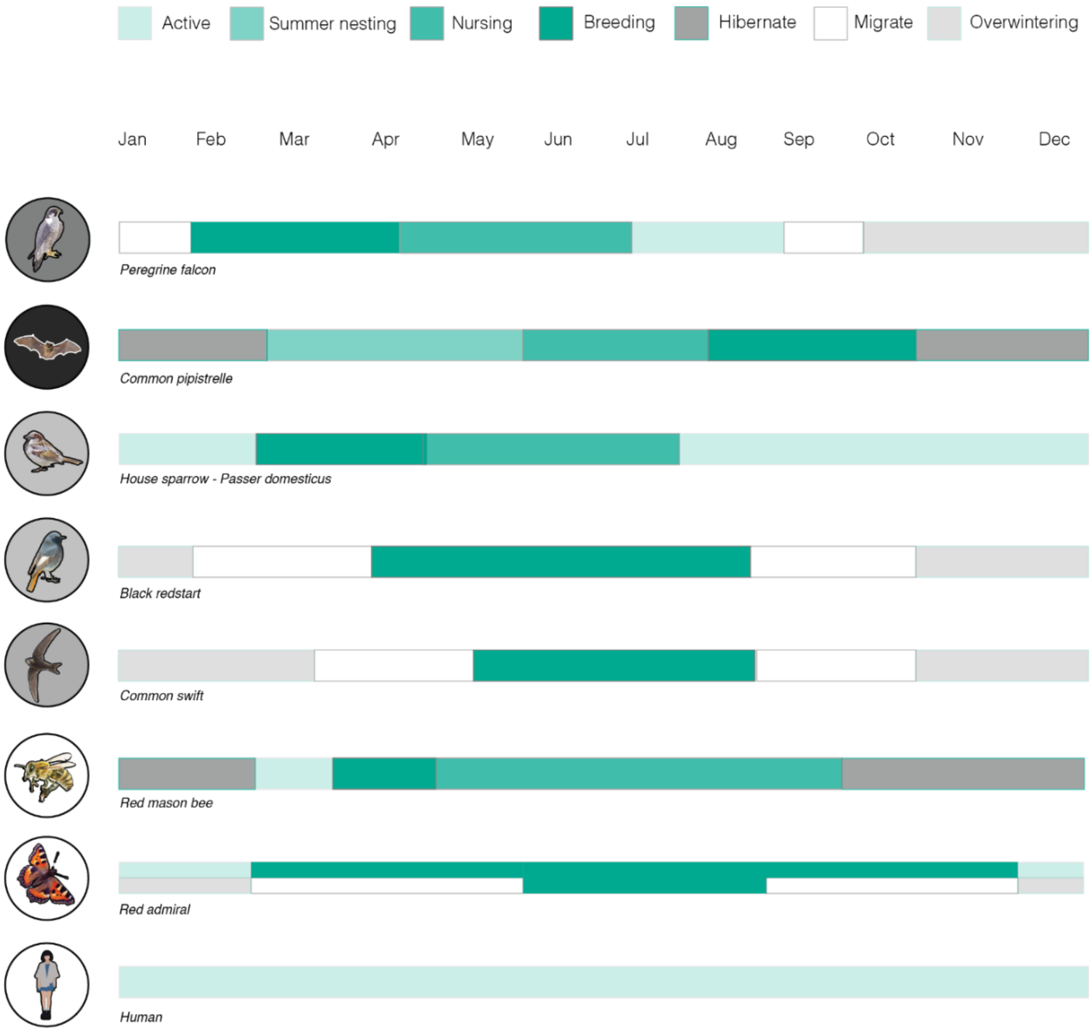


Figure 5. Life in a year of chosen building reliant animals of the Rock biotope.

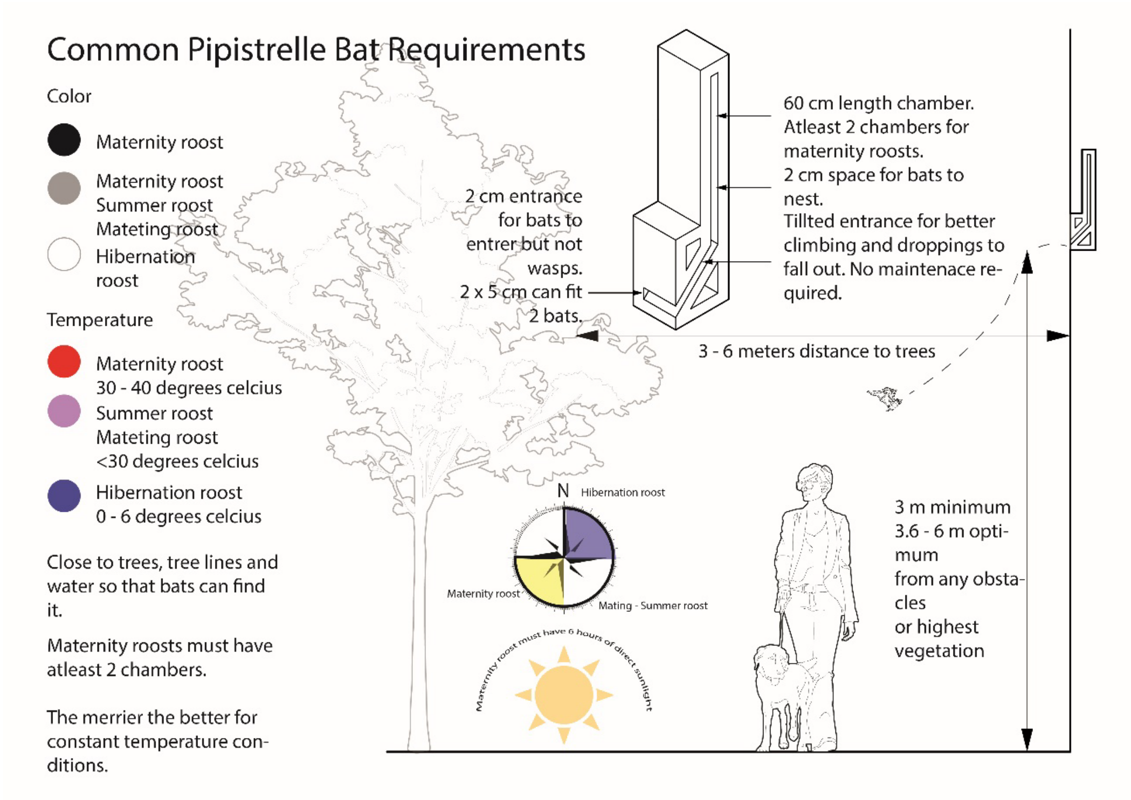


Figure 6. Common pipistrelle bat requirements.

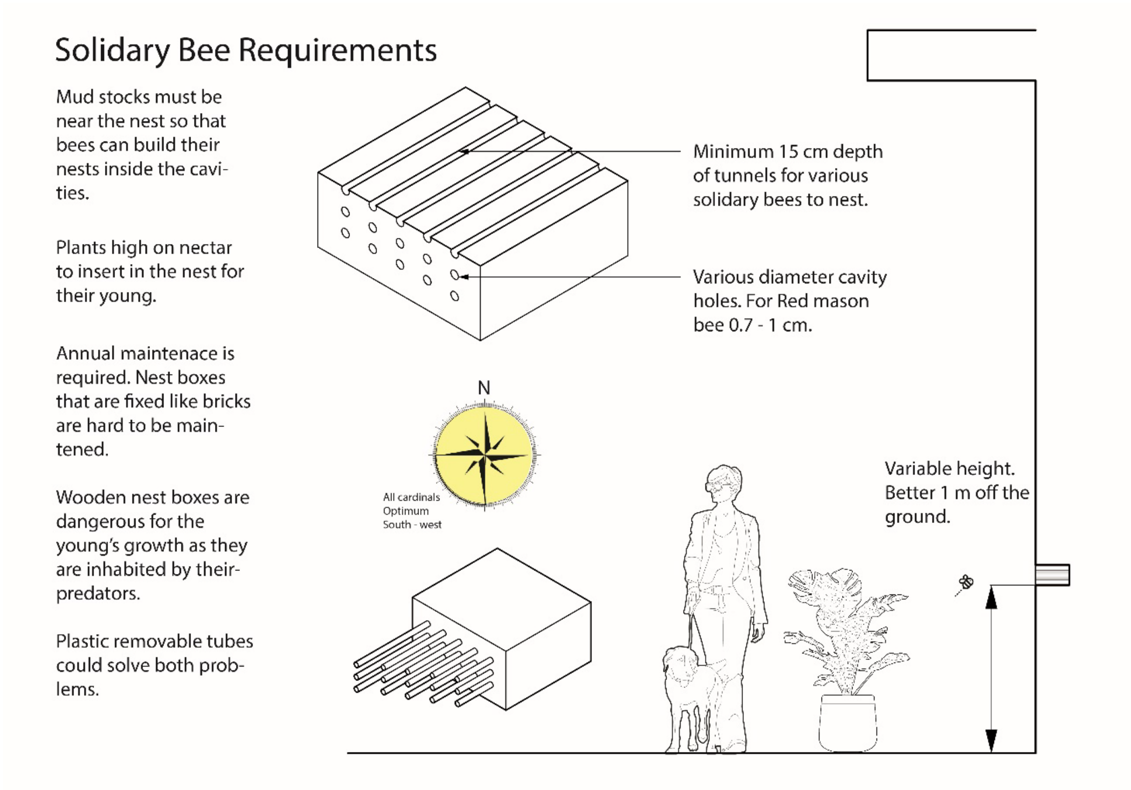


Figure 7. Solidary bee requirements.

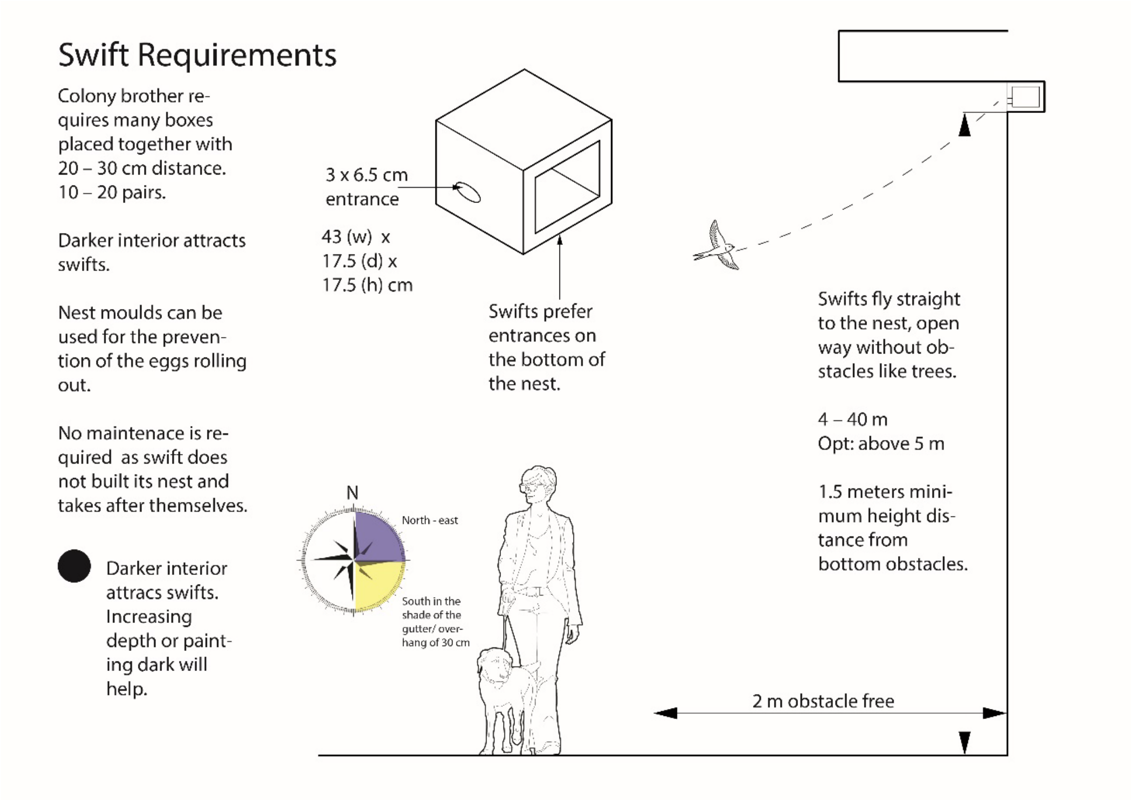


Figure 8. Common swift requirements.

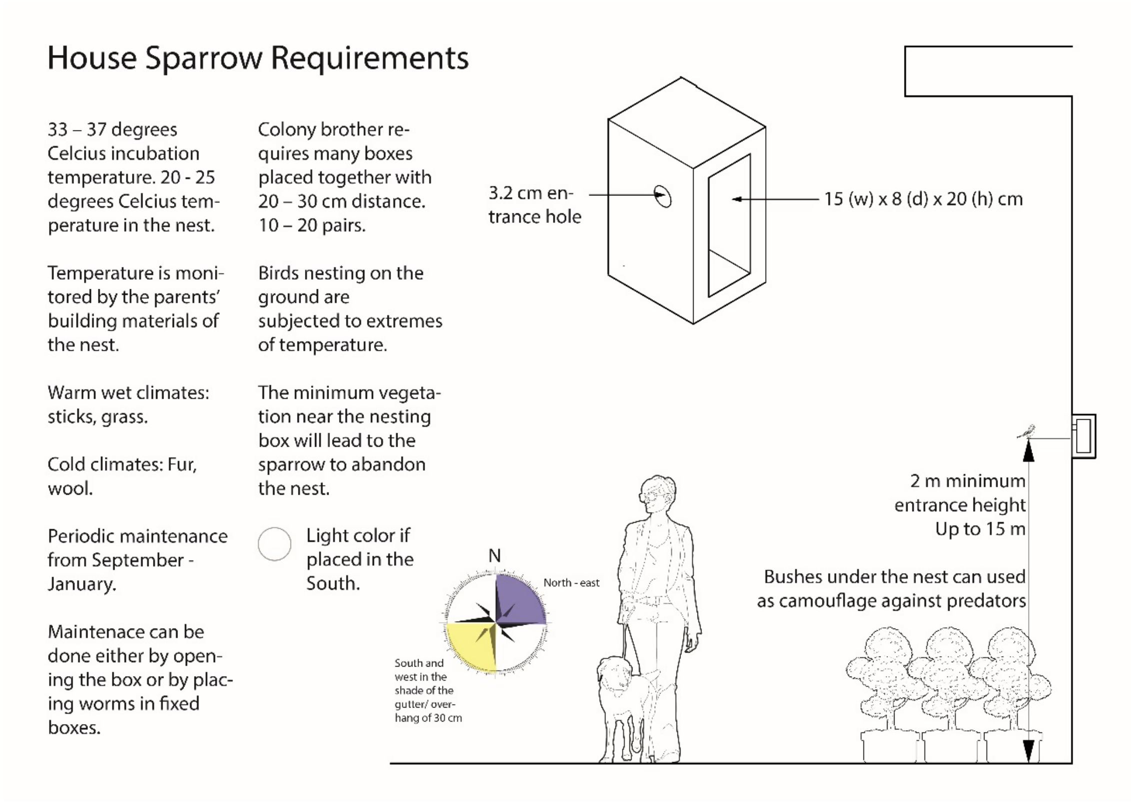


Figure 9. House sparrow requirements.

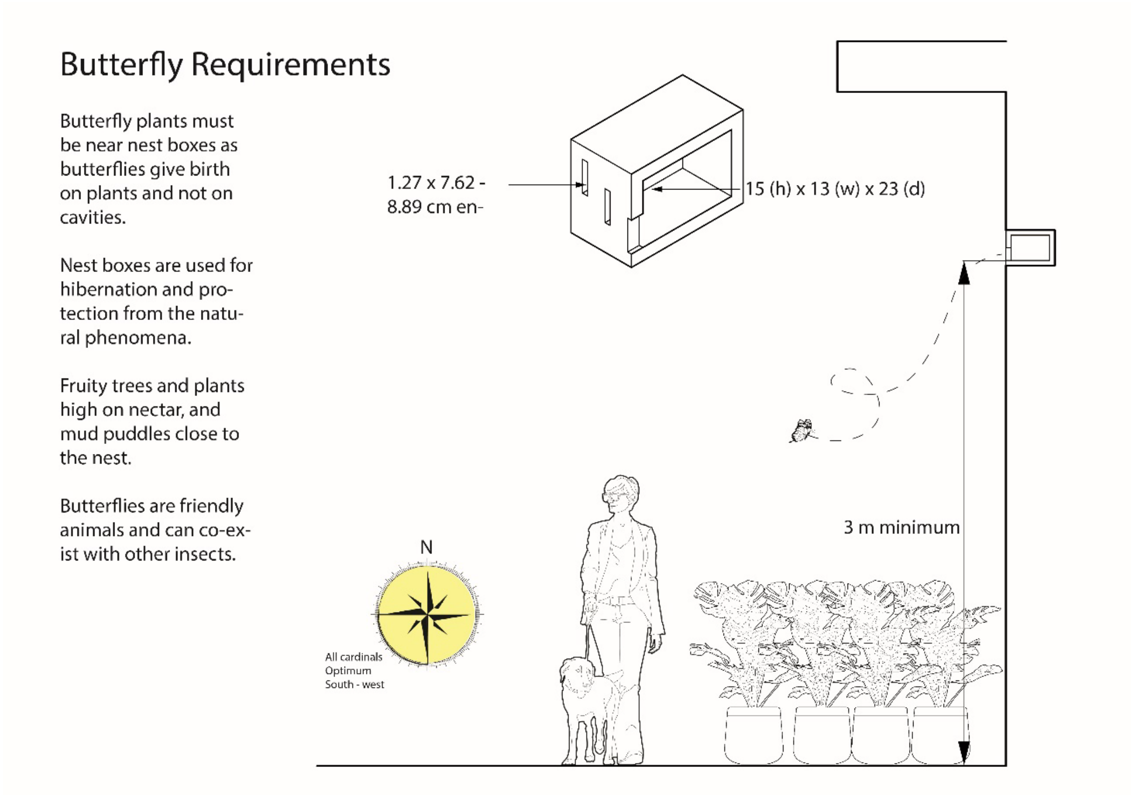


Figure 10. Red admiral requirements.

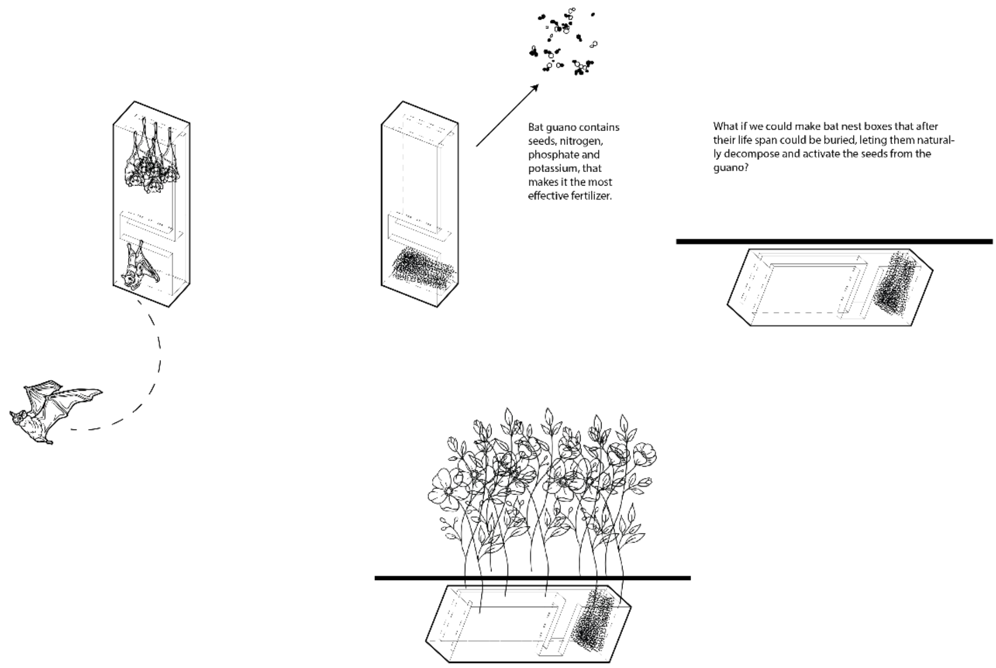


Figure 11. What if nest boxes were the fruit of the building, which after their lifespan could be buried and continue to five life?

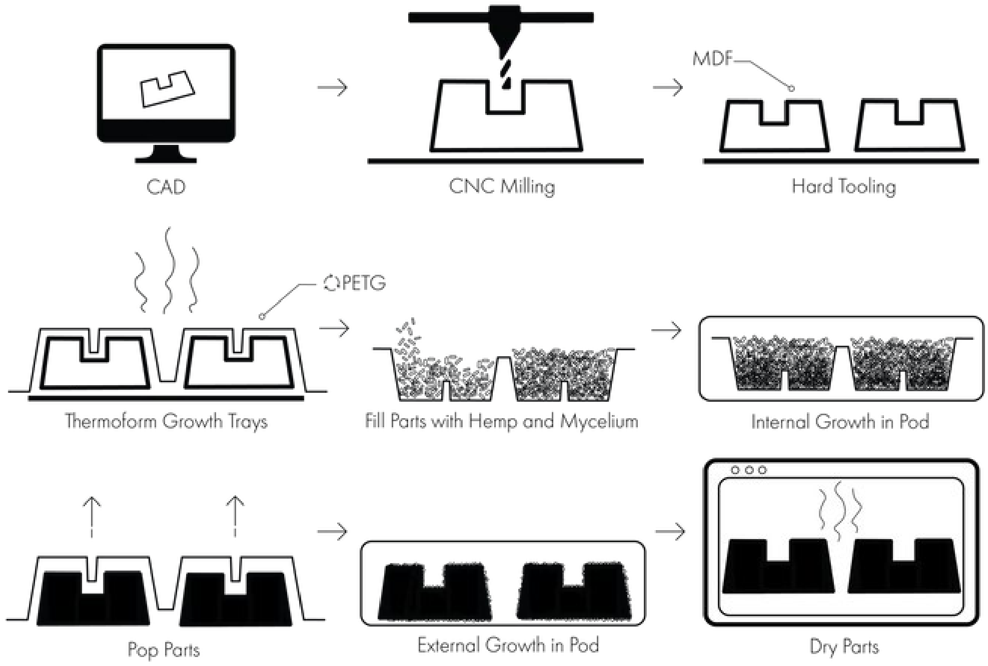


Figure 12. Ecovative's process for mycelium packaging.

Source: https://mycopedia.net/Production-Techniques

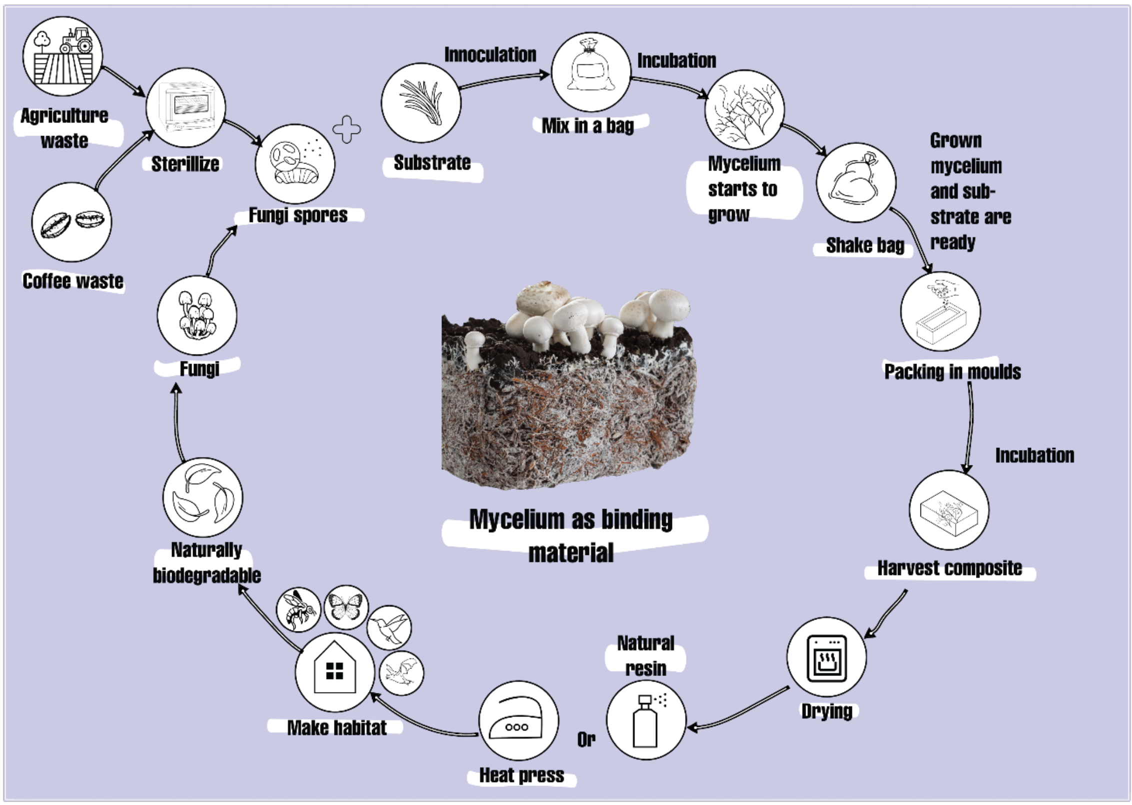


Figure 13. Mycelium as binding material.

Figure 14. Vivara Pro Woodstone Swift Box, Dim (mm): 310 x 170 x 170, Entrance (mm): 30 x 65,

Source: https://www.wildcare.co.uk/11269-vivara-pro-woodstone-build-in.html

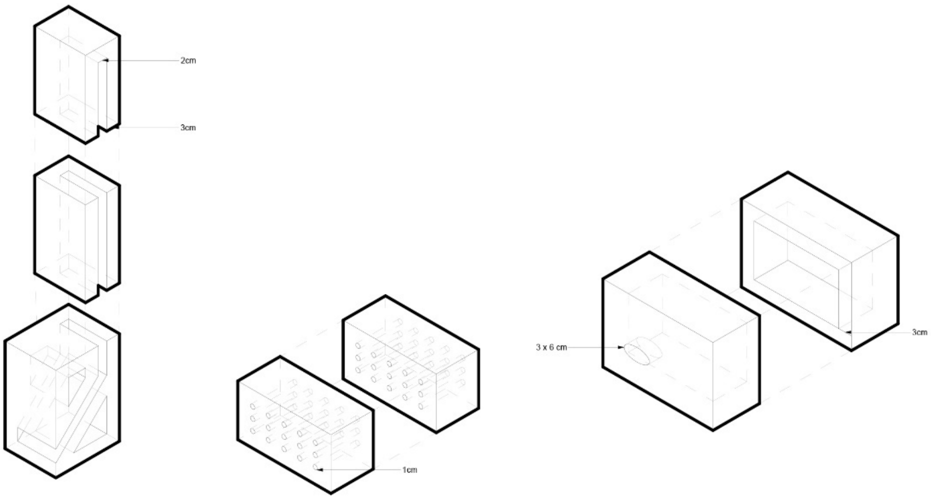
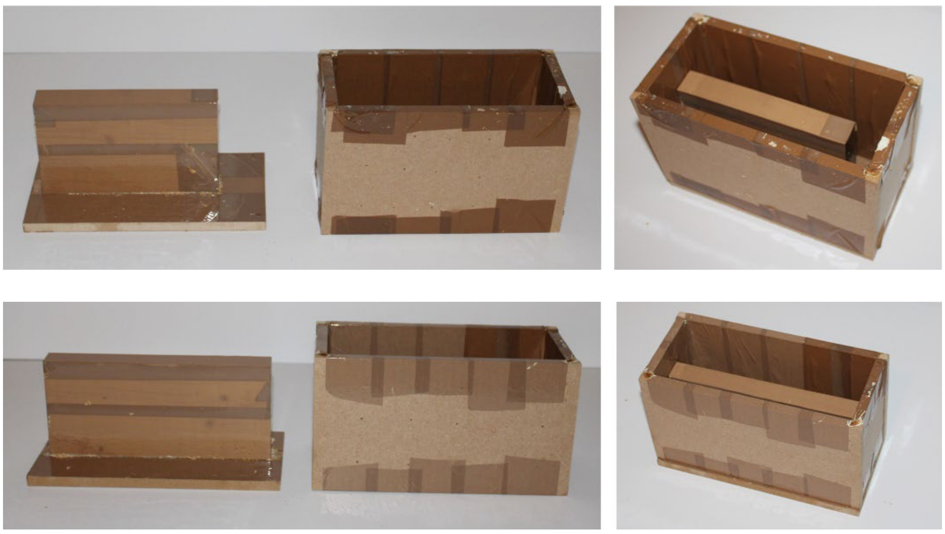


Figure 15. Mycelium composites to be grown.



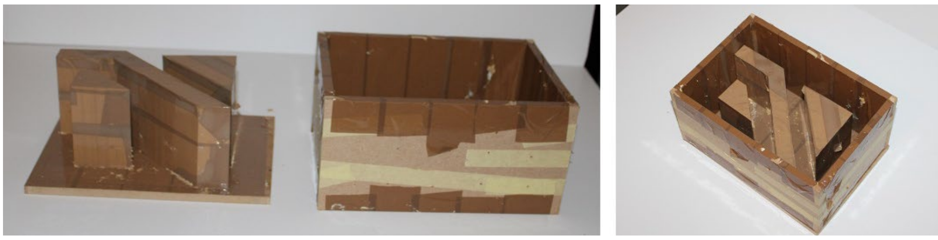


Figure 16. Molds of 9mm MDF for bat nest box.

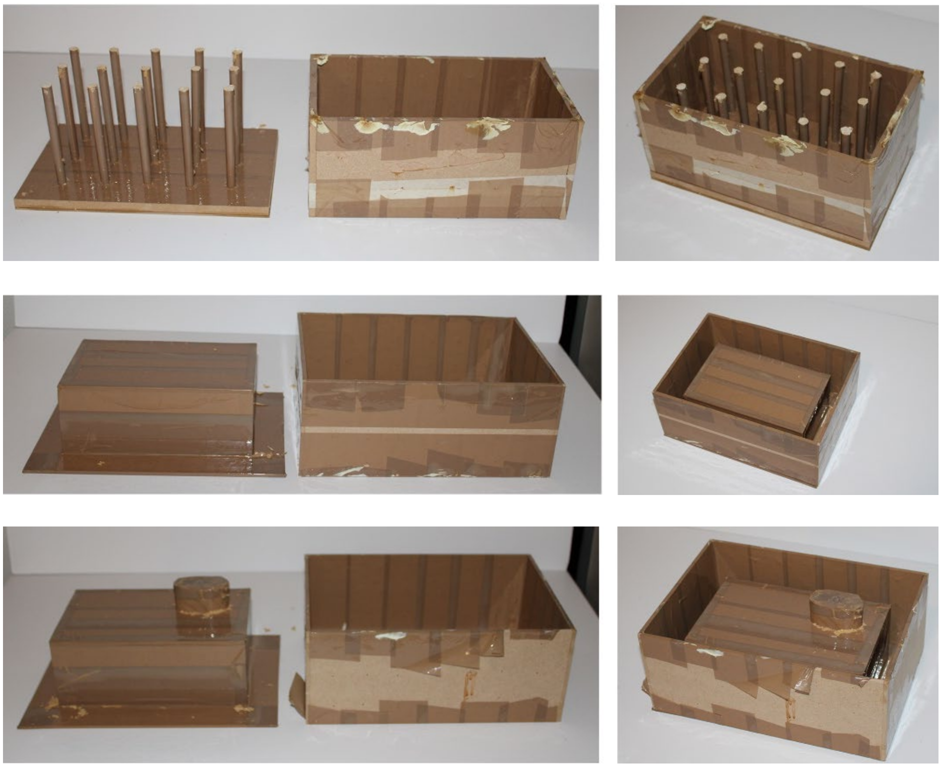
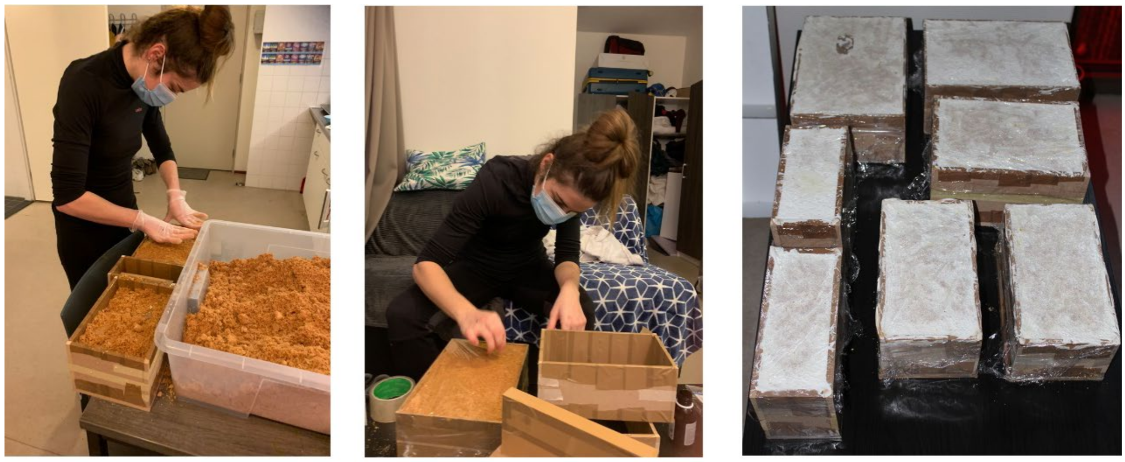


Figure 16. Molds of 6mm MDF for Bee nest box the first one and for the Swift nest box the last two.

Step 1: Make molds and cover them with plastic tape.

Step 2: Shake the mycelium till homogenous.



Step 3: Fill in the molds. Step 4: Punctuate the membrane. Step 5: Wait till Mycelium grows.

Step 6: Dry the harvested composite for 2 days. Step 7: Bake in 95º Celcious till weighting 35% of its weight. Step 8: The composite is ready.

Figure 17. Mycelium production process.

Figure 18. Bricks made in cupboard molds with plastic kitchen foil.

Figure 19. Part of the swift nest box made in cupboard mold with plastic kitchen foil.

Figure 20. Results of the harvested material of the 9mm MDF molds.

Figure 21. Results of the harvested material of the 6mm MDF molds.

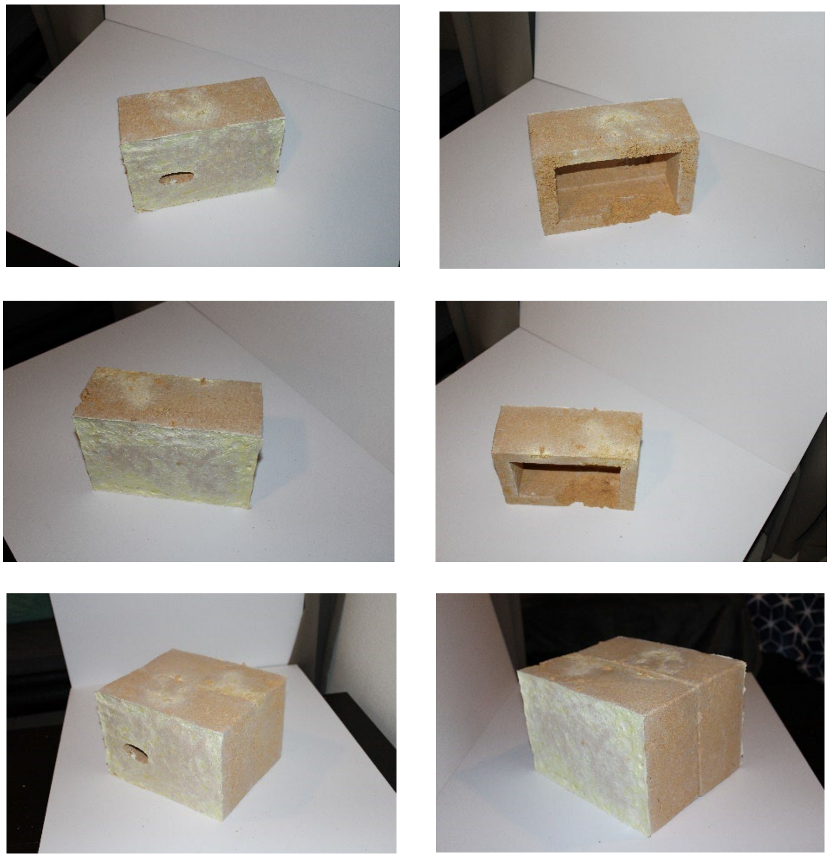


Figure 22. Results of the harvested material of the 6mm MDF molds after completing the whole process.