Research Paper

Exploring the Intersection of Biodiversity and Architecture
within the Theory of Regenerative Developments.

Explore Lab 32

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05.01.2021

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1. CONTEXT

1.1. INTRODUCTION

The apparent inability to understand the long-term consequences of our actions on the very place that we inhabit seems to be a human trait. According to Sing C. Chew "viewed from a broad historical perspective, our present relationship with nature has not changed significantly". Throughout the last 5000 years, this relationship has been "exploitative, primarily to meet the materialistic requirements"[1] and within the last 100 years, we have become more and more efficient in doing so.

In fact within only "a single lifetime – humanity [...] has become a planetary-scale geological force"[2] whose activities inseparably affect the earth system.

The rising global temperature, the impending sea level rise, the degradation of the very natural systems that we depend upon are all already observable consequences.[3]
There is a need to change our view from "ecosystems as inexhaustible stores of resources for use of humans, to understanding that humans live within them as integral parts".[4]

Approaching this through the built environment makes sense regarding the considerable part it has within the total impact on our planet. In fact, "the built environment generates more than 1/3 of the waste within the European union and the manufacturing of construction products alone account for 11% of the global CO_2 emissions.[5] The built environment as an umbrella for all related activities even accounts for 39%.[6] and is responsible for half of all globally extracted material".[7]

The heightened interest in sustainable developments and constructions have a "tendency to focus on carbon- and material-related issues".[8] A good start for sure but with the importance of biodiversity in mind, an architecture more aware of biodiversity should be encouraged.

A good start for sure but with the importance of biodiversity in mind, an architecture more aware of biodiversity should be encouraged.
What makes biodiversity so important is the essential role it plays for the proper functioning of the ecosystems which are sustaining all life on the planet. A healthy biological diversity ensures the functioning of ecosystem services that make life on earth possible, providing the essentials such as clean water, air or food for example.

A theory that acknowledges the importance of the natural systems that buildings are developed in, is the "regenerative theory". With the aim of creating a development that responds precisely to the local natural systems and will ultimately represent a positive contribution for the health and prosperity of a place, the impact on biodiversity through the scale of a building is not addressed precisely enough.

This research tries to clarify the role a single building can have on the biodiversity of a place and offers simple solutions one might consider when designing a small scale project.

The research question therefore is :

Within regenerative architecture, how can a small scale residential building address and positively contribute to biodiversity ?

How can biodiversity be addressed through architecture ?
Which architectural elements can affect/contribute to biodiversity ?
How can these different elements play a vital part of the biodiversity surrounding them ?

The research question is set within the regenerative theory because it aims at achieving a positive contribution rather than minimizing an impact. Which aligns with the aim of finding design solutions that attempt to actively contribute to the local biodiversity of a building project.

2. REGENERATIVE

2.1. BASIC PRINCIPLE

Regeneration, “the act of something growing again” and/or “the act of improving a place or system” [9], lays at the core of this line of thought.

Under the term regenerative design, one understands a development aspiring to become an active part of the complex interlinked systems that make a particular place. The pursuit of a development that seamlessly slips within the multiple gears of the natural cycles of the world surrounding us defines this theory.

According to Raymond J.Cole, one of the more prominent thinkers within the field of regenerative theory, a Regenerative Development promotes a “co-evolutionary, partnered relationship between humans and natural systems rather than a managerial one and, in so doing, builds, rather than diminishes, the social and natural capitals to ‘grow the caring’ required to make sustainability real.” [10]

It is important to underline the difference between a regenerative design approach and a more traditional sustainable design approach. In fact all the currently considered “best practice” sustainable approaches towards design have to be considered a baseline for any regenerative project. In order to display the relation between all of these, a historic timeline of the various sustainability paradigms should provide a better understanding.

2.2. BRIEF HISTORY

According to Pamela Mang and Bill Reed the beginning of sustainable practices within the built environment can be traced back to 1898, when Ebenezer Howard published his book Tomorrow: A Peaceful Path to Real Reform. He called for a shift away from the growing trend of people moving towards the big cities governed by machines and profit and instead argumented for a rediscovery of the humans relationship to nature and its processes. His ambition was to integrate “ecological thinking” into the planning of “human settlements” [11] which led to the garden city movement with two towns actually build according to the main principles of his ideas.

Another counter reaction to the growing migration towards cities in the beginning of the 20th century came from Patrick Geddes, who in 1915, made the distinction between the “industrial era, producing this destructive growth of human settlements” [12] aptly naming it “Paleotechnic” and the “Neotechnic era”, an era focused “on conserving energies and organizing environment towards the maintenance and evolution of life, social and individual, civic and eugenic.” [13]

This initial idea of a more ecological thinking related to a human settlement can be traced throughout time until now. An example of this is the presentation of the word “ecosystem” by Arthur Tansley who focused on the interactions and the consequent outcomes between humans and the natural systems surrounding us.[14] Tansley’s conclusion that our “western design thinking” is based on a clear “human-nature dichotomy” out of which many of the problematic points of human developments spawn out of.

In 1978, the concept of Permaculture was introduced by Bill Mollison. An idea that according to Mang&Reed “was the first ecological design system to introduce the concept of a regenerative effect”.

Mollison’s permaculture would regenerate the natural systems it is situated in by reintroducing energy and resources that were generated during the growth process. This way of doing agriculture stepped away from the exploitative practices which were considered common practice at this point.[15]

In the year 1984, John Tillman Lyle pointed at the need for a better understanding of the "ecological order operating at a variety of scales" which has to be "linked to human values" in order to "create durable, responsible, beneficial designs." He underlined the importance for humans to first understand the complex interlinked systems which define the natural world around us before trying to design or create something within it.[16]

The first actual "practical guide" for regenerative systems design followed in 1996, published by Lyle under the name "Regenerative Design for Sustainable Development". Lyle referred back to Patrick Geddes dark perception of the humans behavior in the bigger picture, a being fueling off of the demise of its natural surroundings. With his regenerative guidelines he proposed a potential way to "reverse the environmental damage caused by "industrial land use practices"". In his alignment with Geddes he describes what he sees as the core problem of our current relationship to nature. Lyle states that while nature works through a complex interlinked system that keeps on evolving through time through the "continual cycling and recycling of materials and energy" [17], we the humans, on the other hand, have " designed readily manageable uniformity" [18] resulting in a one-way linear system, which will ultimately "destroy the landscapes on which it depends".[19]

His ultimate aspiration was for regenerative design to lead to alternate systems which would provide "continuous replacement, through own functional processes, of the energy and materials used in their operation".[20]

In 1995, in part inspired by Lyle's genuine set of ideas, the Regenerative Collaborative Development Group in which Bill Reed and Pamela Mang are co-creators, laid together a more refined proposal for a regenerative development. A proposal according to which communities would be enabled to "co-evolve with the natural living systems they inhabit while continuously regenerating environments and cultures." Similar to Du Plessis [21], they identified the damaged relation between the human and the natural world as the core issue leading to "environmental problems as symptoms" of this disorder/ailment. Therefore the aim of a regenerative development is to have a much deeper impact on the human thinking and perception of the natural world. They argue that only once we as a people have realized and reasserted our position within the natural systems, towards a more holistic view in which we are a conscious part of the natural systems, the current ailments could be acknowledged and worked on.

Regenerative developments are seen as catalysts for such a shift, designing the context as well as the living solutions for a "harmonious integration with nature" benefiting not only the people but also the specific place it is situated in.[22]

2.3. DEFINITION

The Regenerative Theory "offers a system of technologies and strategies based on an understanding of the inner working of ecosystems. Regenerative design solutions regenerate rather than deplete underlying life support systems and resources, are grown from the uniqueness of place, and works to integrate the flows and structures of the built and natural world across multiple levels of scale, reflecting the influence of larger scales on smaller scales and smaller on larger." [23]

What makes a regenerative development stand apart from other sustainable approaches is that the "core issue" is "cultural and psychological, and only secondarily technological".[24] This means according to the Regenesis Group that we as humans need to stop perceiving ourselves as "separate from nature" and instead acknowledge that we are "part of a co-evolutionary whole, in symbiotic relationship with the living places we inhabit".

A well-executed regenerative design should initiate this change of perception of the inhabitants living in it.

A regenerative design considers all the other "sustainable" building practices as a given and builds on top of these. The following table made by Shady Attia is a visual representation of how one "eco-conscious" theory led to another, ultimately leading to the regenerative theory predicted as the new best practice in the field of sustainable developments.[25]
According to Shady Attia, at this very moment we are "on a verge of a paradigm shift that operates from a positive impact creation through environmentally effective sustainable buildings".

Paradigm	Years	Influencer	Paradigm
Bioclimatic architecture	1908–1968	Olgyay, Wright, Neutra	Discovery
Environmental architecture	1969–1972	Ian McHarg	Harmony
Energy conscious architecture	1973–1983	AIA, Balcomb, ASES, PLEA	Energy efficiency
Sustainable architecture	1984–1993	Brundtland, IEA, Feist	Resource efficiency
Green architecture	1993–2006	USGBC, Van der Ryn	Neutrality
Carbon neutral architecture	2006–2015	UN IPCC, Mazria	Resilience
Regenerative architecture	2016–Future	Lyle, Braungart, Benyus	Recovery

Attia, S. (2018). Regenerative and positive impact architecture: Learning from case studies. Springer Verlag.

This means that a regenerative development should fulfill the current highest sustainable industry standards while aiming towards a positive contribution to the place it is built in. This means that it should be a building with a positive footprint regarding every single aspect it touches; carbon, food, energy, water, waste, materials, community and nature.

2.4. IMPLIMENTATION DIFFICULTIES

One of the difficulties of a regenerative development is the lack of an internationally accepted and renowned certificate such as a LEED or BREEAM certificate which takes away financial incentive for a lot of developers. Another hardship for such a development will be that potential benefits to the ecosystem a project is developed in, will not be visible immediately. In fact according to one of the co-creators of the term "regenerative development", states that positive changes are only visible after 15 years on average. [26]

This means that the public will have to change the understanding of how to judge a buildings role and/or function. Since unlike traditional building projects, "the benefits of regenerative design and development cannot be fully understood at the completion of a project". [27]

The longer timeframe however is not the only constraint, with no direct tangible economic benefits tied to potential ecosystem benefits resulting from a regenerative development, stakeholders are less incentivized to embark on a more complex building project. The complex nature of a regenerative development is another critical point that might deter people from pursuing a regenerative building project. Taking into the account multiple stakeholders that might be part of the specific place of the project, as well as every possible source of potential impact on the natural systems during the entire lifecycle of the building add a significant layer of complexity to a building project. According to Belle&Mang however, "the capability to image complexity while coordinating the integration of a large number of technical solutions into a physical form is intrinsic to designers", which makes the task of a regenerative design an attainable one. [28]

2.5. NODAL INTERVENTIONS

Simplified, a regenerative development can be divided into 4 main steps.

1. uncover the regenerative potential of a place
2. define the holarchy of the project
3. uncover the distinctive character and potential of the place and the projects distinctive role
4. identifying nodal interventions [29]

Once the specific place has been properly understood on a larger scale, concerning the geographical, social and ecological characteristics , certain nodal interventions have to be identified. One of these nodal interventions is the building for example.

The build form will be the result of the many interlinked considerations that have taken place and will therefore find itself at a crucial "node" within a regenerative development. All the actors and systems involved will come together through time at the built object. [30]

An example is given in Pamela Mangs Book [31] where a particular node was identified as unsuitable to serve as the plot for the development of a house in the "mountains of north Arizona". They came to the conclusion that too many natural flows were concentrated at this area, namely "flows of wind, water, fire, cold air drainage and wildlife traffic". They changed the building plot to a different more "calm" place, which safeguarded the house during a "forest fire followed by monsoonal flooding" unlike all other homes which were destroyed. [32]

Architecture will have to be designed very carefully in order to respond to the multiple intersected criteria unique to a specific place. In a way the build object will be the result or a potential answer to a certain web of local requirements.

2.6. MISSING LINK BETWEEN THEORY & PRACTICE

With this in mind, it is quite remarkable that the extensive theory of regenerative developments does not specify clearly how this ought to be achieved. In fact the link between regenerative theory and practice particularly at the scale of architecture is not clearly defined.
Dr. Raymond J. Cole acknowledged this by underlining that "while the aspirations and key principles of regenerative design can be readily understood, its operation and practice are less clear." [33]

With no exemplary architectural projects yet to inspire or guide architects, there is no reference which could serve as a baseline to understand the key design principles to follow. The lack of any "translational arm" [34] showcasing the theory in practice as well as no tools that "are comprehensive enough to clearly guide designers",[35] pose a great hurdle in the way of achieving regenerative architecture.

2.7. ROLE OF THE BUILDING WITHIN REGENERATIVE THEORY

Within the regenerative theory, the building gets much higher demands imposed on it compared to a regular project. According to Raymond J.Cole the building could be a "catalyst for positive change within the unique 'place' in which it is situated".[36] This refers back to the building being one of the nodal points necessary to bring about a positive change to the place in question. In order to know which roles the building should address and positively contribute to, Pedersen Zari stresses the importance of understanding "ecosystem services at a larger scale".[37]

This requires a different set of knowledge than the one usually associated with architects/ designers but in case of a regenerative development is absolutely crucial. Benne and Mang therefore [38] make clear that "designers must have the will to engage beyond the narrow scope of designing physical infrastructures, and train their minds to embrace complexity without getting overwhelmed".

Once the necessary focus points are identified, the building will be designed and planned in a way to try to positively affect these actors or conditions. An important characteristic of a regenerative development is that these contributions/effects should not be finite. That is why Mang&Reed point out the importance of time for such a project. While designing/ planning the building, one should, after a thorough analysis of the multiple actors and systems, "ensure that the ongoing regenerative capacity of the project, and the people who inhabit and manage it, is sustained through time". [39]

Leaning on the concept of time, J.Cole points at the importance of "designing the capability of the constructed world to support the positive co-evolution of human and natural systems" instead of designing a building as a "building as a product". [40]

2.8. CRITIQUE

As promising as it sounds, some voices within the field are pointing out certain critiques of the regenerative theory.

Interestingly, Raymond J.Cole is the only prominent key figure who is issuing a critique towards the current regenerative discussion. He points towards the issue that exemplary projects described are "almost exclusively non-urban, set within relatively coherent community contexts and with greater access to natural amenity" and goes on to question the feasibility of such a regenerative project in a "densely urban setting".[41]

It has to be mentioned that the theory being relatively young and arguably still fringe in the built environment, real life projects are essentially nonexistent while the ones trying to achieve a certain regenerative character are of a small scale and are indeed located in natural environments, which is explained due to the more manageable scale of these places. Like for any new line of thought smaller tests have to be conducted in order to get a better understanding until it can be applied in a more complex and difficult setting.

2.9. BIODIVERSITY NOT THE FOCUS

Reading and collecting an extensive amount of information around the topic of regenerative developments it seems odd that while biodiversity plays such a defining role for the functioning and health of a specific place, no real explanations on how to identify/understand and address this can be found. In regard to the importance of biodiversity from a local to a global scale this is hard to comprehend. Sometimes the issue of biodiversity is not even mentioned within the guiding principles of a regenerative development.

One such example can be found in the book "Regenerative and Positive Impact Architecture – Learning from Case Studies".[42] While biodiversity is mentioned multiple times in the introduction when presenting the theory of "Regenerative Developments", it is not mentioned at all in the rest of the book. Instead the focus lays on materials, energy efficiency, comfort and performance. The fact that the book is relatively recent (2018) and is based on case studies, is a good reminder that there is a lot left to do in order to move towards a "regenerative" building.

In general regarding sustainable building, instead of biodiversity, "there has been a tendency to focus on carbon- and material-related issues" [43]
This is due in part, to the lack of any financial incentive linked to the preservation of or even contribution towards biodiversity. [44]

3. WHY BIODIVERSITY ?

3.1. DEFINITION

Biodiversity, also called biological diversity, the variety of life found in a place on Earth or, often, the total variety of life on Earth. [45]
The term encompasses every single living thing, "including plants, bacteria, animals and humans".[46] Altogether, they form a complex system of relations and interdependencies from a local to a global scale, making it the "basis of many ecosystem services" [47] making the "earth habitable for all species, including humans". [48] Despite the initial perhaps selfless perception of someone working towards preserving biodiversity, it is ultimately an act of self-preservation for us humans here on earth.

The contribution and impact of Biodiversity in general is remarkably broad and essential. It "plays a critical role in providing food, fiber, water, energy, medicines and other genetic materials; and is key to the regulation of our climate, water quality, pollution, pollination services, flood control and storm surges." Additionally, it provides us humans with "inspiration and learning, physical and psychological experiences" which ultimately "shapes our identities". [49]

Considering the trends in biodiversity, our current practices are hard to argument for much longer. According to the Living Planet Report 2020 there is a 68% fall in "populations of mammals, birds, amphibians, reptiles and fish between 1970 and 2016". This data is relevant since the "species population trends" are a good measure of "overall ecosystem health". [50]

With such important/crucial values at stake it becomes unquestionable to work towards conserving biodiversity in every field we humans have an impact upon it. Unfortunately, in the case of the built environment, "biodiversity considerations seem to be one of the least priorities when assessing new development projects". [51]

Within the field of the built environment as well as any other human activity, It is time to acknowledge that "Biodiversity is not an additional option in an ideal world, but a fundamental need not only in the context of truly sustainable building, but also for our quality of life and the long-term sustainability of our planet. The loss of biodiversity is one of the biggest threats facing our planet." [52]

3.2. BIODIVERSITY & THE BUILT ENVIRONMENT

Once the importance of biodiversity conservation has been recognized, the question arises how architecture could mitigate any negative impacts on biodiversity or even contribute towards biodiversity. It is important to acknowledge that a built object has passive and direct repercussions on biodiversity during its entire lifecycle.
In fact when looked at closely, "biodiversity is connected with all the sustainable building criteria", ranging from energy to water as well as the materials for example. [53]
With the built environment being one of the drivers for "biodiversity loss" Dr. Maibritt Pedersen Zari, believes that when applied properly, it "also has the potential to mitigate the causes of such loss".[54] This means that the built environment can be a powerful and exemplary tool to maintain and/or enhance the local biodiversity while also raising awareness about biodiversity. Showcasing the importance for biodiversity conservation through architecture provides opportunities for "environmental education" which in turn will form "support for biodiversity protection".[55]
Building with biodiversity means that the "existing resources in the habitat" should be protected and the resulting building should "interact positively with nature".[56] Unfortunately, similarly to the regenerative theories, translating the theoretical aspirations into practice is not yet fully developed. In this case, the current "sustainability assessment tools" needed "to consider fully the impact of all construction activities on biodiversity" [57]

are insufficient and further developments/ improvements are needed.

So how do buildings affect biodiversity then ? According to Brian Edwards, this happens through the roof, walls, landscape as well as the materials considering their sourcing, assembly and disposal. Furthermore any resources needed during the use of the building, such as energy or water and any potential “adverse effects of buildings in terms of air and water pollution” should be thought of. [58]

Another attempt at describing the elemental points to consider while developing a biodiversity aware building comes from the European Environment Agency (EEA). They underline the importance of establishing an “ecological baseline” before the development and then aim at strengthening this. Designers should create “habitat opportunities” and link these to other habitats further away and they should also create “opportunities for humans and nature to interface”. [59]

It is interesting to note that these two different recommendations on how to approach biodiversity through a built development focus on different things, one on more indirect consequences for biodiversity and the other one on the direct ways of addressing the local flora and fauna.

4. LESSONS LEARNED FROM LANDSCAPE ARCHITECTURE

With a relatively limited amount of resources considering guidelines for biodiversity implementation, the field of Landscape Architecture might have certain answers that could be translated into architecture. Unfortunately in this field too, there is an apparent lack of translational guidance from the theoretical ideas into real world applications.

Some approaches, although theoretical, do seem relevant for a biodiversity driven architecture. In order for a development to contribute towards biodiversity, an "interdisciplinary approach" is needed.[60] That is why it is crucial to involve ecological experts not only during the beginning phases of the project but also throughout. In current landscape design practices however, the involvement of ecologists is limited to the early stages of the development.[61] Another issue concerning design for biodiversity is the common lack of "site- or species- specific" knowledge which makes designing for these particular places in a precise and meaningful way quiet problematic.[62] Furthermore "monitoring" projects designed for biodiversity conservation is "rarely conducted" which leads to uncertainty whether the expected effects are manifesting themselves.[63]

4.1. LANDSCAPE FACTORS & LOCAL FACTORS

What can be taken from landscape architecture is the advice to plan for different scales, habitats and species. A crucial step is to consider both, the "landscape factors" as well as the "local factors".[64] Landscape factors, operate at the bigger scale, describing the total size of an area and the consequent species richness. The species richness is in relation to the higher number of diverse habitats that can be found in a bigger area of land. [65]
The "local factors", define the habitat structure [66] and therefore "determine habitat diversity".[67]

The local factors are mainly defined by the habitat structure and the habitat composition. Perhaps the most interesting lesson to take away for architecture is the habitat structure. It describes the "vertical layering of vegetation" which in turn "has a large influence on the level of biodiversity". [68] The habitat composition is specifying the flora found in the habitat. It has been concluded that "the more diverse the flora composition, the larger the diversity of fauna" will be in that habitat. [69]

In regards to architecture, the local factors can be a very important tool to address biodiversity. Especially for "highly mobile species" like birds for example the local habitat quality can be crucial. This is due to the importance of "particular structural features" which provide opportunities for shelter or nesting.[70] In the architectural context this means that providing enough diverse conditions through the use of layered vegetation features should be beneficial for various animals potentially finding shelter within the complex local vegetation structure of the building.

4.1. HABITAT QUANTITY & HABITAT QUALITY

It is important to underline the difference between habitat quantity and habitat quality. While habitat quantity depends on the habitat area and its connectivity, habitat quality is largely defined by habitat structure and habitat composition. Both, quantity and quality contribute towards biodiversity but the quantity does not necessarily implement the habitat quality. Whereas a larger habitat quantity does usually lead to a higher number of species, the habitat quality can generate the specific conditions needed for a target species. [71]

5. DESIGN FOR BIODIVERSITY

5.1. HOW CAN BIODIVERSITY BE ADDRESSED THROUGH ARCHITECTURE ?

An inherent difficulty when thinking about coupling architecture to biodiversity is the static element of architecture juxtaposed to the dynamic character of the natural systems.[72]
This however could be overcome through a thorough understanding of the local biodiversity leading to a coherent design, responding to the specific local biodiversity needs.

5.2. 8 STEPS TOWARDS BIODIVERSITY

A project with the intention to contribute towards biodiversity should consider 8 main steps.

1. Analyze and Assess the area across multiple scales

This initial step is about getting to know the place one will be working with. As mentioned earlier, the importance of uncovering the characteristics of a specific place is one of the chore principles of the regenerative theory as well. In this case the ecosystems should be studied and the underlying connections should be understood.

2. Decide for a strategic plot (if possible)

Resulting from the "uncovering of the place" 73 certain areas of interest should stand out. These will be areas that should not be disturbed at all, zones that might require some sort of biodiversity improvements and areas that could host a potential architectural development. This again can be referred back to the regenerative theories, where such areas of interest are defined as "nodes", points where a high concentration of flows intersect.

3. Determine the Biodiversity Baseline (make ecological assessment)

Once the right building plot has been decided on, an ecological assessment will have to be conducted. This will try to give an as good as possible representation of the health and functioning of the biodiversity on that plot. It might highlight potential shortcomings and help guide developers into assessing which biodiversity actors to focus on. For this highly specific task, it is best to collaborate with an ecological expert.

4. Set Biodiversity Targets

The ambitions of the project have to be defined in accordance to the findings from the ecological assessment. The "appropriate scale" 74 required to achieve the ambitions of the project should be fixed. Target species will be decided on and long-term goals should be discussed.

5. Create and/or retain the specific conditions for potential habitats

During the design process, the conditions necessary for the desired flora and fauna will have to be integrated. Concerning the flora, it is important to underline that only native species should be planted with the exception of exceptional benefits from non-native species provided that they are not invasive. The plants used should provide "food (nectar, pollen, fruit, leaves) and/or shelter". 75
Any potential space created by a project can be seen as an opportunity to create the conditions required for a potential habitat. "Roofs, Walls, Balconies, […]paths" could be utilized for example. 76
It is crucial to choose the right locations in terms of placement within the project as well as orientation towards the sun, wind or rain. Furthermore distances and connections between certain flora and fauna will have to be designed in a well thought through manner.
In most cases the ecological assessment identifies already valuable biodiversity assets on the plot which then need to be protected. In general one should "retain mature trees, hedges and vegetation of value to wildlife". 77 This step essentially focusses on the "local factors" and therefore on the "habitat quality" mentioned earlier in the report. 78

6. ensure connections between different habitats

In order to have a lasting impact, the habitats created within a singular building for example should be part of a larger system of habitats. Connections on a smaller scale (within 1 building) as well as connections on a larger scale (in the surrounding area) should both be taken care of. This will be made possible through the good understanding of the ecosystem on a larger scale established during the first step of the assessment. A new building will most probably "create unnecessary barriers to the movement of animals" 79 that is why creating diverse habitats within the building should help reduce the building impact. Green corridors or stepping stones (green islands) can be used to link different habitats over longer distances.

The potential habitats created within an architectural project should not be seen as the final destination of certain plants and animals but rather as a piece within a larger system.

7. "Design for co-living between humans, plants and animals" [80]

This step is very important because it represents the embodiment of a project aiming at working with nature. A buildings chance to succeed over a prolonged period of time in contributing towards biodiversity should also showcase the mutual benefits coming out of such a design. Many design interventions aiming at creating habitat opportunities for certain animals or plants do have real benefits for the building user as well. The visual connection to nature can have measurable psychological benefits for the humans living or using the building for example. [81]

When applied in a thought through manner, natural elements can provide shading and cool down the incoming air while also establishing the living conditions for certain animals. More precise examples can be found further on in the report.

Another potential consequence of a design successfully managing the co-living between humans, plants and animals could be a change in awareness considering the importance of the natural world for the wellbeing of the human.

8. Monitoring

Monitoring the building for a prolonged period after completion is an important step for the developers to observe and assess which design interventions worked and which did not. It is through this simple empirical approach that one can learn from past mistakes and improve on them in order to get a better understanding of the issues and apply this knowledge on better solutions in future projects focusing on biodiversity. [82]

6. PROJECT LOCATION

BIODIVERSITY OF HALMAHERA ?

This paper being written in relation to an architectural graduation project exploring the human-nature interrelationships in the context of an archipelago in north-east Indonesia, the following architectural elements will be illustrated within that specific context. Showcasing examples with local flora and fauna.

This particular area in north east Indonesia is part of an "important part of the region known as Wallacea, which contains a very distinctive fauna representing a mix of Asian and Australasian species" [83] and according to the "Köppen climate zone system" this region is classified as a "tropical wet climate zone".[84]

The "natural vegetation is tropical lowland evergreen and semi-evergreen forest".[85] This region has "almost optimal growth conditions" resulting in most trees being higher than 30 meters. The "overall biodiversity is low" but the "overall endemism is moderate to high" resulting in "perhaps the highest levels of endemism" for this size ecoregion anywhere in the world. The Halmahera Rain Forests ecoregion has a low number of mammals, "only thirty-eight species" out of which eight are endemic. Considering the bird species however, it is an exceptional region. A total of 223 bird species can be found in this part of Indonesia, out of which "an astounding twenty-six are found nowhere else in the world." [86]

The exemplary building of the graduation project however, will not be on Halmahera but on a smaller island instead. It is therefore interesting to consider what this means for the biodiversity. According to Elaine Fisher, a marine conservationist, "island ecosystems appear to be less resilient than mainland systems". This is due to the smaller natural system, made out of less actors, present in a smaller, more isolated piece of land. In general an island ecosystem has "fewer species per unit area than on mainland" as well as "disharmony" meaning that there can be a "different balance of species" than on mainland. The "increased vulnerability" means that any intervention within this system will have to be made carefully and with biodiversity in mind. [87]

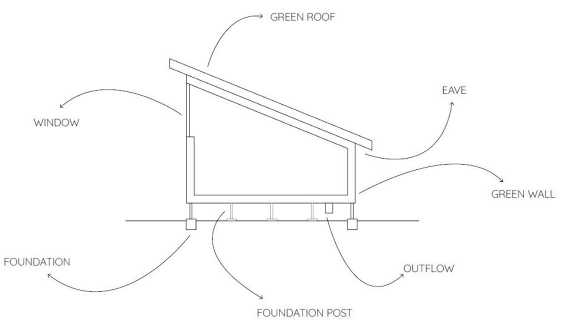
7. THE ROLE OF THE BUILDING

7.1. WHICH ARCHITECTURAL ELEMENTS CAN CONTRIBUTE TOWARDS BIODIVERSITY ?

This paper aims to lay out in a clear and simple manner how an architect/developer can contribute to biodiversity with a building. In order to provide a better overview different categories of how a building can address biodiversity have been defined.

on the building
around the building
outside the building
within the building

7.2. ON THE BUILDING



7.2.1 GREEN ROOF

Generally the roof offers a large space available to be used for contributing towards biodiversity. Building up a green roof creates a large green area with different potential habitats potentially benefiting multiple plants and animals. For the vegetation, native plants adapted to the harsher conditions should be chosen. The resulting green roof "can be supporting a whole range of invertebrates" [88] like insects, spiders, worms and beetles for example. [89] It is important to underline that with the green roof being high above the actual ground, a different type of habitat is being created. This means that a green roof does "not directly compensate" [90] for the initial ground on which the building has been constructed.

It can however create opportunities to thrive for different species like certain butterflies or birds for example. In general there will be a contribution towards biodiversity since the conditions for native plants are being created, leading to the arrival of invertebrates looking for food, which in turn will attract bigger animals like birds for example. The "array of insects and the seeds produced by the flowering plants" constitute a good source of food for a range of birds. [91] However next to the promising prospects for biodiversity, it is important to make clear that "green roofs are considered hostile environments for numerous species and the list of those that could adapt and survive high temperatures, dry conditions, and space limitations is scarce." [92]

There are three types of green roofs.
Extensive green roofs, which are rather shallow and lightweight, do not require any active irrigation or maintenance and therefore only accommodate plants that are used to harsh conditions. With the substrate depth being "one of the key features that determine plant diversity and performance", extensive roofs have less options considering the vegetation and the "desired conditions" are strongly dependant on "the moisture retention layer and substrate composition". [93] (70-150mm)
Intensive green roofs are deeper, allowing to have more substrate creating better conditions for a larger variety of plants which in turn attracts more diverse animals. This roof however requires maintenance and irrigation. (20-30mm)
Semi Intensive green roofs, which use principles of both before mentioned roofs, usually resulting in a lower maintenance budget compared to an intensive roof. [94]

For the examplary case of a small scale residential building located on an archipelago in north-east indonesia the choice has been made for an extensive roof, due to the lower mass beneficiary for a building located in a location prone to earthquakes. The choice for the right vegetation is complicated since "few considerations have been given to which

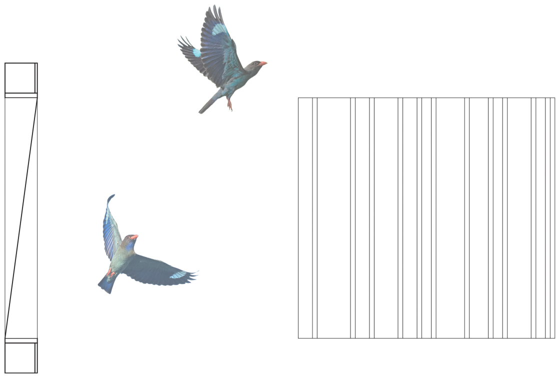
species would be suitable for green roofs in the wet tropics". [95]
Next to the potential biodiversity benefits the mass of the green roof provides "thermal stabilization" which in combination with the "evaporative cooling" of a vegetation layer leads to a decrease of 1.5°C for the indoor temperature of a building.[96] A green roof furthermore helps to buffer "storms with intense rainfall" by retaining rainwater and only releasing it over time. [98] With rainwater harvesting for human consumption in mind, a downside will be that rainwater will be polluted by organic matter leaking from the soil. [99]

From the little information available of the local fauna and flora, potential examples of plants could be 3 types of orchids (Vanda Orchid, thrixspermum, aporum) as well as morning glory (Convolvulaceae). A potential bird species which occurs on the archipelago could be the Rainbow Bee Eater for example.

7.2.2. WINDOW

Windows can be especially problematic for birds, which collide regularly with the, for them invisible, glass plane. A collision that for many of them ends in death. [100] In order to prevent these collisions there are an array of possibilities.

Silhouettes of birds can be put on windows, resulting in lesser collisions for example.
A specific kind of UV light reflecting glass makes it clearly visible for birds and can avoid collisions.[101]
Tinted or non-reflective glass can also be beneficial. Downward angled glass will reflect the ground instead of the sky and therefore be recognized as an obstacle for birds.
Another solution could be vertical lines in the glass (2cm wide & 10cm apart) which again should make the glass plane visible for the birds.[102]



For the examplary case of a small scale residential building located on an archipelago in north-east indonesia a viable option could be a downward angled window in combination with wooden vertical battens (20mm wide) in front of the glass plane. By combining these two low-tech solutions the resulting window should be fitting for the context the exemplary building will be located in.

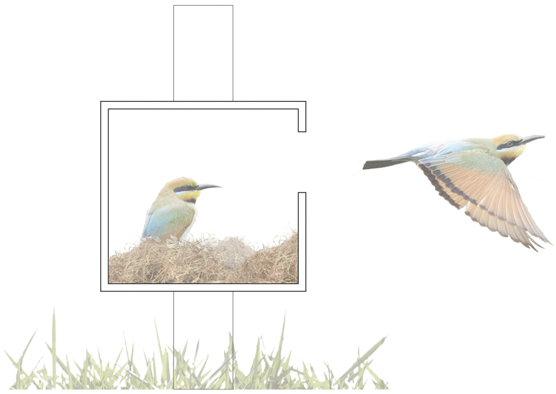
7.2.3. FOUNDATION

In the case of the examplary a small scale residential building located on an archipelago in north-east indonesia, the foundation also presents an opportunity to create opportunities for biodiversity. The building will be elevated from the ground standing on timber piles which in turn stand on foundation blocks. This is due to the presence of termites requiring a minimum height of 400mm from the ground.

A potential solution could be achieved by using dead coral rock as a foundation block. This could form the equivalent of a so called "insect-hotel", a structure that is extremely porous and therefore offers a multitude of niches and crevices should be very attractive for all sorts of invertebrates seeking shelter from wind and rain. In order to provide the right conditions to attract these animals, the coral rock foundations should be located on the sun exposed side (in this case the north side) as well as in close proximity of "nectar and pollen-bearing flowering plants, shrubs and trees".[103] It is interesting to note that the structural properties of coral stones as foundations seem to be sufficient as well. Considering the compressive strength of coral rocks, it is similar to a medium grade concrete. This concludes that it "could be adequate for domestic constructions".[104]

7.2.4. FOUNDATION POLE

As mentioned beforehand the exemplary small scale residential building will stand on pillars, which again might offer an opportunity to create habitat for certain animals. In the case of an archipelago located in north-east Indonesia, certain ground nesting birds especially in proximity to a fresh water source might be inclined to stay there. A nesting box could be installed on some of the foundation piles. As long as the shelter is on close proximity of abundant food sources, the rainbow bee-eater might be a potential species to inhabit these.

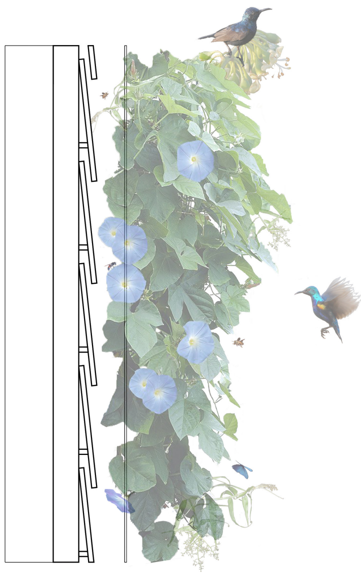


7.2.5. GREEN WALL

The walls of a building present a great opportunity to design the right conditions for plants to grow, attracting invertebrates which will in turn attract birds coming for the multiple food sources. Often dense green walls can offer good shelter for certain birds. In order to create the best chances for this to happen, it is crucial to use native plants that are "nectar rich, berry bearing and drought-tolerant".[105] Furthermore it is important to consider the orientation of the sun relative to the different facades, as this will "define which types of plants can be used".[106] In regards to the sun, a green wall can be beneficial in providing shade especially on low sun angles, preventing the sun to heat the building walls.

There are two types of green walls,
an irrigated modular green wall system, which requires much more care and maintenance

can be used in cases where there is no access to the ground and soil. The individual planting boxes need a mounting system and irrigation is most often mechanical. "for true sustainability" it is suggested to irrigate "via rain or grey water systems". [107]
A more cost effective and simpler version of a green wall is achieved by using climbing plants (vines for example) with a supporting system, made out of thin cables for example. These systems require less maintenance and can often be naturally irrigated.



In the case of the exemplary a small scale residential building located on an archipelago in north-east Indonesia, the more low tech solution seems most fitting. Especially since the scale of the building allows for a direct connection to the ground of these supporting cables on which the vines will be able to grow. The green double facade not only benefits the local animals but also the human inhabitants, since the cavity between the wall and the greenery creates "an insulating layer of air".[108]
In case of an opening behind the green facade allowing for air to flow through the plants and the building, such a green facade can lower the inside temperature to up to 6°C within the specific case of a tropical climate. This however will also lead to an increase of the interior air humidity of the building. [109]

The plants to be used within the case study could be the CONVOLVULACEAE (Morning Glory) and FLAGELLARIA INDICA. The nectar rich flowers of the "Morning Glory" could attract invertebrates like local butterflies for example and the Black sunbird (nectarine Aspiasa) for example.

7.2.6. EAVE

In close proximity to the green elements created on the same building, the eave presents itself as a sheltered space ideal for nesting boxes for local birds. These potential habitats are suitable for birds that are usually nesting in hollow tree trunks. The nesting boxes should not be placed above windows and not on the sun side of the building. Furthermore the access should be kept obstacle free and vertical plants should be accessible within 5 meters of their nests, offering food and shelter.[110]

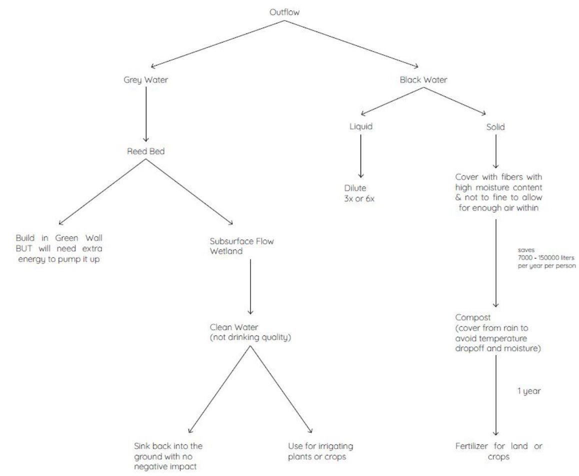
In the case of the exemplary a small scale residential building located on an archipelago in north-east Indonesia, the eave facing south, east and west might be an option. Together with the green facades and roof, ample food and shelter should be available in order to provide some of the local bird species with the right conditions to serve as a habitat for them. In this case the "Golden Bubul", a bird species endemic to the specific archipelago, might be a potential inhabitant.

7.3. AROUND THE BUILDING

7.3.1. WASTE TREATMENT

What a lot of people consider as waste can, if treated correctly, be a great resource to be used for other needs, like irrigation or fertilizing for example. For Biodiversity this means that plant growth can be enhanced through the use of fertile compost as well as clean irrigation water. A separation has to be made between grey water and black water, both coming out of the building.
Black water being constituted by the biological waste created by the inhabitants should be regarded as part of the building planning and strategy for its impact on biodiversity. Once one sees waste not as waste but as a source of energy that can be recycled and used to fertilize soils for example, new opportunities arise. If the aim of the project is to also grow food on the property, composting becomes an interesting option. For the exemplary building this research is involved in, the isolated situation on an island makes composting a very convincing strategy since it omits any need for a major waste treating infrastructure.

With the goal of composting human waste, a regular toilet will not work, instead a waterless toilet which allows to collect the waste is needed. Next to recycling valuable nutrients, a waterless toilet also allows to safe between 7000 and 150000 liters of water per year per person.[111] In combination with the right material to cover the excrements, a separation between liquid and solid waste is not needed. The covering material should be a "clean carbon-based organic material to prevent odor, absorb moistures and prepare the material for composting." Sawdust from timber processing, coconut fiber or rotten leaves are examples of usable cover materials. The filled collection buckets will have to be dumped into an "above-ground pile" which has to be covered from rain to avoid additional moisture and any temperature drop off that could hinder the necessary chemical reactions happening inside of the composting pile. After one year, once the potential pathogens are neutralized and the curing period is completed, it can be used as a fertilizer "to grow plants, trees, vines, shrubs and flowers". [112]



7.3.2. FILTRATION SYSTEM

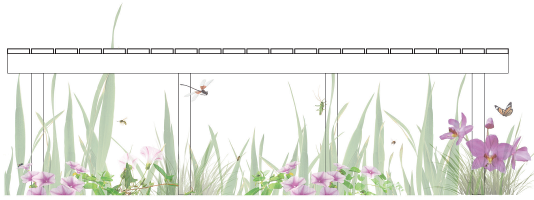
The grey water coming out of the building can be filtered with the help of a constructed wetland. These constructed systems use a combination of microorganisms within the root system of the reed plants embedded in a basin filled with inert materials like "granular leca" an expanded clay lightweight aggregate for example. A constant water flow, which "remains under the surface" will run through the reed bed made possible by a height difference between the in- and outlet. The pathogens in the grey water will be reduced by running through "multiple transformation pathways" created by alternating zones containing "different specialized families of microorganisms", resulting from higher oxidation of the water around the root systems. [113]

For the exemplary building, the "subsurface flow wetland" will be constructed with a "sand or gravel bed" and the reed used will be "Phragmites Australis" which exists in Indonesia but not on the archipelago. It will be important to contain this species exclusively to the reed bed since it is not an actual native species. Its suitability for "alternating wet and dry conditions, makes it one of the best water clearing plants for the tropics" however, is a property which motivates the use of this non-native species. [114]

A constructed wetland not only allows to filter and reuse greywater from a building without the need of any chemicals or specifically manufactured filters but also creates a biodiverse feature outside of the building. The reed plants will attract all sorts of insects which in turn constitute a great source of food for many bird species. Especially in combination with the various other habitats created on the building, this additional food source could be part of a range of conditions appealing to the "moustached treeswift" for example a bird species which occurs on the archipelago.

7.3.3. ELEVATED PATH

In order to reduce the impact on the constant circulation between different buildings or areas on a plot, one might consider the use of elevated pathways. By leaving the ground beneath undisturbed, the elevated walkway will "improve seedling survival" and can become an attractive potential habitat for plants, insects and "small wildlife". In order to not block the sunlight from reaching the ground, the wooden decking will have to be installed with sufficient gaps in between while the height of the walkway should not be too low. [115]



7.3.4. ARTIFICIAL LIGHT

When designing a building that should not disturb the local wildlife, it is important to consider the use and impacts of artificial light during the night. Artificial light disturbs invertebrates, birds, amphibians, fish and mammals alike. Often the effects can be devastating. . In the case of flying insects for example, "it is estimated that as many as a third of flying insects that are attracted to street lights will die as a result of that encounter".[116] Light can also harm invertebrates indirectly when shiny surfaces reflect the light, it will attract "egg-laying females away from water" [117] where they should be laying there eggs. As for birds, unnatural behavior has been observed as well. For example some birds start singing next to artificial light which could lead to a continual lack of sleep potentially resulting in a disturbance of the breeding season in the long term.[118] In conclusion one can say that artificial light should be avoided as this will in some way disrupt the natural cycles of the animals living in that area.

For the exemplary case of a small scale residential building located on an archipelago in north east Indonesia, artificial lighting should be kept to a minimum. Lights should only be on when needed and should never be "upward pointing". Additionally, "narrow spectrum bulbs" should be used since they "emit minimal UV light and avoid white and blue wavelengths" therefore attracting less insects. [119]

7.4. WITHIN THE BUILDING

On the smallest scale, the surface of the materials can offer a potential habitat for mosses and lychens which despite their small sizes are considered an "important part of biodiversity". Within them "a microscopic world" is manifesting itself including creatures like "rotifers, tardigrades and nematodes." [120] The material surface of these bioreceptive materials has to have various cracks and crevices in which microclimates can emerge, allowing for water retention, water storage and nutrient accumulation and consequently allowing mosses and lychens to grow. Contrary to some misconceptions, this greenery on a wooden façade for example does not harm the wood, since the plants are epiphytes, which means that they derive all nutrients and moisture from the environment without harming the substrate. [121]

7.5. OUTSIDE THE BUILDING

It is important to see the different building elements and their biodiversity potential not isolated from each other. These different parts of a building all have unique potential and can together form an attractive environment for several plants and animals to flourish. While some areas are better at providing food, others will be more interesting to provide shelter. This interconnected system works over multiple scales. From the building elements towards the building related interventions like the constructed wetland for greywater purification all the way towards the buildings in its proximity for example. The ambition should always be to create "opportunities for positive connections" between the designed building "with adjacent buildings and surrounding natural systems". [122]

8. CONCLUSION

As the consequence of our current practices are being felt and recognized increasingly, the call for a paradigm shift grows louder. A shift, as Cole and Du Plessis describe, "that acknowledges the world as a complex, dynamic system" [123] Aware that the built environment and generally how people live, does have a considerable impact on the natural world of which we are a part and therefore dependent of, different ways of "designing, producing, building and consuming" [124] should be explored.

The Regenerative theory which shares the same ambitions sees a broad "change in perception" of the people towards the world they live in as the core solution in order to arrive at a notable positive change. [125] Clear practical guidelines for a regenerative design however are not well described yet posing a hurdle for its implementation. Furthermore the importance of biodiversity and the lack of addressing it within the built environment are underlined. Attempting to lay out a basic approach for designing towards biodiversity that can be followed by an architect or developer, certain practices from the field of landscape architecture are explored and applied. Finally the potential to play a supportive role towards biodiversity of a small scale residential building is identified and context specific examples of different building elements and their biodiverse potential are displayed.

This paper is intended to give a brief overview as well as simple practical examples of how a small scale building could create the right conditions which the local fauna and flora could find useful.
While the proposed solutions should work in theory it is not sure at all whether they will work in practice. This paper therefore gives suggestions but no promised solutions. Furthermore it has to be underlined that in order to have the best possible design for biodiversity it is imperative to work together with an ecologist or biologist specialized on the local fauna and flora throughout the entire design phase of the project as well as the monitoring phase after completion.
For further research it would therefore be highly valuable to work together with such an expert in order to set up more precise area specific guidelines. This could be a much needed step towards a built environment that has "net positive environmental benefits for the living world".[126] Which could then be used by any architects and developers from that area.

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