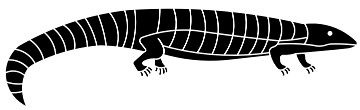
Towards Multispecies Spaces

Rethinking architectural practice
in the context of urban biodiversity loss



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Abstract

The loss of biodiversity is one of the defining issues of our time. Even though cities provide valuable spaces for many animal and plant species urban habitats are endangered by increasing densification. By fragmenting habitat networks, the built environment currently poses one of the main causes for biodiversity loss in urban areas. Urban biodiversity strategies are often lacking practical approaches to tackle the conflict between nature conservation and urban development. This shortcoming calls for a new and systematic design approach that reconciles the spatial needs of human and non-human inhabitants.

This thesis aims at developing a framework prototype for determining points of intervention in the urban sphere as well as finding ways to incorporate animal species needs into planning and design process. The methods used include a geospatial network analysis of the example city as well as an experimental design process. The analysis aims at determining building sites suitable for the application of a Multispecies Design framework. Based on the analysis as well as species occurrence data, one exemplary animal species was chosen to develop the design framework. Parameters for the design process were determined and tested throughout the process and include the spatial and climatic habitat requirements of the chosen animal species. In a multilevel process, these parameters were iteratively merged with requirements given by building regulations and site context through the Rhinoceros' computational design and analysis plugin Grasshopper and its extensions, Kangaroo, Anemone, and Ladybug. Three main design scales were approached and schematically articulated throughout the process: building mass distribution, building zoning, and habitat geometry. This process resulted in a complex network of parameters, tools and actions which were then organized to outline the framework. Additionally, the framework was exemplarily illustrated, and the findings of the process evaluated within the scope of the thesis.

As a result, urban wastelands were determined as potential intervention points to apply a Multispecies Design framework as they constitute building land as well as biodiversity hubs. The potential of Multispecies Design to converge urban development and nature conservation lies in integrating ecological knowledge into the process and acknowledging the site as part of a natural ecosystem. The necessity but also the challenge of integrating ecological knowledge into architectural practice became evident during the process. By thoroughly documenting the framework design process, moments in time when ecological knowledge is needed are mapped out and provide orientation points for multidisciplinary collaboration. Finally, the design process showed the potential of computational design as tool to address the problematic impermeability of contemporary building typologies. The insight resulting from design investigations is that to diminish the barriers created by the built environment a new urban typology is needed and could be approached through computational design. Adapting building mass and space distribution based on data derived from simulation and environmental information in Rhinoceros and Grasshopper points at a new field of informed space articulation that could potentially converge human and non-human needs.

Keywords: Multispecies Design, Urban Ecology, Articulated Landscape, Wastelands

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Introduction

1.1 Background

Urbanization is a threat to biodiversity (Aronson et al., 2017; Puppim de Oliveira et al., 2011; Sukhdev et al., 2013). Yet, urban areas can provide valuable habitat for many animal and plant species (Sukhdev et al., 2013). The built environment causes serious disruptions to habitat networks and therefore hinders animal movement through the landscape (Jongman et al., 2004). Green infrastructure (GI) is an approach to preserve habitat connectivity and promote biodiversity at regional and national levels (Ahern, 2007; Lennon & Scott, 2014). The Berlin biotope network is a city-wide concept that similarly targets the preservation, restoration, and development of functional and ecological interconnections in the landscape (Strategie zur Biologischen Vielfalt Begründung & Ziele, 2015). Located within this network are areas of particular interest to developers as well as to many rare plant and animal species. These sites, referred to as wastelands among others, are abandoned places with spontaneous vegetation (Gandy, 2013). Due to their historical particularities, they provide habitats and dispersal corridors for a variety of rare animal and plant species. However, due to the need for housing and the lack of building space in many cities, urban wastelands are considered in densification strategies that includes the activation of vacant urban spaces to minimize urban sprawl (Böhme et al., 2006).

1.2 Problem Statement

The built environment poses one of the main causes for biodiversity loss in urban areas (Jongman et al., 2004). Even though listed rare animal and plant species are protected by law, their habitats are prone to fragmentation and isolation due to enormous densification pressure. Furthermore, the complexity and fragility of habitats is not acknowledged in nature and habitat protection laws. Even though many habitats are protected, the corridors animal and plant species rely on for various reasons are not included (Hauck & Weisser, 2015). If development projects are built on or close to ecological networks, they create movement barriers for non-human animals. Hence, if urban wastelands are not developed with their non-human users in mind, ecological networks will be seriously disrupted. At present rare animal species are being resettled to assumingly suitable compensation areas, when found in a building site. This measure potentially weakens the already fragile central areas of ecological networks as most compensation areas can be found in semi-urban or rural sites (Senatsverwaltung für Umwelt, 2017). The current anthropocentric planning and design practice produces building typologies impermeable to non-human animals, restricting species to move freely through the landscape (Dr. Kwet et al., 2021).

To which extend the natural world is included in building design is manifold and depends on the intended contribution to biodiversity preservation. Some strategies like Nature Based Solutions (NBS) and often citizen initiated projects are aiming at increasing overall biodiversity by creating more urban green (e.g., Madre et al., 2015), others intend to create novel habitats on building envelopes (Monarch Sanctuary, 2019) or the exterior space of buildings (Hauck & Weisser, 2021) inspired by specific animal species' needs. Some are strengthening the human-nature connection by creating new spaces of encounter between the human and the non-human world (Platform for Humans and Birds, 2021). Despite this variety of designs and concepts, a strategical application of ecological knowledge to establish urban ecological networks is missing. Due to the place-based reality of architectural projects, design proposals are usually limited to construction site boundaries and rarely incorporate the complex habitat network systems it is embedded in. This shows a gap between biodiversity concepts like biotope networks and the spatial articulations to improve their structure. In addition to the place boundedness, Multispecies Design proposals, meaning 'the practice of designing systems and artefacts that address the needs of humans as well as wild animal species' (Metcalfe, 2015) are currently limited to the exterior of the built environment and often included at later stages of the building process (Hauck & Weisser, 2015).

1.3 Research Questions and Objectives

The primary research question of this thesis is how a paradigm-shift towards Multispecies Design could be further articulated in the urban context. The general objective is to develop a methodical approach for reconciling human and non-human need for space on conflicted building sites. The aim is to establish and illustrate concrete steps for integrating ecological species knowledge into the design process. The intent is to investigate a possible framework implementation within a concrete urban setting and to thereby articulate knowledge gaps, helpful tools, required data, and promising topics for future explorations.

1.4 Methodology

Urban biodiversity, the dichotomy of nature and the built environment, urban wastelands and their importance for biodiversity are studied through reviewing the literature. My focus is on ecological networks and the inherent species' specific habitat requirements. Information collected from the literature and via case studies in the novel field of Multispecies Design are used to determine a target species and simplify its habitat requirements into parameters. In an iterative and intuitive process, these parameters are diagrammatically integrated into the design process. In this thesis, the possibilities of computational design thinking provide the tools for generating a complex and responsive framework model. The discussion of the design process and findings are based on a literature review, conversations with an urban ecology expert, and the authors current knowledge about design with a multispecies ethos.

1.5 Limitations

My thesis discusses urban planning and building design from a multispecies perspective. Therefore, the importance of urban wastelands as unregulated sites for exploring freedom, space appropriation and placemaking for citizens is acknowledged but is not included in the literature review.

My goal is to create a scalable framework for integrating habitat requirements into new buildings, planned in areas equally important for humans and non-humans. On these grounds the focus is on the process of finding those sites and integrating habitat parameters into the design. Due to the specific scope of a master thesis, spatial articulations of the classical scales of urban design were reduced to a diagrammatic level. Therefore, anthropocentric architectural design parameters like daylight incidence, building depth and project costs were of secondary importance.

Biodiversity is a highly intricate construct consisting of interconnected living elements and ecosystems. Creating novel habitats for endangered animal species is equally complex and would generally require the cooperation with experts from the field of ecology and biology as well as extensive experiments and research. To make the thesis tangible for architecture and urban planning professionals, I therefore limited the design exploration to one animal species whose habitat provides living space for many other species as well.

My basic software skills in Rhinoceros and Grasshopper were challenged and improved during the process of developing the framework concept. The variety of approaches for responsive and adaptive design was acknowledged and the chosen differential curve growth algorithm is only one of innumerable ways to go for creating complex habitat geometry. The change in scale and complexity from human to animal could for example also be explored with space colonization, cellular automata, or differential edge growth algorithms.

1.6 Thesis structure

The thesis is structured into four chapters: Introduction, Literature Review, Methodology and Framework, and Conclusion. After the introduction, the Chapter Literature Review will present and discuss research related to the topics of urban biodiversity, urban wasteland, and multispecies design. The aim is to explain why a multispecies perspective is relevant in the context of urbanization and biodiversity loss and what role urban wasteland could play in this discussion. The third chapter (Framework) applies gained knowledge from the literature review to develop and test the methodology for the multispecies design framework. In the final chapter, I discuss knowledge gained throughout the process. The research questions and the framework's potential will be discussed and evaluated. Furthermore, I discuss potential shortcomings of the framework, and outline possible further steps.

1.7 Terminology

Algorithm = 'A step-by-step procedure for solving a problem. An algorithm usually takes an input, performs a process, and creates an output' (Jabi, 2013)

Anthropocene = 'The period of time during which human activities have had an environmental impact on the Earth regarded as constituting a distinct geological age' (Merriam-Webster, n.d.-a)

Biodiversity = The diversity within species, between species, and of ecosystems (Díaz et al., 2019). This thesis uses the term primarily for describing species diversity and population size in a specific area.

Biotope = 'A region uniform in environmental conditions and in its populations of animals and plants for which it is the habitat' (Merriam-Webster, n.d.-b)

Ecology = The study of living organisms and their environments. 'Includes all living organisms and the inert or non-living physical aspects of that ecosystem such as air, soil, water and exposure to the sun', also human-made ecosystems (Holden & Liversedge, 2014).

Ecosystem services = The benefits that ecosystems provide for humans, and all the benefits that humans get from nature. Their contribution to human well-being defines ecosystem services since they are end products of various ecosystem functions (Sukhdev et al., 2013).

Green infrastructure (GI) = 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' (European Commission, 2013).

Habitat = 'The natural environment in which an animal or plant usually lives' (Cambridge Dictionary, n.d.)

Nature-Based Solutions (NBS) = 'Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits' (IUCN, 2016)

Parameter = 'A parameter is just a number, often one of several, that can define the state or behavior of a system (or, in computer coding, a value given as input into a procedure; other resulting values or behavior are determined by this parameter)' (Ervin, 2018). In the thesis, the term is understood more broadly as measurable information

Parametric design/ modeling = 'A process based on algorithmic thinking enables the expression of parameters and rules that define, encode, and clarify the relationship between design intent and design response' (Jabi, 2013)

Simulation = 'A model of a set of problems or events that can be used to teach someone how to do something, or the process of making such a model' (Cambridge Dictionary, 2020a)

Urban Green Infrastructure (UGI) = 'The strategically managed network of urban green spaces and natural and semi-natural ecosystems situated within the boundary of an urban ecosystem' (Joachim et al., 2019)

II

The Multispecies City

Urban Wastelands

Multispecies Design

Literature Review

This literature review positions the thesis within the context of the contemporary conflict between the built environment and nature and the pivotal role the emerging field of Multispecies Design could play in creating biodiverse cities. The first section of this chapter outlines the topic of the city as habitat, the concept of Green Infrastructure (GI), its importance for species inhabiting the urban environment, the impact of urbanization on GIs, as well as an introduction to Berlin's biotope network strategy. The second section provides information about urban wastelands in the context of GI and outlines the conflict these special land use types are under in terms of biodiversity and urban densification concepts. The third section introduces the field of Multispecies Design and outlines its potential to strengthen habitat networks.

2.1 The Multispecies City

This chapter outlines the concept of biodiversity, the role cities play for nonhuman species, and the current challenge of biodiversity loss. In this context I focus particularly on habitat fragmentation and loss due to urbanization. Furthermore, the strategy and shortcomings of GI will be summarized and elaborated using the example of the Berlin biotope network concept.

2.1.1 Why the urban fabric needs greenspaces

The term 'biodiversity' is commonly used to describe the number of species in a habitat or community. In this context, biodiversity can also be referred to as species richness (Díaz et al., 2019). Generally, the term biodiversity can also discuss the number of genotypes or ecosystems, the balance of their distribution, the variety in functional attributes, as well as their interrelations (Hooper et al., 2005). In this thesis, the term biodiversity is used mainly to describe species richness within an area. The functioning of all ecosystems is related to a high amount of plant biomass, plant cover and species richness, thus biodiversity plays a crucial role for the planet's health and resilience (Hooper et al., 2005).

Through an array of activities, mainly to meet the growing demand for resources, humans are altering ecosystems at various scales. This causes changes in their structure and usually results in substantial and often irreversible loss of biodiversity and a decrease in ecosystem services. (Reid et al., 2005). The term 'ecosystem services' was introduced in the late 1990s to establish an awareness of nature's value (Schröter et al., 2014). It refers to the direct and indirect benefits of ecosystems to the well-being of humans (Sukhdev et al., 2013). Functioning ecosystems are vital for all life on earth, including humanity as they provide us with food, water, and a regulated climate amongst others (Reid et al., 2005).

Even though alterations of ecosystems have a negative impact on biodiversity, urban environments can often have higher species richness than their surrounding landscapes (Ives et al., 2016). This is inter alia due the fact that cities were often strategically built on areas with beneficial geographical and geological characteristics like fertile soil, accessible topography, freshwater availability, and mild temperatures (Kühn et al., 2004). Even though urban areas have always been home to many animal and plant species, the field of urban ecology emerged relatively recently, during the 1970s (Soulsbury & White, 2015). With increasing urbanization rates, the field is gaining importance as the need to understand its influence on urban nature to avoid irreversible destruction of ecosystems constantly becomes more pressing. Urban environments particularly host more threatened species than non-urban areas (Ives et al., 2016). This makes cities a crucial place to target species protection measures.

2.1.2 Urbanization and habitat fragmentation

The rate of urbanization is increasing with already over half of the planet's population living in cities (Seto et al., 2012). Urban growth in recent decades has been mostly in the form of urban land expansion rather than population growth (Sukhdev et al., 2013). Even though cities are still home to a large variety of animal and plant species (Newbold et al., 2015), physical urbanization such as land-use change has likely caused the local extinction of thousands of species throughout human history, even without considering regional and planetary effects in the longer term (Díaz et al., 2019). Urban development damages biodiversity mainly through land disturbance and conversion to impervious surfaces, the removal of native vegetation, and the introduction of non-native species, and the fragmentation and isolation of remaining natural areas (Bryant, 2006). This thesis focuses on the challenge of habitat loss and fragmentation (Fig 1).

The term habitat fragmentation is often used to describe the reduction of continuous tracts of habitat to smaller, spatially distinct remnant patches (Fahrig, 2017). Habitat loss typically occurs concurrently with habitat fragmentation (Collinge & Forman, 2009). Habitat fragmentation and its effect on biodiversity is an extensively researched topic. Differing approaches of measuring fragmentation as well as a lack of distinguishing between habitat fragmentation and habitat loss resulted in aberrations of conclusions and interpretation of the effect. Generally, it can be said that habitat loss has a stronger negative effect on biodiversity than habitat fragmentation (Fahrig, 2003). However, it is generally acknowledged that by dividing existing populations into often small and isolated groups, fragmentation is changing the characteristics of the remnants with time and thereby contributes essentially to local species extinction (Baur & Erhardt, 1995).

Furthermore, the designation of protected areas has not stopped the decline of numerous animal and plant species as the loss of areas specific to the species far exceeds that of new protected areas (Díaz et al., 2019).

The preservation and promotion of urban biological diversity and its ecosystem services is a goal of many regional, national, and international strategies (Aronson et al., 2017; Puppim de Oliveira et al., 2011). Green Infrastructure (GI) is one of the leading approaches to promote sustainability and climate resilience by incorporating natural processes into spatial planning policies and practices (Ahern, 2007; Lennon & Scott, 2014). The European policy framework defines Green Infrastructure as 'a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services' (European Commission, 2013). The concept applied to the urban context is diversely and broadly defined, among others by Benedict and McMahon as 'an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife' (Benedict & McMahon, 2007). Irrespective of its increasing recognition (Mell, 2017; Wright, 2011) Green Infrastructure is, regarding the appropriate scale, function, and precise implementation, still a broadly defined concept (Lähde, 2020). In this thesis, the term Green Infrastructure is used to refer to the strategic approach to maintain and connect the elements of the Berlin biotope network concept, introduced in the following chapter. I chose Berlin as an example case based on the availability of easily accessible species occurrence data. The biotopes, potential habitats, existing and potential dispersal corridors mapped in the Berlin biotope network concept provided the base for envisioning the multispecies design framework.

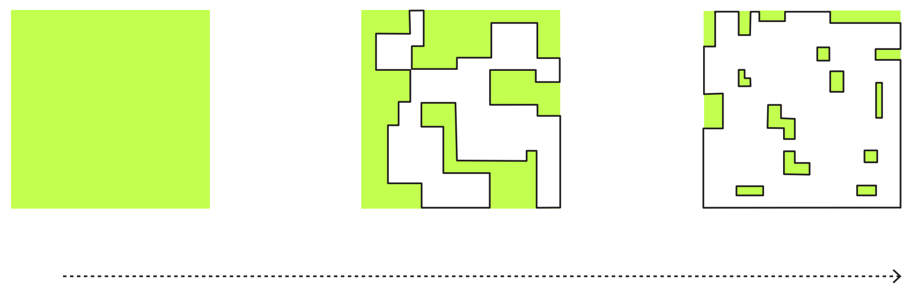


Figure 1
The process of habitat fragmentation where a large expanse of habitat is transformed into a number of smaller, isolated patches

2.1.3 The Berlin biotope network concept

In 2012 the senate of Berlin released its own strategy for the conservation and promotion of biodiversity. It focuses on special characteristics of urban habitats and covers topics like species and habitats, genetic diversity, urban diversity, and society (Peters et al., 2022). The concept is supported by a strategic planning instrument for the protection of nature and landscape in Berlin, the *Landschaftsprogramm einschließlich Artenschutzprogramm* (LaPro).

The LaPro is an instrument for daily work in planning and administration. Due to LaPro, nature conservation and landscape conservation are increasingly considered in land use planning. It is binding for all authorities in the country dealing with area developments, urban planning and landscape planning competitions or similar tasks. LaPro was passed in 1994 and supplemented in 2004 with the city-wide compensation concept, Gesamtstädtische Ausgleichkonzeption (GAK) (Senatsverwaltung für Umwelt Verkehr und Klimaschutz, 2017).

In collaboration with the LaPro and the species protection program, the implementation of the biotope network aims at establishing a network of connected biotopes to permanently secure the populations of wild animals and plants, their habitats, biotopes, and communities. Functional ecological interactions, migration and natural dispersal corridors should be preserved, restored and developed to ensure genetic exchange between the populations found in Berlin. The biotope network strategy is based on a target species concept which focuses on 34 representative animal and plant species that are particularly dependent on spatial and functional connections and from whose protection other species can benefit. The basic structure of the biotope network is identified in the new LaPro, which specifically refers to the actual and potential habitats of these target species. The biotope network consists of biotopes, the core habitat areas of each target species, and network corridors, areas which are connections between biotopes but not biotopes themselves. These include 43 nature reserves, 15 NATURA 2000 areas, national natural monuments, biosphere reserves or parts of these areas, parks, graveyards, and the former border strip of the Berlin Wall. Furthermore, linear biotope connections are of importance and include waterbodies, riverbanks, and areas along the transport routes, especially along railway lines. Built up residential areas are also important for the biotope's network function as up to nine target species are existing in these areas.

One important land use type for the biotope networks are wastelands. These areas are of special interest to my thesis and is further elaborated in the following chapter. Species distributions were visualized in target species maps with potentially suitable areas and areas with connection structures (Fig 2).

Generally suggested measures to improve biotope networks include the design of near-natural banks, the protection of reeds, the creation of culverts or the use of native species for greening, the partial cleaning of dense vegetation, forest aisles, and the development of forest edges into structurally rich fringe biotopes. At the regional level, linear and punctiform elements required to connect biotopes, in particular hedges and field borders as well as steppingstone biotopes, are to be preserved, especially in landscapes shaped by agriculture (Peters et al., 2022). Even though the biotope network

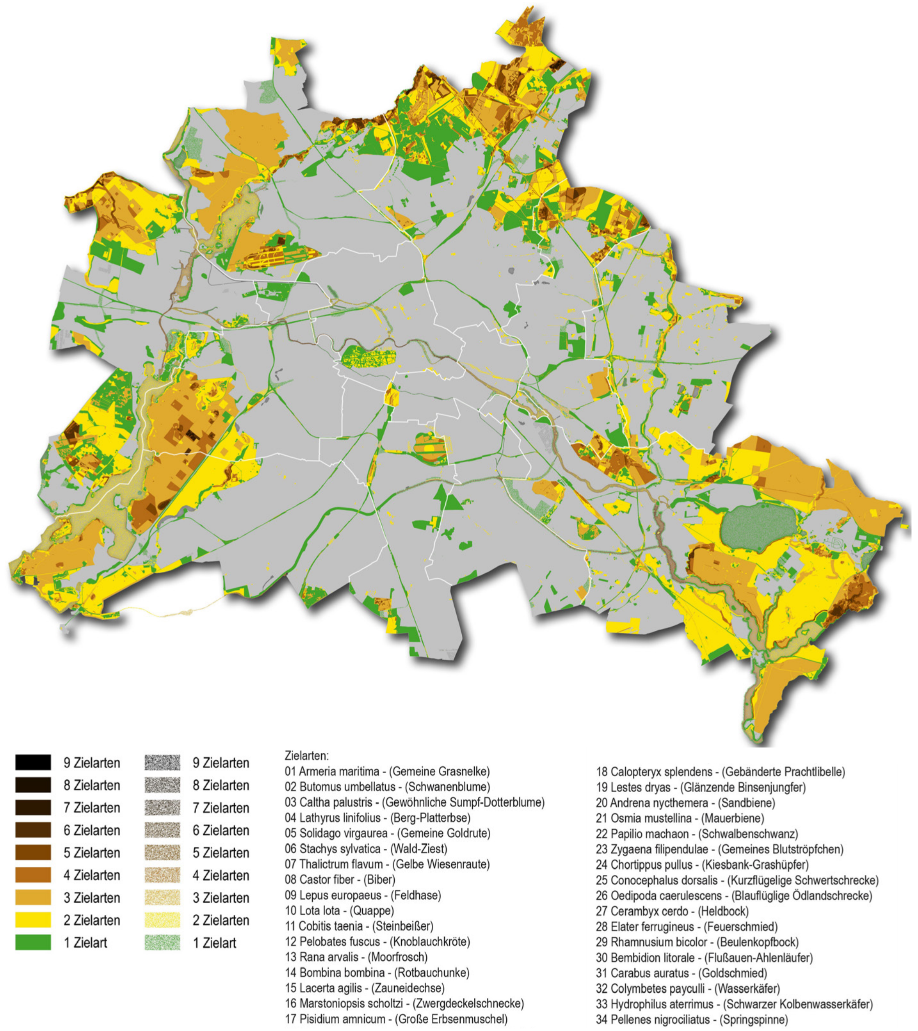


Figure 2
Map of the Berlin biotope network. Overlapping of potential core and connecting areas of the target species in Berlin 2009 (Senatsverwaltung für Stadtentwicklung)

is included in LaPro it is not legally binding. Particularly the areas which function as corridors between biotopes are not protected by law, LaPro solely suggests considering measures to ensure habitat connectivity in (future) settlement areas (Gesetz Über Naturschutz Und Landschaftspflege (Bundesnaturschutzgesetz-BNatSchG), 2009).

2.1.4 Key findings of chapter 2.1

1. Because the functioning of all ecosystems is linked to biodiversity, protecting, and promoting it is crucial for the planet's health and human and non-human well-being (Hooper et al., 2005).

2. Urban environments can be seen as pivotal element to target biodiversity conservation and promotion measures because they often host many threatened species (Ives et al., 2016).

3. Urban development damages biodiversity by for example causing fragmentation and isolation of remaining natural areas (Bryant, 2006)

4. Even though nature conservation concepts like Green Infrastructure are widely recognized, the loss and fragmentation of urban habitats is ongoing (Díaz et al., 2019) and practical implementation approaches are lacking.

2.2 Urban wastelands

Although habitats in urban areas suffer from high fragmentation rates, this mosaic of heterogeneous open spaces creates interesting and diverse habitats. Besides parks, gardens, and urban forests, some species thrive in other urban green spaces like street trees, green roofs, and vacant lots (Oliveira Hagen et al., 2017). The following chapter will take a closer look at vacant open spaces, their origin, characteristics, and their importance for urban biodiversity. Finally, the conflict between new development and urban nature will be outlined by the example of this extraordinary land use type.

2.2.1 Context

The complex relationship between the social and natural context wastelands shows in a diversity of often philosophical approaches to define urban vacant spaces. There is no unified definition of the term as precise cultural or political connotations of urban vacant spaces are interconnected with wider dynamics of historical changes in planning and urban dynamics (Gandy, 2013). In the Anglo-American urban planning context, the commonly used term *fallow land* has its origin in agriculture as a term for an uncultivated field that is left for regeneration purposes in a three-field system. In this system, the field is being taken out of use to improve soil structure and hydrologic balance (Herbst & Herbst, 2006). The term *brownfield* implies a more technical definition of these sites, indicating former industrial land use. The geographer and urbanist Matthew Gandy uses the term *wasteland* as an English equivalent to the German term *Brache* to describe 'marginal sites of spontaneous nature' (Gandy, 2013). The Oxford English Dictionary defines wasteland as 'an empty area of land, especially in or near a city, that is not used to grow crops or built on, or used in any way' (Cambridge Dictionary, 2020b). Other terms relate rather to radical architectonic discourse than to their characteristics of use. For example, 'edgelands, interim spaces, interstitial landscapes' (Gandy, 2013), and *terrain vague* (de Solà-Morales Rubió, 1993).

The common emphasis of all these definitions is on the unproductive characteristics of a site in relation to agriculture, industry, or former land uses. More recently, the terminology used by ecologists for unused spaces changed from brownfields to terms which display the increased recognition of the value of those sites for biodiversity. The term *open mosaic habitat* was introduced by urban ecologists and nature conservationists to emphasize the complexity and species richness of those spaces (Bonthoux et al., 2014). In this thesis, I use the term wasteland based on Gandy's reference to 'ecological refugia' or 'islands of biodiversity' (Gandy, 2013).

2.2.2 Biodiversity hubs and urban densification

The first wastelands emerged due to the distructive nature of wars or other catastrophes. During the economic structural changes from the industrial to the service society, combined with demographic decline, these sites became a more common phenomenon in many European and North American regions (Kowarik, 2018; Martinez-Fernandez et al., 2012). As the definition of wastelands is broad, spaces included in the definition vary. Spaces falling into the definition include open spaces after housing or infrastructure demolition (Gardiner et al., 2014), vacant railway areas and railway verges (Albrecht et al., 2011) and post-industrial sites (Gallagher et al., 2008). Due to their variety in age, wastelands' vegetation stages range from pioneer to pre-forest, and therefore offer an abundance of habitat for different plant and animal species (Twerd & Banaszak-Cibicka, 2019). Wastelands are therefore often seen as urban biodiversity hubs (Goddard, Dougill, & Benton, 2010; Kowarik, 2011; Rega-Brodsky & Nilon, 2016; Rudd, Vala, & Schaefer, 2002; Snep, Van Ierland, & Opdam, 2009).

In Germany, a reduction in land consumption has been a declared political goal for many years. In 2004, the federal government published a national sustainability strategy to promote internal urban development over external urban development and to reduce the daily land uptake from 93 ha per day to 30 ha in 2020 (Böhme et al., 2006). The increasing pressure on urban land, and ecological considerations like the protection of areas surrounding cities are pushing land use decisions towards wasteland rather than green and open spaces (Böhme et al., 2006).

Approaches for integrating valuable wastelands into planning schemes, for example as new green space for urban dwellers, already exist (Rall & Haase, 2011; Unt & Bell, 2014). Here the goal is to increase the acceptance of urban wasteland as valuable green spaces, and therefore ensuring their conservation. However, wastelands that are not high in biodiversity per se but crucial dispersal corridors within habitat networks like the biotope network in Berlin, are rarely perceived as valuable and are kept in their current state. These potentially valuable spaces are not protected from urban development by law like actual habitats in the Biotope network. But if they are developed with the current anthropocentric design approach, these sites could produce barriers in urban ecological networks and could consequently contribute to habitat fragmentation.

2.2.3 Key findings of chapter 2.2

1. The negative connotation of urban wasteland as unproductive and neglected sites experienced a positive shift when urban ecologists recognized their importance for urban biodiversity (Gandy, 2013).

2. Even though a wasteland's high level of biodiversity is acknowledged, the high pressure of urban development goals often leads to the destruction of these sites and therefore to habitat fragmentation and loss.

3. Strategies to protect valuable urban wasteland exist, however, they are place bound and do not take the crucial connectivity of urban habitat networks into account.

2.3. Multispecies design

The previous chapters have outlined the importance of non-human life for the planet's health, and the ongoing destruction of urban habitat networks. This chapter aims at approaching the question of how to make cities more hospitable to non-human life and avoid damaging urban habitats in the future by integrating non-human species into the planning process of urban infill development. This chapter outlines the emerging paradigm shift towards Multispecies Design, discusses its potential to increase urban biodiversity, and to strengthen urban habitat networks.

2.3.1 Emergence of a multispecies awareness

To understand the meaning of a *more-than-human* (Roudavski, 2020) or *multispecies design* (Metcalfe, 2015), it is vital to acknowledge the persisting believe of a dichotomy between culture and nature in the new geochronological era we call the *Anthropocene*. Human-animal relations have always been characterized by the assertion of the dominance of human over non-human, for example by hunting or domestication (Fry, 2014). Until today, a human-centered mindset prevails in the Western worldview and produces environments which fulfill human demands for aesthetics and functionality, generally by ignoring non-human needs (Dodington, 2014; Hauck & Weisser, 2021). Even though non-human life forms are part of our city and our everyday life, the common understanding of culture and urban life excludes nonhumans and nature in general (Griffiths & Dunn, 2020). Seen from the opposite perspective, nature protection zones, represent the same separation of animal and human territories (Hauck & Weisser, 2015).

The shift towards multispecies design promotes urban systems as an integral part of our ecosystem with the aim to include wild animals into human habitats (Metcalfe, 2015). In this thesis, I use the term multispecies design based on Metcalfe's definition as 'the practice of designing systems and artefacts that address the needs of humans as well as wild animal species' (Metcalfe, 2015). The goal is to increase sensitivity and acceptance of human-animal interactions in urban environments by purposefully designing shared spaces. Despite persistent power relations between human and non-human animals, multispecies design can be used 'as a tool for reconciliation, inclusion and promoting empathy' (Metcalfe, 2015).

2.3.2 Contemporary and future discourse

Despite the diversity of sustainable design approaches, the discussion about architecture and design as an active player in tackling biodiversity degradation is still developing (Metcalfe, 2015). Design usually focuses on minimizing its negative effects on natural systems rather than intentionally addressing nature as another stakeholder (Delesantro, 2020). A harmonious coexistence of human and non-human animals in urban green spaces is often visualized in contemporary architecture and landscape design concepts (Hauck & Weisser, 2021), indicating a shift towards a new nature-integrative mindset. However, the attitudes towards wildlife in urban areas differs greatly between nature conservationists, advocating for least human interference with nature, and (landscape) architects, aiming at including nature into a design but often with little consideration about biodiversity and non-human needs (Hauck & Weisser, 2021). Hence, non-human animals are still often overlooked in spatial planning and design (Wolch, 1996, 2002).

Considering ecological network barriers created by dense built structures, a modification of current design practices towards the integration of non-human animals and the incorporation of ecological knowledge could potentially increase the city's permeability and incentivize the settlement of native animal and plant species (Parris et al., 2018). In fact, focusing on individual species proved to be a successful approach because detailed knowledge of a species' biology and its habitat requirements enable practical action programs (Völkl et al., 2011) and could therefore contribute to reaching biodiversity conservation goals. In this context and at the intersection of ecology and design, artificial habitat structures are one approach to support animal populations in disturbed environments (Watchorn et al., 2022). The strategy is to alter or substitute natural habitat structures in areas degraded or disturbed through human interference. As this approach is mainly targeted at spaces for explicit animal activity like nesting, hibernating, or basking, rather than whole habitats (Cowan et al., 2021), it currently operates at smaller spatial scales (Esteban et al., 2018).

Currently, aspects of animal ecology are considered in planning and approval procedures and are implemented via various examination instruments. Legal regulations that provide the framework for considering animals in planning and assessment are in Germany the Federal Nature Conservation Act, the Environmental Impact Assessment act (EIA), and the Federal Building Code. These frameworks act mainly for the goal of conserving nature and landscape, and therefore animals indirectly. The Nature Conservation Act for instance provides instruments for the promotion and resettlement of animal species. (Gesetz Über Naturschutz Und Landschaftspflege (Bundesnaturschutzgesetz-BNatSchG), 2009; Strategie zur Biologischen Vielfalt Begründung & Ziele, 2015).

Planning concepts targeting the conservation of biodiversity like Green Infrastructure or Nature-Based Solutions (NBS) (Benedict and McMahon, 2012; Eggermont et al., 2015; European Union, 2013; Tzoulas et al., 2007) are often imprecise regarding animal conservation (Hauck & Weisser, 2021). Even though there are various ecological tools for animal conservation, planning for the more-than-human still appears hypothetical when compared to the prevailing practice of architecture and urban planning (Parris et al., 2018). The question is how the occurrence of animals can be included in the processes of urban planning and the design of open spaces (Hauck & Weisser, 2021). Speculating further on this approach, I see potential of multispecies design to be applied in a systematic way to increase connectivity of habitat networks.

2.3.3 Key findings of chapter 2.3

1. Non-human life permeates the urban fabric, however, acknowledging and integrating it does not play a major role in current design practices.
2. Multispecies design bridges the gap between design and urban ecology by integrating ecological knowledge and perceiving the city as part of natural ecosystems.
3. The arising multispecies design paradigm shift has the potential of sustaining biodiversity within human-dominated areas, and of creating more opportunities for humans to interact with other species in a meaningful and respectful way.
4. In the context of urban planning and design, multispecies design still appears hypothetical and requires further articulation.

III

Methodology

Framework process and prototype

Conclusion

Framework

The imminent multispecies paradigm shift in contemporary planning and design discourse requires rethinking of the architectural practice itself and provides an opportunity to augment urban planning and architectural design processes. The literature review presented reasons for acknowledging and integrating more-than-human stakeholders in the composition of the urban fabric. However, practical implementation examples are missing. Due to the novelty of this field, the challenge of developing a new integrative approach was met by formulating questions. “How does planning and architectural design need to adapt when integrating more-than-human needs into the process?” and “How can planners determine target areas for applying multispecies design?” were two broad questions arising at the beginning. The structure of this process, the choice of design tools, the step-by-step process, and the framework structure that emerged along the way are described in the following chapters.

3.1 Methodology

With the goal to further articulate the use of multispecies design in the urban context, the method of choice was to iteratively investigate its implementation within a concrete urban setting. The process structure evolving from this intuitive and experimental approach started with a general question which was gradually refined and rephrased throughout the process (Fig. 3). Meanwhile, I determined data sources and tools to generate the required information leading to the next question. The tools corresponding the questions were manifold and included literature reviews, geospatial analysis tools (GIS), site and building plan analyses, environmental simulations (Ladybug), and computational modeling tools (Rhinoceros and Grasshopper). Throughout this process, relevant findings, knowledge gaps, and potential areas for future research were documented and provide the foundation for the final discussion.

3.1.1 Computational design and thinking

The vastly explorative approach of this thesis required discovering, visualizing, and utilizing complex and dynamic interrelations of human and non-human flows and spaces, spatial requirements, specific but often opposing, as well as their potential spatial articulations. Based on the iterative nature of this process, I worked with computational design and simulation tools as they enable to work with dynamic parameters and in an explorative manner and can be used to systematically generate information (Cantrell & Mekies, 2018; Walliss & Rahmann, 2016). Furthermore, computational design enables the exploration and evaluation of complex solutions, the creation of intricate spatial articulations, and substantially increases the flexibility of the design process (Caetano et al., 2020). Thinking computationally helped me to critically develop a logical sequence of steps, and the formulation of rules to approach the goal step by step. In this thesis the definition of the term computational thinking was adapted from Wassim Jabi who described the approach as "step-by-step techniques that allow designers to rationalize, control, iterate, analyze, and search for alternatives within a user-defined solution space. Furthermore, he mentions that "Computational design (...) enables the discovering between design intent and design response (Jabi, 2013).

3.2 Framework process and prototype

This chapter outlines the development process of the multispecies design framework. Based on an exemplarily chosen site in Berlin, Germany, each step is illustrated, elaborated, and main findings of each step are briefly summarized. Figure 3 displays the elements and their interrelations inherent in the framework design process. The order of elements begins with a question which is approached through various tools processing data and other inputs into useful information. In this step I highlighted the iteration potential within one Q & A pair, between a question and the subsequent Q & A as well as feedback connections to questions in other urban design scales. By documenting each step of the exploratory process, I pinpointed the potential starting points for crossing disciplinary borders by assigning main stakeholders to each step, determining data and knowledge gaps, potential for feedback loops within the framework as well as useful tools to generate necessary information. The In the following chapters each step is explained and evaluated with the goal to contribute to making the discourse of multispecies design in the context of urbanization and biodiversity loss more tangible.

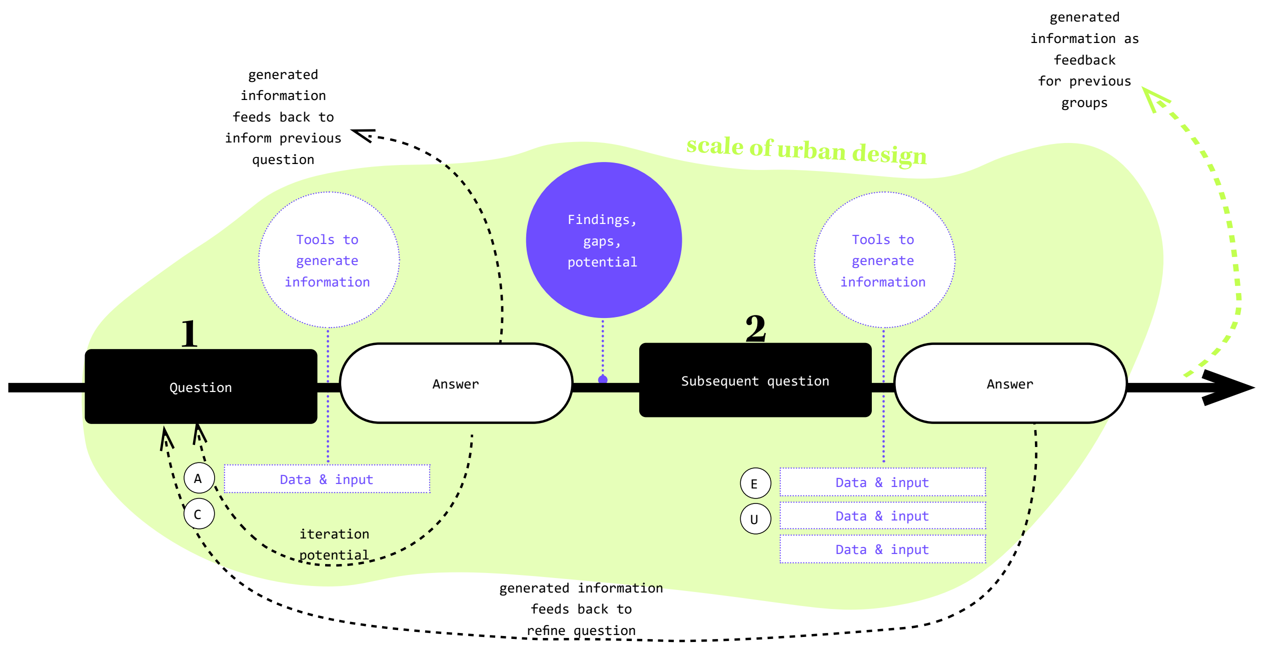


Figure 3
Legend of elements inherent in the framework process diagram.

Disciplines

- (A) Architecture
- (C) Computational design
- (E) (Urban) Ecology
- (U) Urban planning and design

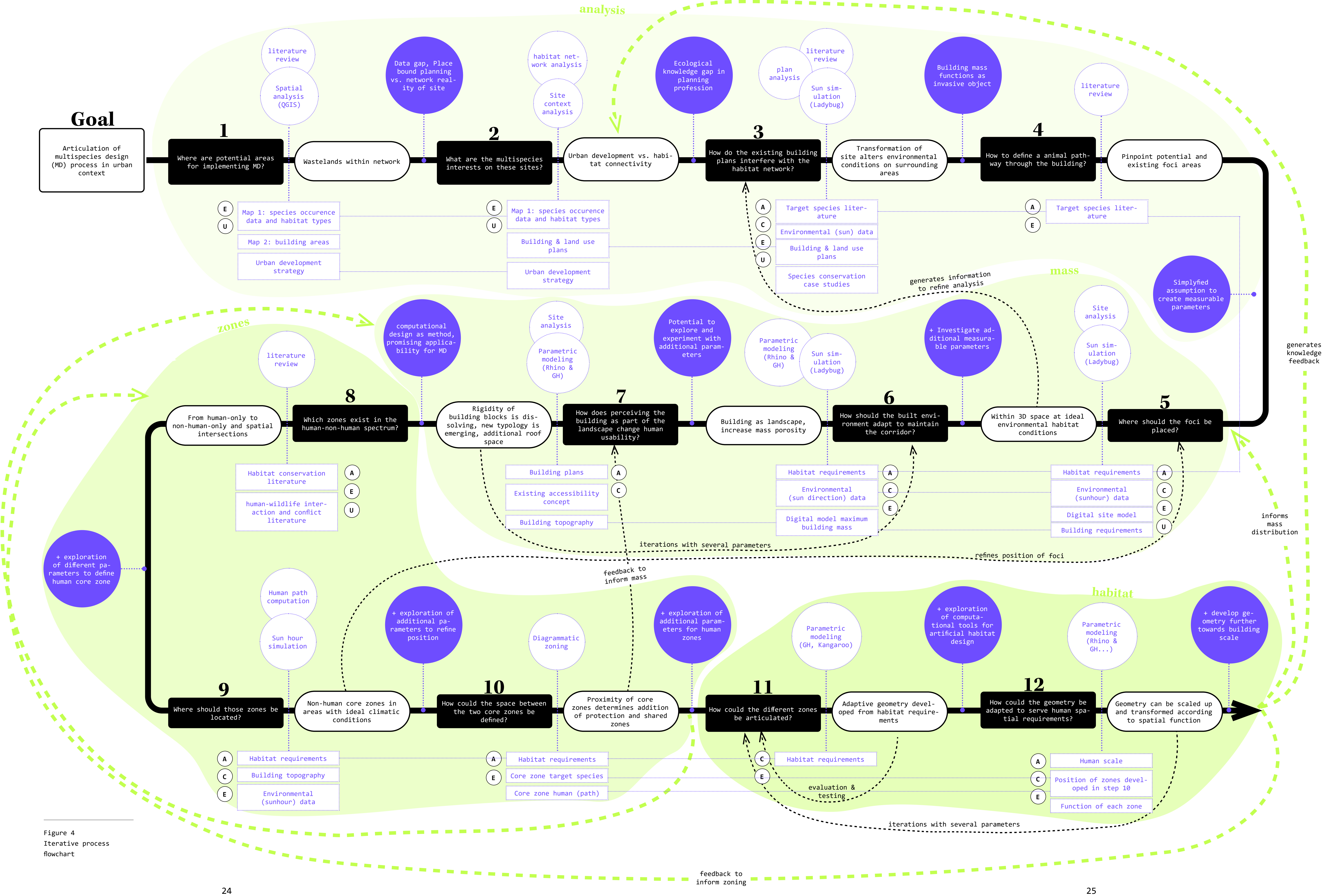


Figure 4
Iterative process flowchart

3.2.1 Phase 1: Finding intervention points

The framework process begins with a thorough geospatial analysis. Based on the literature review urban biodiversity strategies like GI often lack practical implementation instructions (Lähde, 2020). This gap between biodiversity strategies and tangible city planning responses aggravates the determination of target areas for biodiversity conservation and promotion measures. The first question therefore originated in this need for concrete intervention points in the urban fabric:

Where are potential areas for implementing multispecies design? (Fig 5)

The preceding research highlighted the conflict between development and habitat conservation on urban wasteland. The first step was therefore to establish and visualize correlations and areas of conflict between wastelands, habitat networks and potential building land on city scale (Fig 6). Crucial for this approach is the availability of species occurrence and habitat location data.

The Berlin biotope network strategy outlined in chapter 2.1.3 is based on a clearly arranged collection of data, including the location of habitats and dispersal corridors of its target species. I acknowledged the incompleteness of knowledge and data of all non-human species, however, due to the limited scope and conceptional approach of this thesis, the fragmentary species data was sufficient. I derived the required data from the city's spatial data platform FIS-broker, including areas of the biotope network, building sites within this network as well as information about future focus areas for urban densification. The geospatial analysis of the location and types of wastelands as well as their position in the biotope network was conducted and their intersection points were identified as potential sites for applying multispecies design interventions.

In the process of answering this first question, I emphazise comprehensive species occurrence data as vital parameter in the multispecies design approach. Increasing the availability of geospatial species data is one challenge to solve for successful application of the multispecies design approach. Additionally, the dichotomy of the current place bound planning approach, limited to the building site's boundaries, contrasts with the ecological network context of the intervention sites, and could potentially be converged through including urban ecology professionals into the planning process.

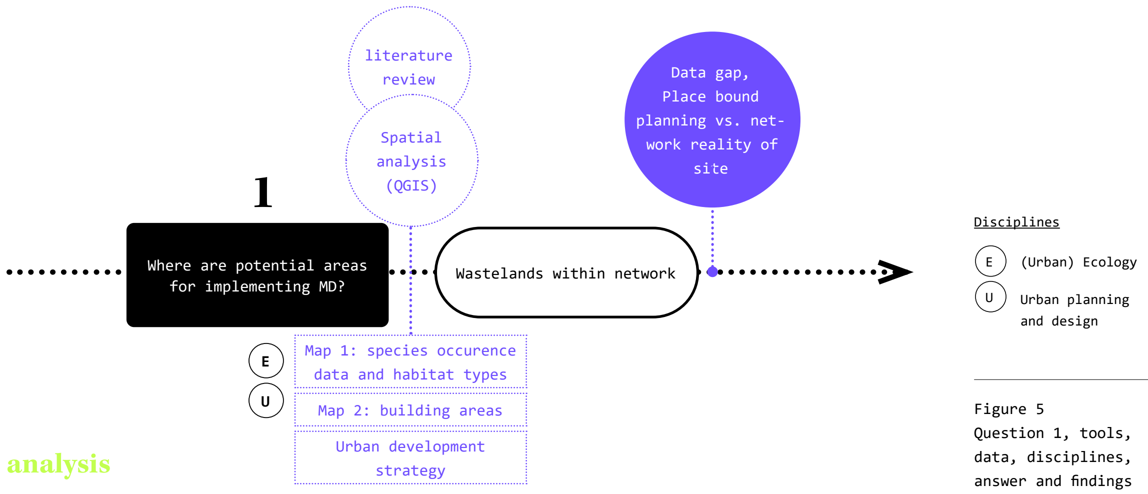


Figure 5
Question 1, tools, data, disciplines, answer and findings

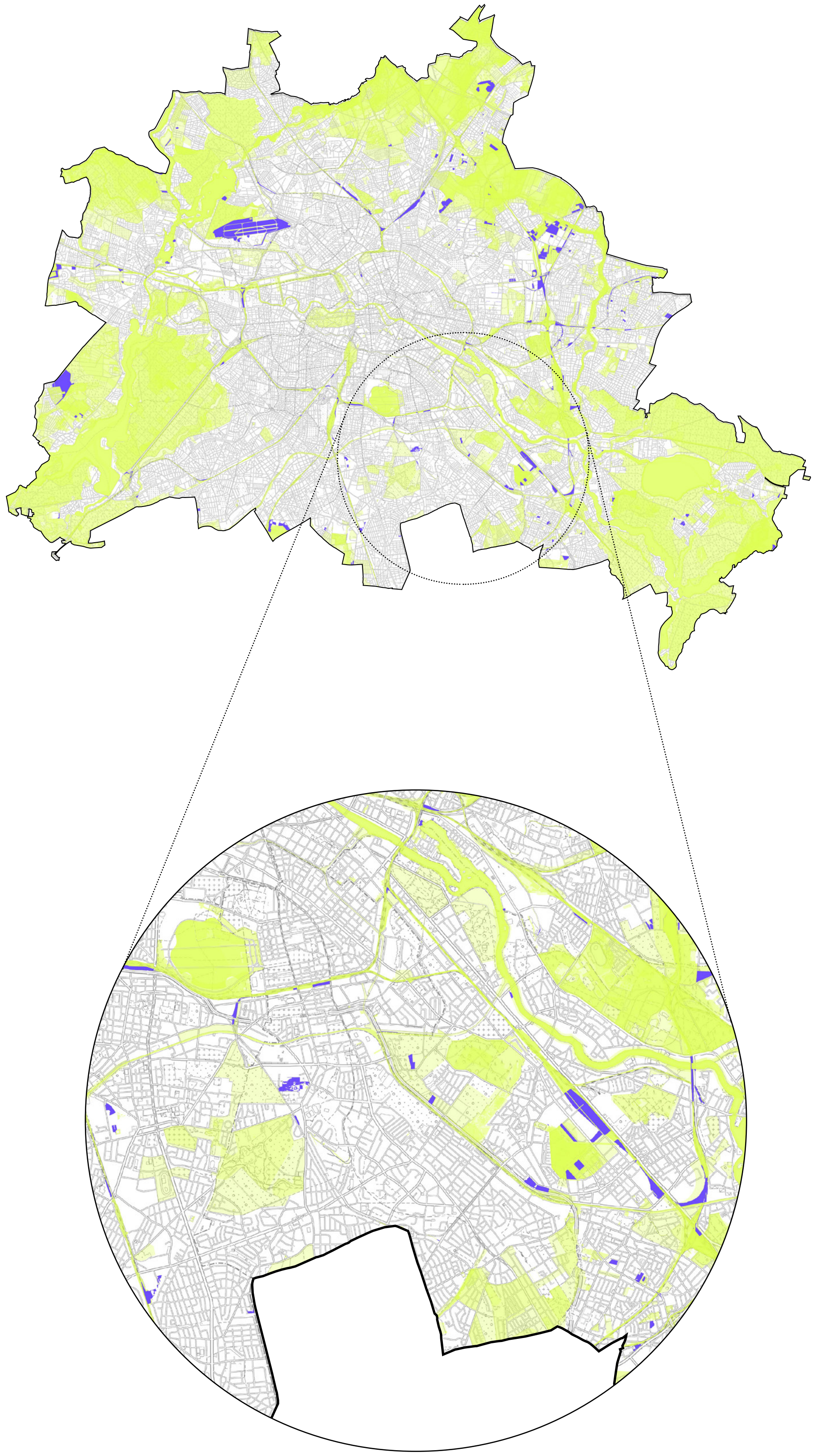


Figure 6
Intersection analysis of areas of biotope network (yellow) and buildable wasteland (blue)

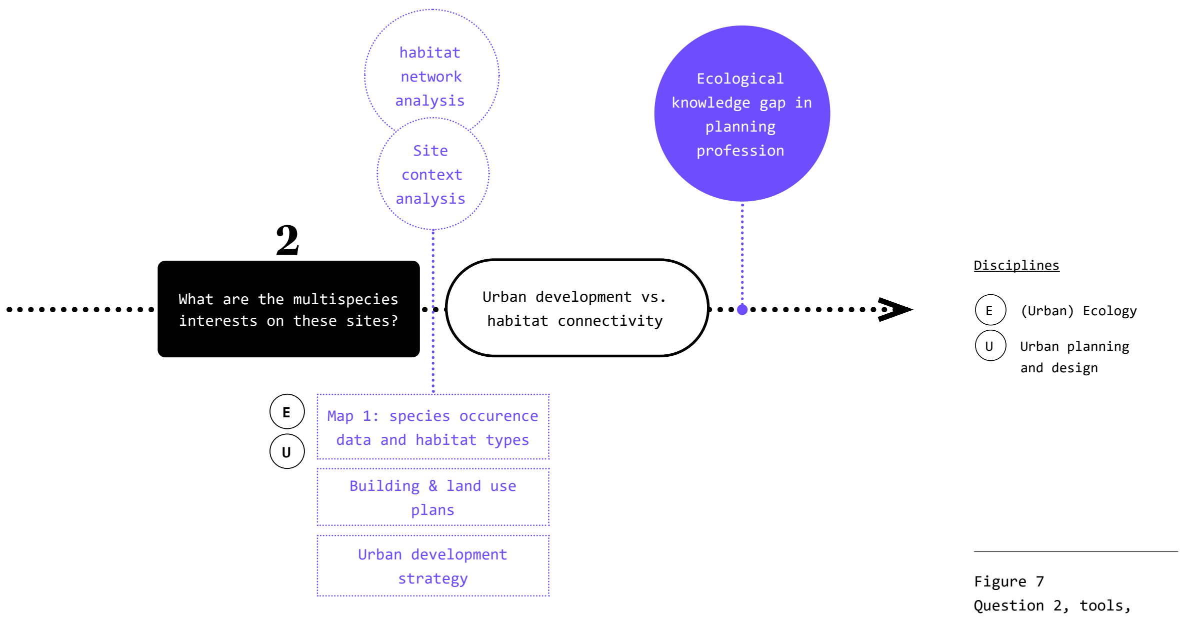
3.2.2 Phase 2: Multispecies interests and conflicts

Once the city-wide intervention points were broadly determined, the next step was to elaborate on the concrete conflicts between human and non-human interests on wastelands.

What are the multispecies interests on these sites? (Fig 7)

With my site choice for investigating an implementation of multispecies design, I assume the potential conflict dimension and urgency of intervention. In the urban center the conflict is particularly acute due to the lack of green space and the pressure on building land (Fig 8). Here the biotope network is already thinned out by the density of building mass and requires special attention. The test site is in a neighborhood of Berlin-Neukölln, a focus area of the city's densification strategy, BerlinStrategie 3.0 (Senatskanzlei Berlin, 2021) (Fig 9).

The land use and building plans of the chosen site propose a maximum building density and a mixed use of residential and commercial buildings to revitalize the neighborhood. In this context I chose one target species to deepen my understanding of its needs and specific spatial requirements. The biotope network lists this site as potential dispersal corridor of four animal species, among them the sand lizard. This small reptile is a widespread species in Berlin (Fig 8) that often conflicts with city planning as it is required to provide a compensation area in case they are found on site. Even their potential existence on a building site causes additional costs because the planner needs to commission an ecological assessment to prove no sand lizards will be harmed throughout the building process. Because the bare sandy patches combined with shrubs and grass around the adjacent railway are typical habitats of this species (Fig 11-13), an assessment was done and measures to prevent the species to enter the site were implemented.



analysis

Figure 7
Question 2, tools, data, disciplines, answer and findings

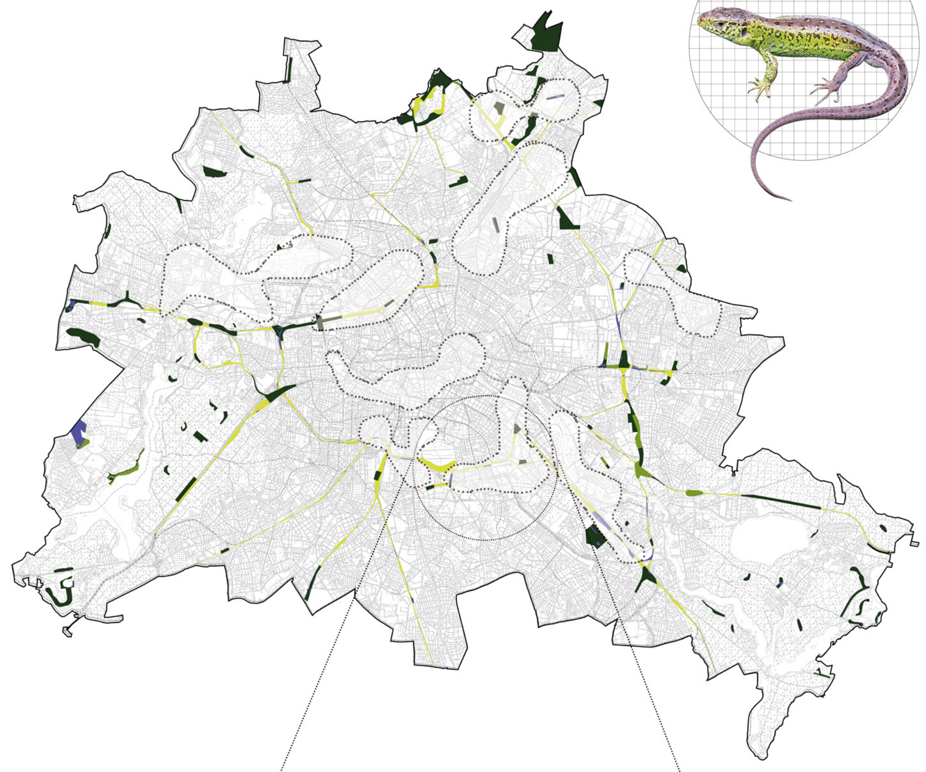


Figure 8
Berlin-wide habitat network of the sand lizard, BerlinStrategie 3.0 focus areas, and wastelands in the habitat network.

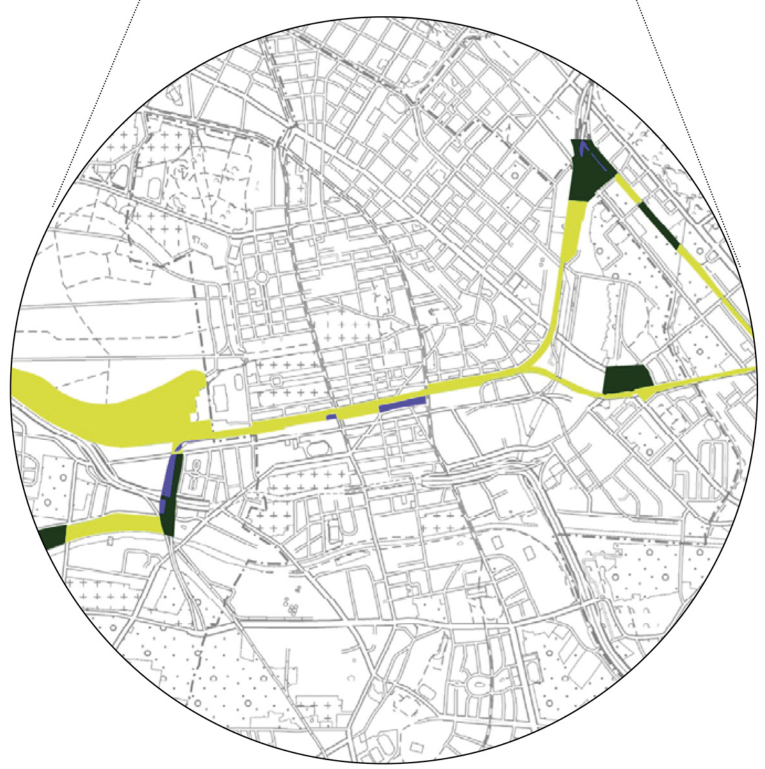


Figure 9
Zoom to focus area Berlin-Neukölln. Context of site in the sand lizard's habitat network

The plan considers the special position of the site in biotope network in a limited manner by conducting a species occurrence analysis to ensure that no animal is harmed in the building process. The measures taken, a lizard fence for example, segregate the site from the potential dispersal corridor to prevent future sand lizard invasion of the site. Even though the planners addressed and reduced the negative impact of building construction, the role of the site as potential habitat connection (Fig 10) is not considered. This exposes once again the lack of the planner's ecological knowledge and of alternative methods handling the human-non-human-interest discrepancy. The integration of ecological knowledge into early phases of the planning process is a chance to cross disciplinary boundaries and minimize the conflict between planning and nature conservation.

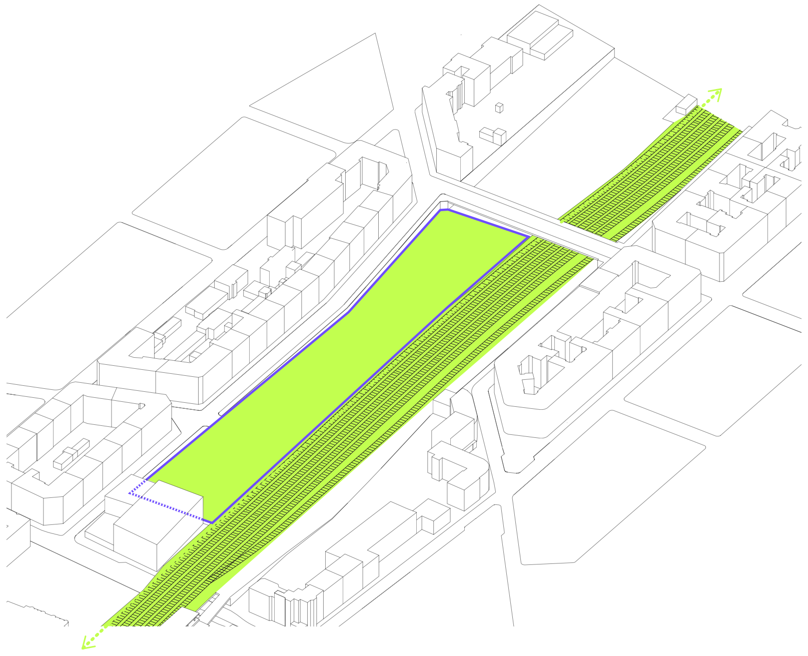


Figure 10
Project site and surrounding environment from human and non-human perspective.

Figure 11
Typical sand lizard habitat.

Figure 12
View towards project site and railway from Hertabrücke.

Figure 13
View towards project site from Hertabrücke, shrubs, bushes and sand point at a potential lizard habitat.

3.2.3 Phase 3: Shifting perspectives

To gain an accurate understanding of the conflict's scope my next question was targeted at increasing my ecological knowledge which I approached through a first perspective shift towards the chosen target species.

In which way do the existing building plans interfere with the habitat network? (Fig 14)

To approach this question, I studied the sand lizard's characteristics and habitat requirements based on species-specific literature and species conservation case studies.

This small reptile belongs to the family Lacertidae, the largest group of reptiles in the Afro-Eurasian context. The family consists of more than 300 species in 39 genera, and are commonly called wall lizards, true lizards or lacertas (Jackson, 2014). The sand lizard is an insectivorous species, it feeds on spiders and insects, bugs, beetles and sometimes its own young (Corbett & Moulton, 1998). Preferred habitat is characterized by extensive areas with low shrub vegetation on poor, sandy soils, a small-scale mosaic of bushes, shrubs, and open areas with boundary structures like heaths and dune areas (Stumpel et al., 2004). In Berlin the sand lizard inhabits border habitats such as railway embankments, forest edges, small gardens, and wasteland (Fig 8, 11-13) (Bengsch, n.d.).

Like all reptiles, the sand lizard is cold-blooded, meaning it does not maintain a constant body temperature and relies on the sun's rays to warm up and shaded areas to cool down. It is active from March to October and during this time needs hiding places, food, sunny and shady places as well as sufficiently sunny sandy areas for laying and developing the eggs (Spellerberg, 1989). In autumn and winter, it is then dependent on a hibernation quarter (Gullberg et al., 1998). For nesting the habitat should include open patches, at least 30 cm deep and in average 50 cm from vegetation. Per hatchery, the habitat should provide 1–2 m2 of vegetation free, loose, aerated substrate (Spellerberg, 1989). Sand lizards need all these structures in immediate vicinity, because they often stay no more than 30 m away from their hiding place throughout their lives (Stumpel et al., 2004). The main factor for a successful settlement of sand lizards is the existence of foci, or core habitat (Senatsverwaltung für Stadtentwicklung und Umwelt, 2016). These are sites with the ideal climatic and topographical conditions outlined previously.

Disciplines

- A Architecture
- C Computational design
- E (Urban) Ecology
- U Urban planning and design

Figure 14
Question 3, tools, data, disciplines, answer and findings

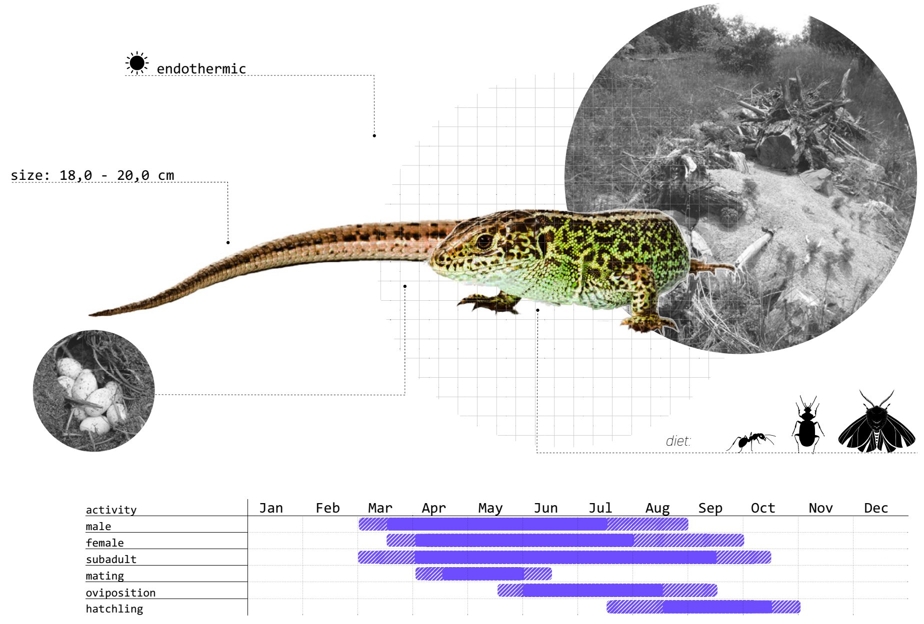


Figure 15
Collage of species profile

Morphology: Total length 18 cm, Tail length approximately 1.5 times the snout-vent length, Males slightly smaller than females but with lager heads
Coloration: Males have bright green flanks in mating season, fades before hibernation. Females are light brown or grayish all year. Markings and patterns are variable and provide good camouflage
(Corbett & Moulton, 1998)

Based on the newly gained knowledge, I evaluated the building plans for negative impact on the sand lizard's territory. This was approached by determining environmental habitat factors which are mentioned in reference literature and therefore assumingly indispensable for the species. I acknowledge the complexity of natural habitats and the incomparability with computationally simulated environments. However, due to the thesis' conceptional approach, the parameters were exemplarily chosen, based on my assessment and their computational measurability.

The main parameter I determined is the sunlight. Because the sand lizard is endothermic, it requires sunny spaces for basking in the active months and warm and dry spaces for hibernation and oviposition. Especially the shading of existing habitats or dispersal corridors caused by newly built elements like noise protection walls causes habitat fragmentation (Dr. Kwet et al., 2021). Therefore, the shadow casted by the proposed building (Fig 16) was simulated with Rhinoceros, Grasshopper and Ladybug. The result showed that the proposed building would function as an invasive object in the habitat network because it would cast shadows on the lizard's territory outside of the building area (Fig 17). In this phase, the need for crossing disciplinary boundaries became evident. The translation of ecological knowledge into a computationally measurable parameter requires the planning profession to augment its skillset with species specific knowledge and computational simulation tools. The collaboration with specialists in the field of urban ecology and species conservation is indispensable.

Figure 16
Building proposal by Werhahn Architekten (2017).

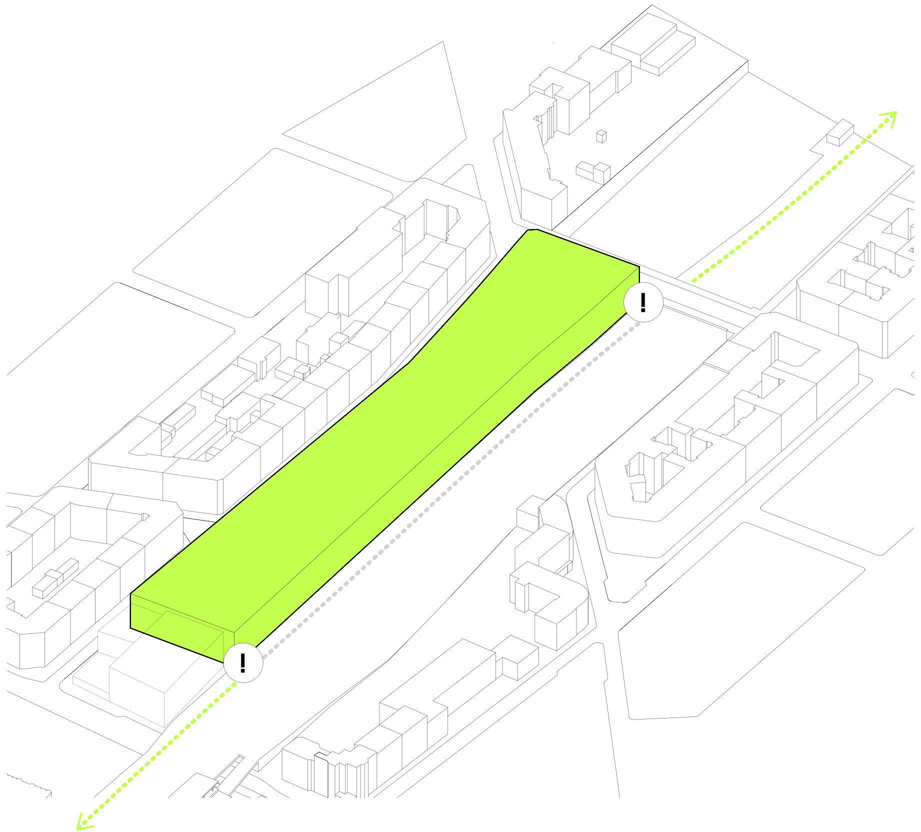


Figure 17
Abstracted mass of building proposal creates severe barriers through shading of dispersal corridor.

3.2.4 Phase 4: A first multispecies guiding principle

To address the impermeability of the proposed building mass, I approached the site from the non-human perspective. As the goal is to maintain the dispersal corridor function of the building site, the next question was:

How to define a pathway for the sand lizard through the building? (Fig 18)

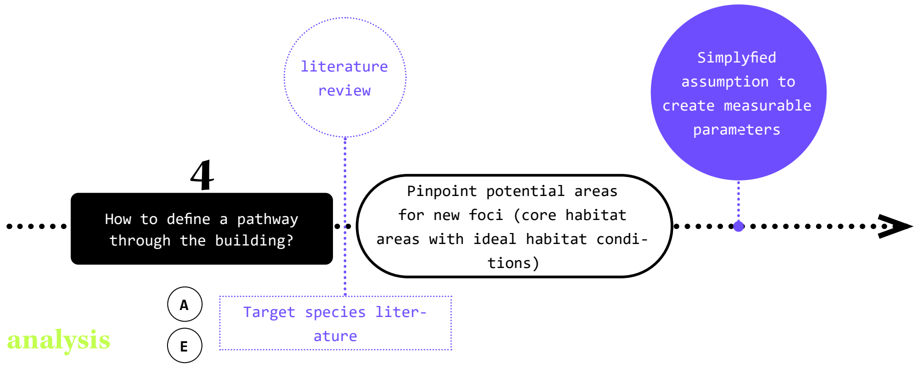
The literature review showed that the sand lizard needs so called foci, core habitat areas with ideal habitat conditions to survive. My approach was therefore to pinpoint potential areas for new foci on the building site.

Where should the foci ideally be positioned? (Fig 20)

The reference points for the lizard's pathway were derived through a sun hour analysis as this factor plays a major role for the development of core habitat (Fig 19). As described in the previous chapter, the sand lizard prefers areas with direct sun throughout the whole year for various activities.

For this reason, the goal of this simulation was to find the areas with the most sun hours even on the darkest day of the year, winter solstice on the 21st of December. The simulation showed that the ground floor does not receive sun on this day. Therefore, the analysis was repeated on multiple levels above ground. The step size of 3 m is based on the average height of building levels of new construction in Berlin and the highest level on the statutory maximum building height of 18 m, mentioned in the land use plan. Every 3,0 m the sun hour analysis was repeated and the center points of the areas with the most sun hours were determined as foci centers. These points as well as the entrance points on the eastern and western site boundary were then interpolated as 'nurbs'-curve.

In this context, I recognized the potential to investigate the implementation of additional parameters like humidity and wind direction and speed, which are also important environmental habitat parameters, in the future (Fig 20). The pinpointed foci areas provide information to feed back into question 3 (Fig. 14) to refine the architect´s and planner´s understanging in which way the building mass disturbes the habitat network. As the sand lizard requires direct sun only in the foci areas, the barrier analysis could be more finely graduated.



Disciplines
A Architecture
C Computational design
E (Urban) Ecology
U Urban planning and design

Figure 18
Question 4, tools, data, disciplines, answer and findings

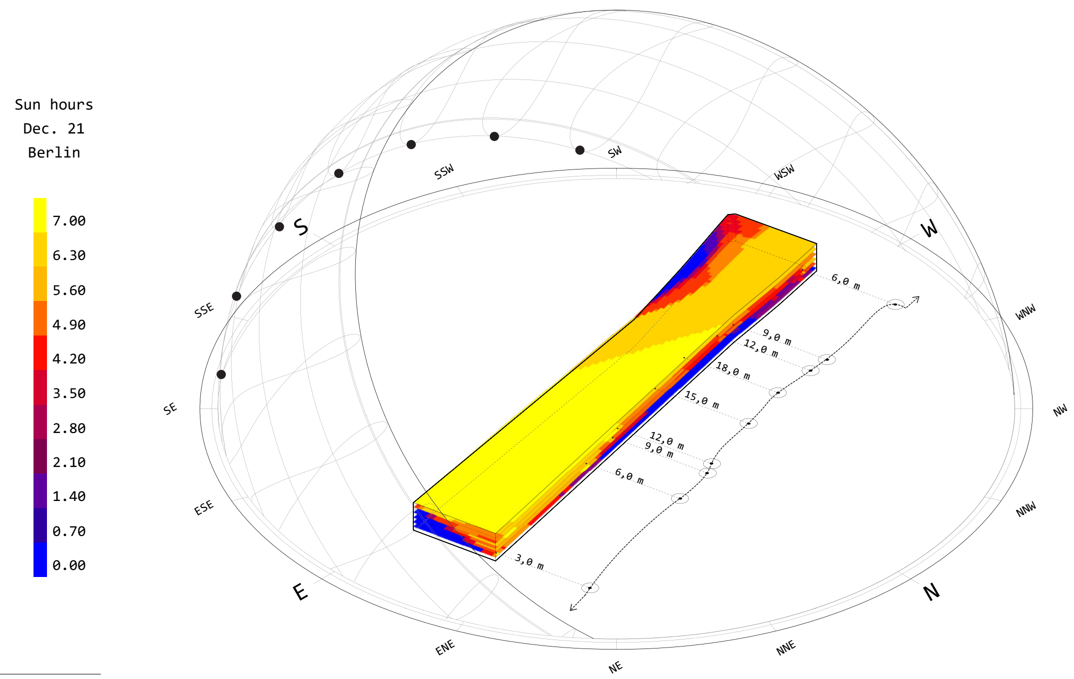


Figure 19
Diagram of sun hour analysis to determine core habitat points

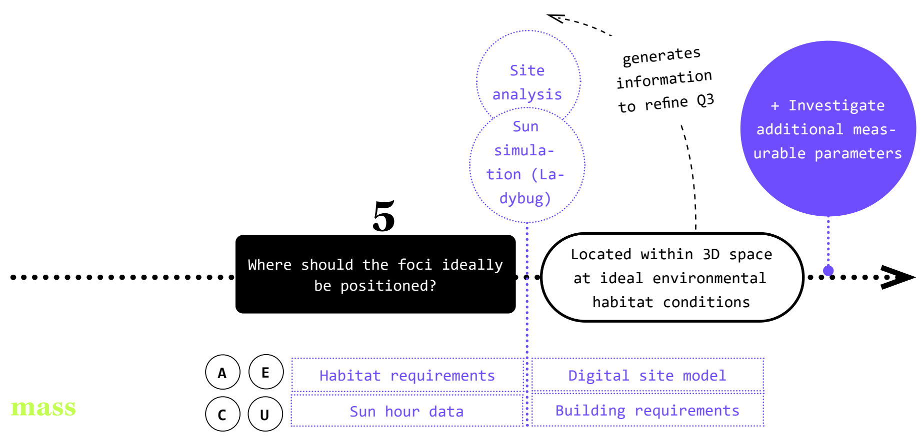


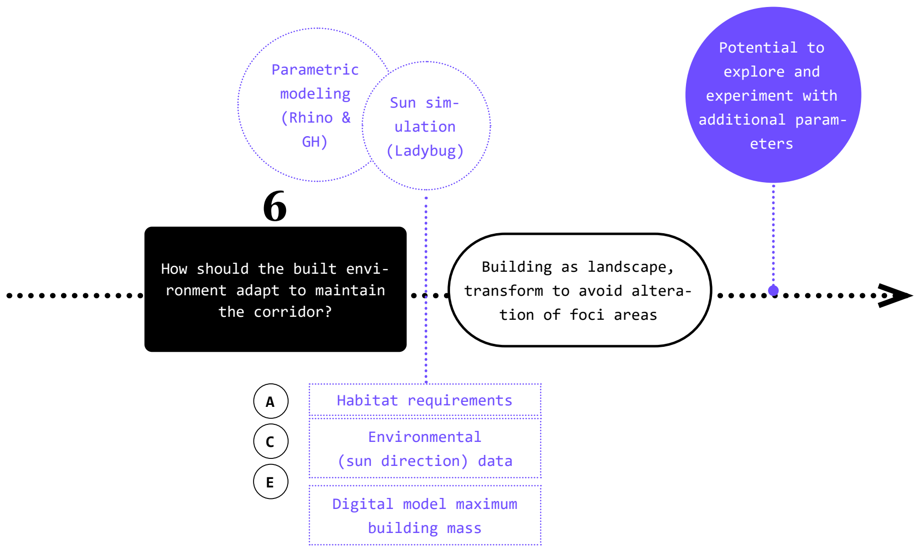
Figure 20
Question 5, tools, data, disciplines, answer, findings and feedback loop

3.2.5 Phase 5: Adaptation of building mass

The curve resulting from phase 4 set the foundation for approaching the building scale of urban design through the question:

How should the built environment adapt to maintain the corridor? (Fig 21)

The corridor determined through the preceding sun hour simulation represents connected points in space with hypothetically ideal habitat conditions. To maintain these conditions, the building mass needs to be reshaped. Due to the climatic requirements of the lizard's core habitats, the building height needs to be adjusted in some areas to avoid shading of the corridor. For this plot the average maximum building height is 18 m or six floors according to the land use plan. To adapt the height, I used the sun direction vectors for December 21st to determine a maximum-height curve. The sun direction vectors of each hour from sunrise at 8:00 h to sunset at 16:00 h were used to project lines from the foci center points to the building site's southern border (Fig 22). The intersection points between vector lines and surface were interpolated to form a guide curve for the maximum height. Vector lines which ended outside the site boundaries were computationally projected onto the site boundary surface. The lizard's pathway curve and this guide curve were then lofted and extruded to ground level to approximate a new building mass distribution (Fig 23).



Disciplines

- A Architecture
- C Computational design
- E (Urban) Ecology

Figure 21
Question 6, tools, data, disciplines, answer and findings

mass

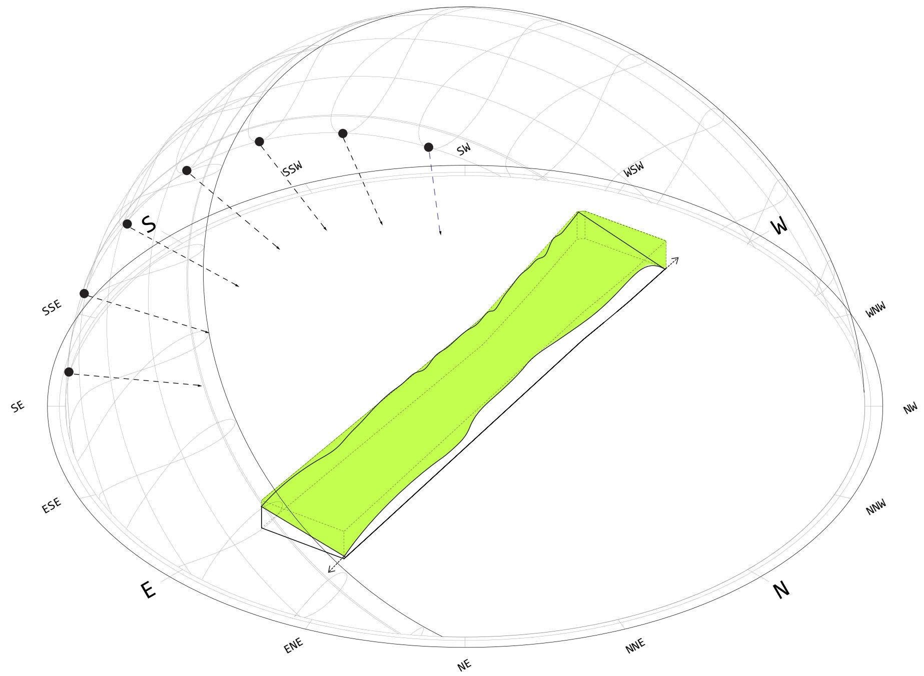


Figure 22
Diagram of shadow analysis to determin shading building mass.

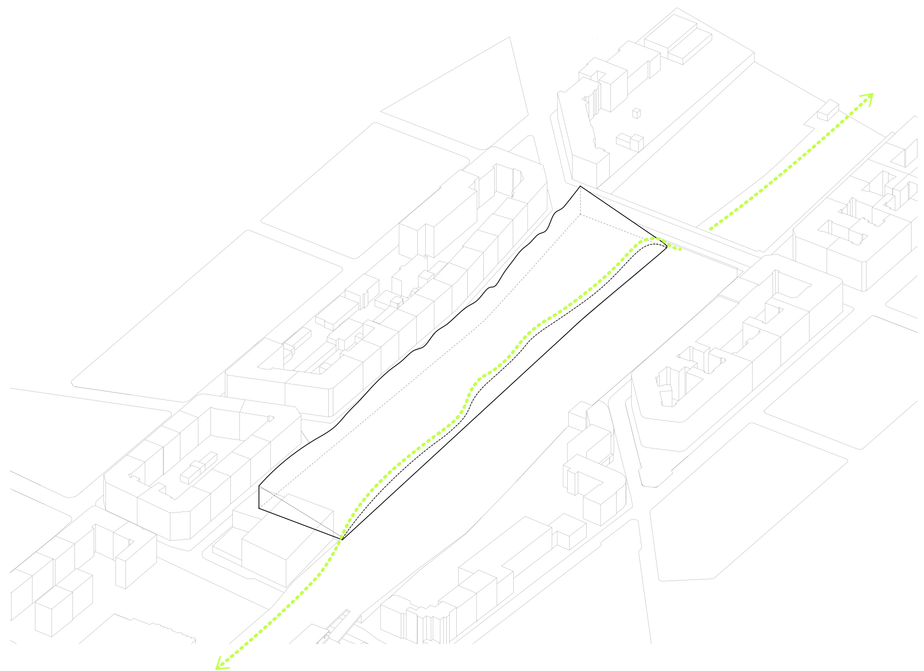


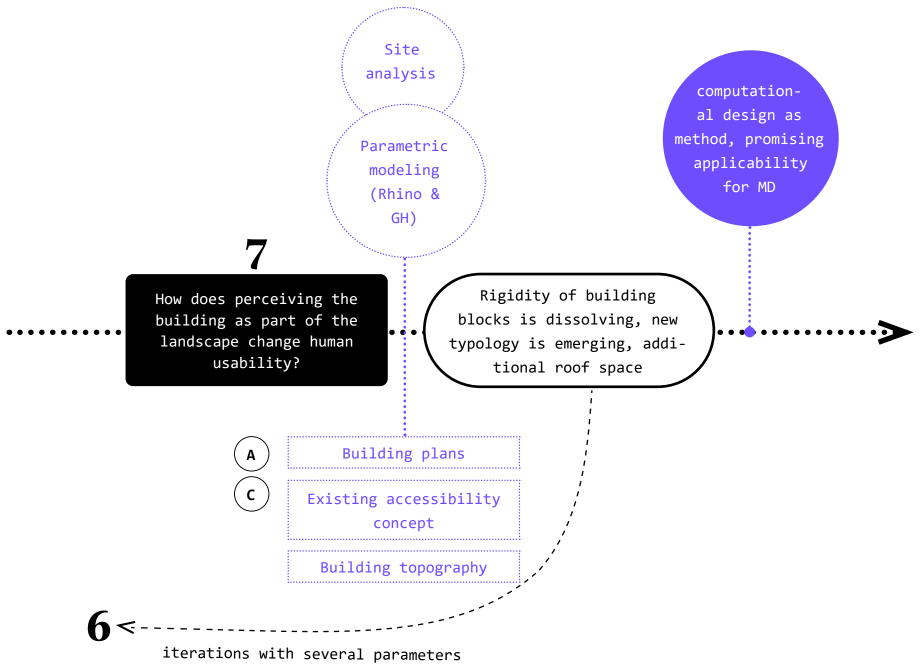
Figure 23
Resulting building mass and possible sand lizard path.

The approach to incorporate a habitat system into the building mass distribution suggests a perspective shift of the building as separated from the environment towards the building as articulated landscape (Fricker & Kotnik, 2020), a new urban typology.

How does the perceiving the building as part of the landscape change human usability? (Fig 24)

The new articulated landscape typology dissolves the rigidity of the common building block and introduces the roof as additional space. To provide access and barrier free circulation for human users, the building mass was adapted again, forming entrances at the points predefined by the given land use, and building plans.

The elementary manipulation of building mass was achieved with basic computational modeling operations informed by data derived from simulation and environmental information in Rhinoceros and Grasshopper (Fig 25-26). This approach indicates a new field of computational explorations which go beyond the scope of this thesis. Nevertheless, I acknowledge the great potential of computational design as method to incorporate and translate complex data input into form and its promising applicability in the field of multispecies design.



Disciplines

A Architecture

C Computational design

Figure 24
Question 7, tools, data, disciplines, answer, findings and iteration potential

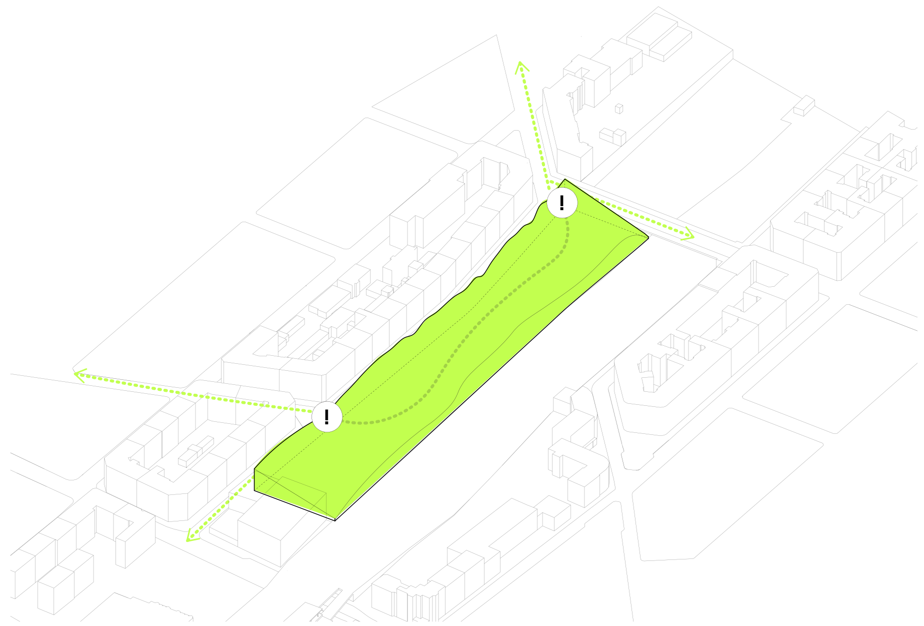


Figure 25
Analysis of building mass regarding human accessibility

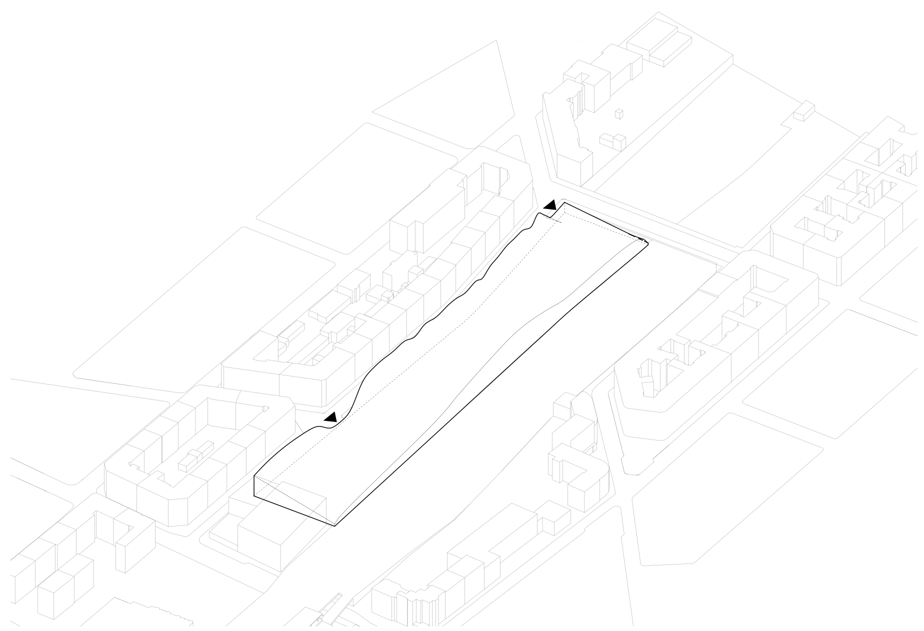


Figure 26
Transformation of shape to allow access to the landscape

mass

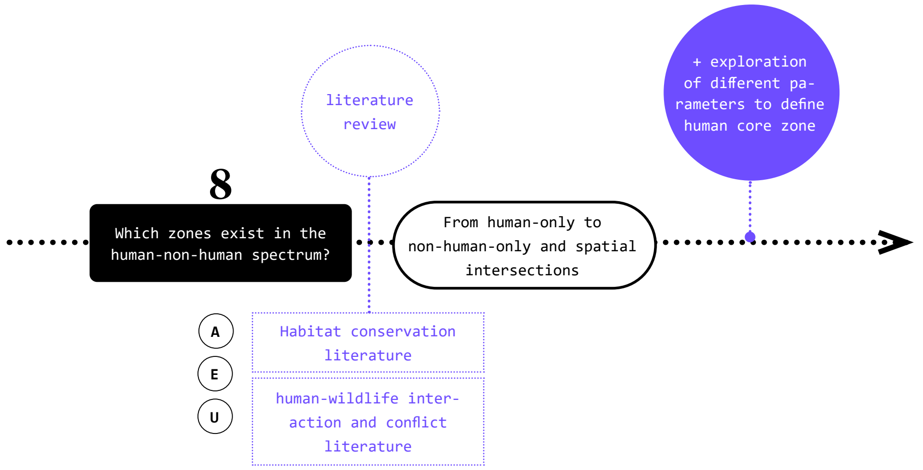
3.2.6 Phase 6: Space zoning

The form created in the previous steps leaves room for refinement and requires approximation to practical spatial questions. The next steps in this process would be to achieve alignment with actual architectural requirements like maximum building depth, light incidence, usability, accessibility, and economic feasibility to name a few. Due to the exploratory nature of this thesis, I deliberately worked on a diagrammatic level to focus on producing a thoroughly documented train of thought. The next level of detail was approached by investigating the distribution of space within the given site boundary.

Which zones exist in the human-non-human spectrum? (Fig 27)

The protection of endangered species' habitats, particularly from human interference, is crucial for its persistence. Most core zones of sand lizard habitats are therefore marked off through fences and signs. These areas are mainly used for hibernation and oviposition, two activities whose disturbance would have a particularly negative impact on the population (Edgar & Bird, 2006a).

Similarly, the intrusion of wildlife into core human zones like domestic premises, roads, or pathways, should be prevented to avoid conflict and animal harm. The creation of spaces promoting the peaceful coexistence of human and non-human animals therefore requires a clear determination of zones. Besides core zones and protection zones, my focus was on finding possible spatial intersections of human and non-human territory (Fig 28).



<u>Disciplines</u>

- (A) Architecture
- (E) (Urban) Ecology
- (U) Urban planning and design

Figure 27
Question 8,tools, data, disciplines, answer and findings

zones

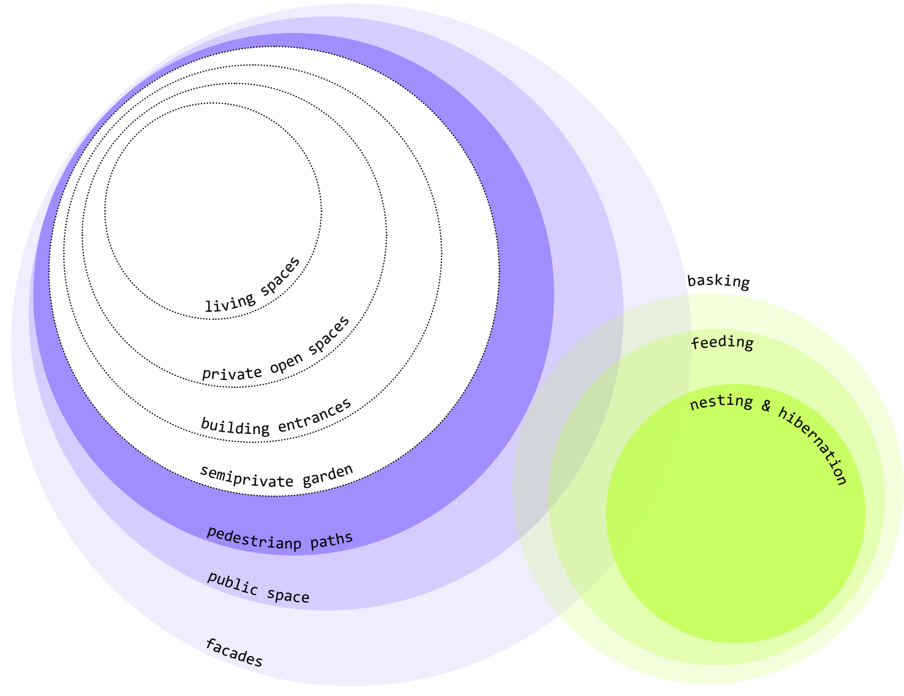
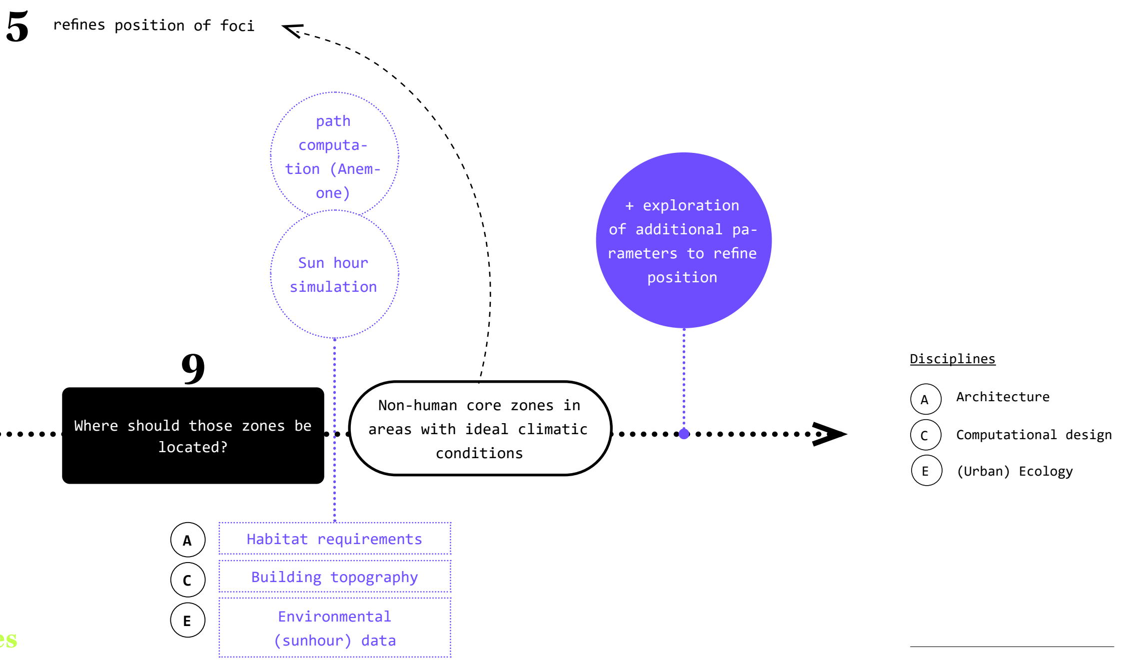


Figure 28
Zones in the human and non-human environment.
Figure 29 Gradient from protected to shared.

Where should those zones be located? (Fig 30)

The position of the sand lizard core zone was developed based on the previously defined parameters of habitat size (100 m2) and the environmental requirement of maximum sunlight throughout the year. The core habitat area is located along the corridor path. An additional three habitats were added in the sunniest place of the surface, identified through another sun hour simulation with Ladybug (Fig 31).

To produce a simple reference point for the second core zone, I chose the circulation path as 'human-only' space. The ideal path leading through the building topography was computed through Grasshopper and the plug-in Anemone with a slope that ensures comfortable walking experience (Fig 32). The human core zone was derived from an offset of this circulation curve. The sun hour analysis defines the ideal areas for sand lizard habitat. Within this area the distribution of foci can be adjusted and refined to inform and iterate the mass distribution outlined in question 5. Also in this phase I was touching upon multidisciplinary topics which required expertise in the field of architecture, computational design as well as urban ecology.



zones

Figure 30
Question 9, tools, data, disciplines, answer, findings and feedback loop

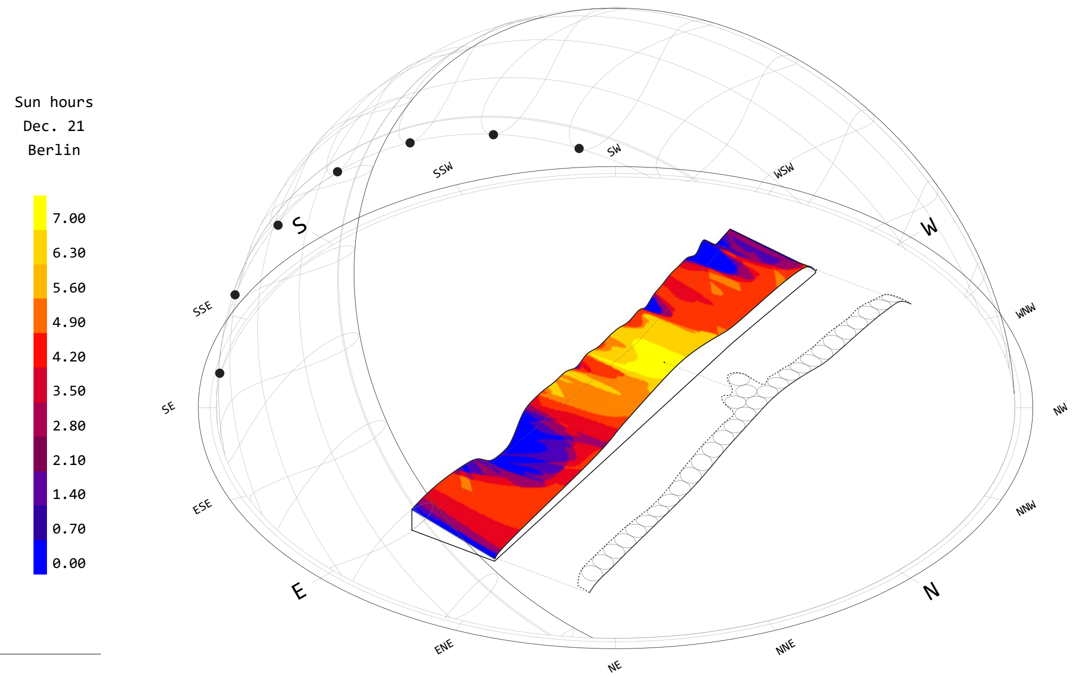


Figure 31
Sun hour analysis to determine maximum area for habitat placement.

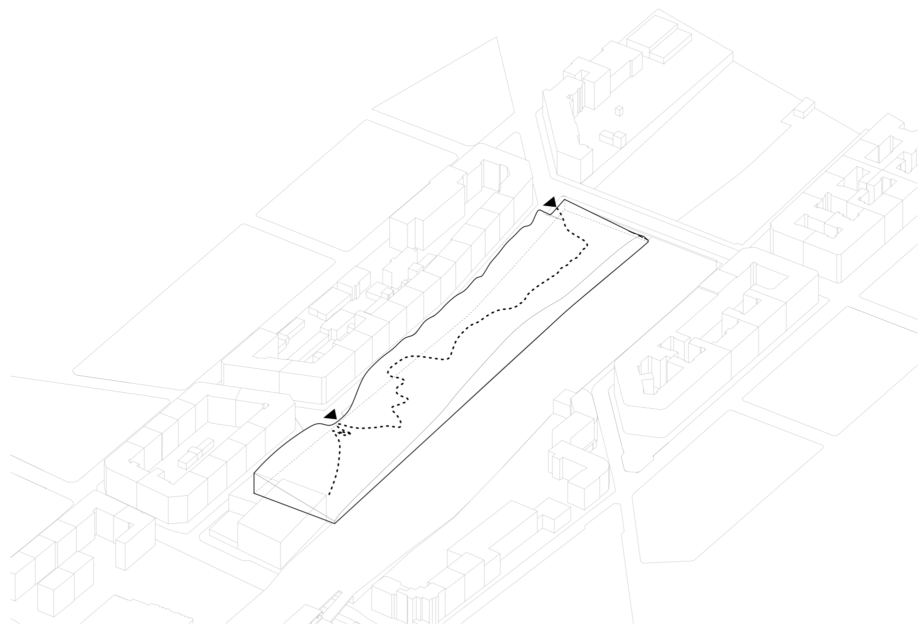
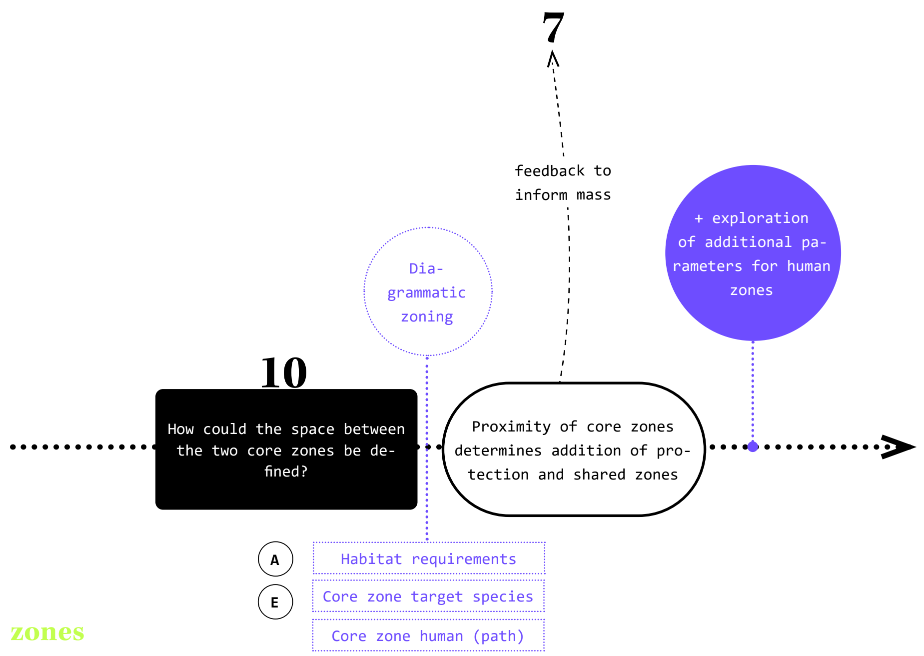


Figure 32
Computed path as core human zone.

After defining the position of core zones, I shifted my focus to their potential intersection:

How could the space between the two core zones be defined? (Fig 33)

The shared zones are based on the position of the core area for humans and the core habitat area (Fig 34). The guiding principle is their proximity to each other. A basic ruleset was developed to respond to various interplays between the zones. In direct proximity with each other, the habitat areas are supplemented with a protection zone (Fig 35). Secondly, the intersecting or adjacent zones are merged into a multispecies shared zone (Fig 36). Lastly, a sun protection zone is determined based on sun angle and approximate height of shading element to provide shade in some human areas but avoid shading of core lizard zones (Fig 37). As the building boundary is shaped primarily according to the lizards need for sun, it requires further iterations regarding shading. These four diagrammatically developed zones each come with their own parameters whose potential spatial articulation were investigated in the next step. The development of these zones required me to learn about species and habitat conservation strategies as well as potential conflicts of human-animal cohabitation. Even though I gained valuable and useful insights into the field of nature conservation, the expertise of ecologists is absolutely vital in this step to avoid conflicts and harm through design and arrangements of core-, protection-, and shared zones. The information generated through zoning the building mass can be used as feedback to inform the building mass in the previous urban design scale. By iterating between mass and zoning, the building shape can be refined until human and non-human space requirements are met.



Disciplines

A Architecture

E (Urban) Ecology

Figure 33
Question 10, tools, data, disciplines, answer, findings and feedback loop

Figure 34
Derivation of zones in the human-non-human spectrum based on their proximity to each other.Human core zone (blue) and lizard core zone (green)

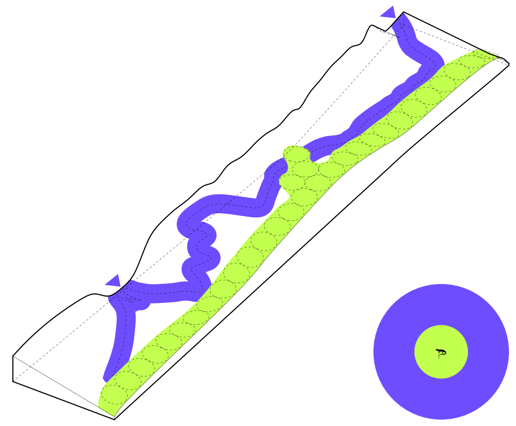


Figure 35
Buffer zone for lizard protection at intersection points.

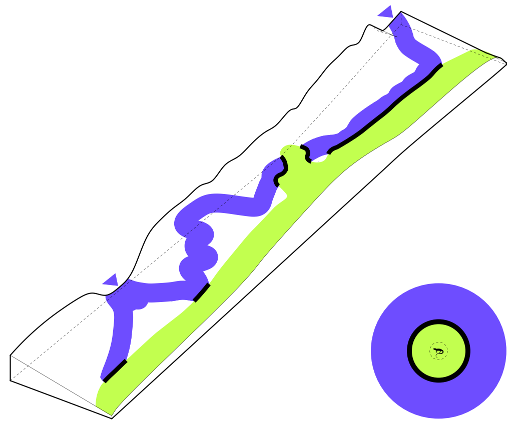


Figure 36
Shared zones adjacent to protection zones.

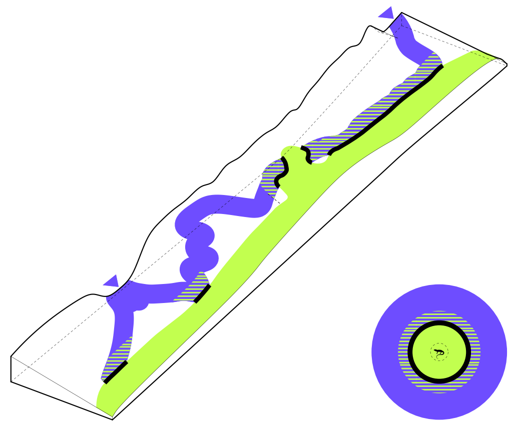
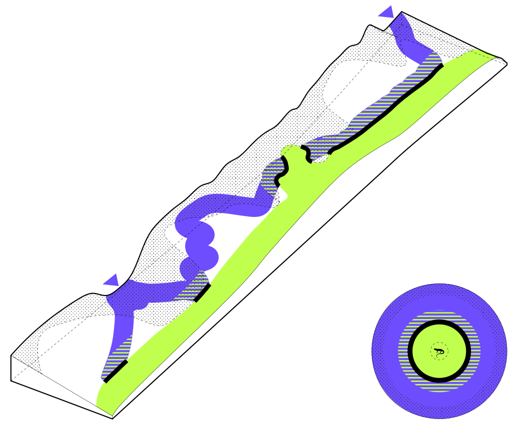


Figure 37
Potential zones for shading elements.

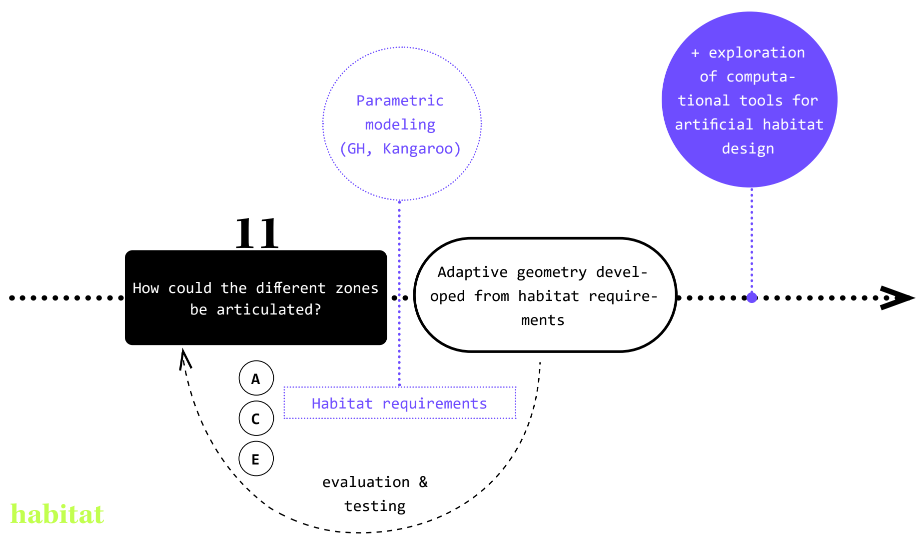


3.2.7 Phase 7: Adaptive habitat geometry

Based on the information generated in the previous step, I investigated the next level of detail, the habitat geometry:

How could the different zones be spatially articulated? (Fig 38)

As the focus of this thesis was on incorporating more-than-human needs into the planning process, this question was approached from the non-human perspective. An indication for the articulation of these zones was given by the sand lizard's habitat requirements. Based on these parameters I developed a set of rules for the design of the initial foci-geometry. The first parameter is based on the climatic precondition of direct sun all year round. To meet this condition, the foci-areas were elevated to minimize shade from the surrounding environment (Fig 39). Secondly, the elevated areas for basking should be equipped with closeby hiding possibilities (Fig 40). The core habitats should provide space for hibernation and nesting in loose ground with a recess of at least 30 cm (Fig 41). Additionally, the sand lizards need a continuous mosaic of protected and open space, and slopes to disperse unhindered and to move quickly from basking to hiding (Fig 42). The habitat geometry should provide a variation of these parameters with micro diversity in scale and height to maximize the chances of space colonization. I translated these requirements into an adaptive habitat geometry which will be elaborated in the next step. This step provides immense potential to iteratively explore computational tools for artificial habitat design at the disciplinary intersection of architecture, computational design and ecology.



Disciplines

- A Architecture
- C Computational design
- E (Urban) Ecology

Figure 38
Question 11, tools, data, disciplines, answer, findings and feedback loop

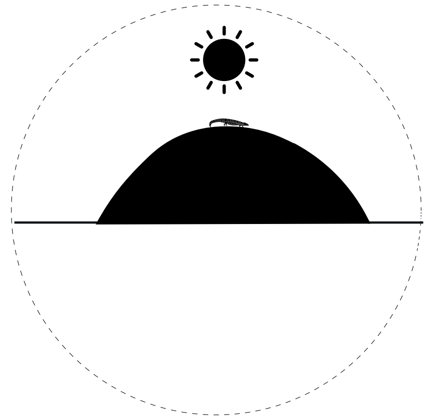


Figure 39
Derivation of core habitat parameters. Parameter 1: Piled shape to provide direct sun for basking.

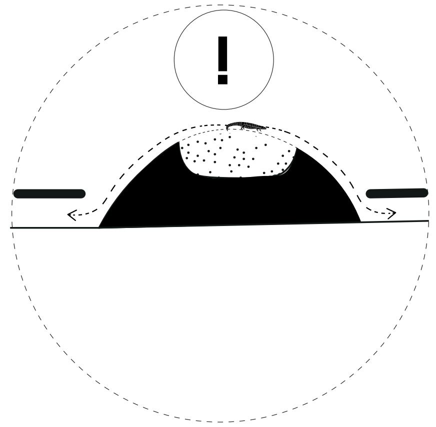


Figure 40 Parameter 2: Hiding spaces close to basking spots.

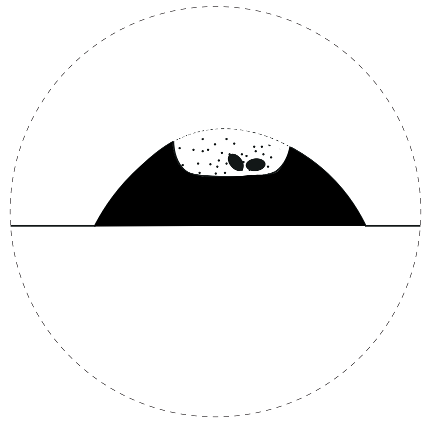


Figure 41
Parameter 3: Recesses with loose ground for ovipositioning and digging burrows

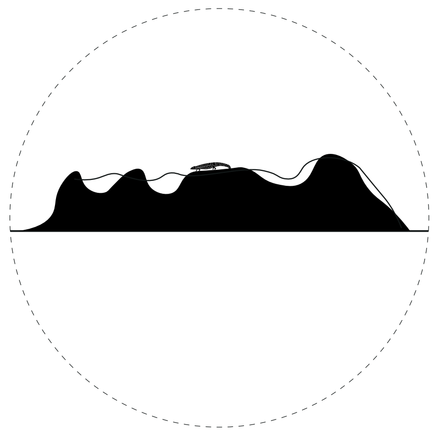


Figure 42
Parameter 4: Slopes and alternating spaces and continuity of habitats to ensure mosaic like habitat and barrier free movement.

Based on these parameters, I chose to explore the potential of the differential curve growth simulation of the Grasshopper plug-in Kangaroo (Fig 43). The simulation is structured to operate with line segments growing with a set factor and sphere colliders at their segmentation points. While the lines are growing the sphere collision is prevented, and the curve is created.

Given a thickness and extruded into a pile like shape the geometry provides a structure which, filled with soil, sand, and vegetation, contains all habitat parameters I determined previously (Fig 44). Due to major advances in construction methods and material, those complex and organic shapes can be built already today. It could be 3D printed either on site or in several modules and then brought to site. Companies like Hyperion Robotics are already working with recycled concrete to create printable artificial habitat structures like coral reefs (Fig 45-46).

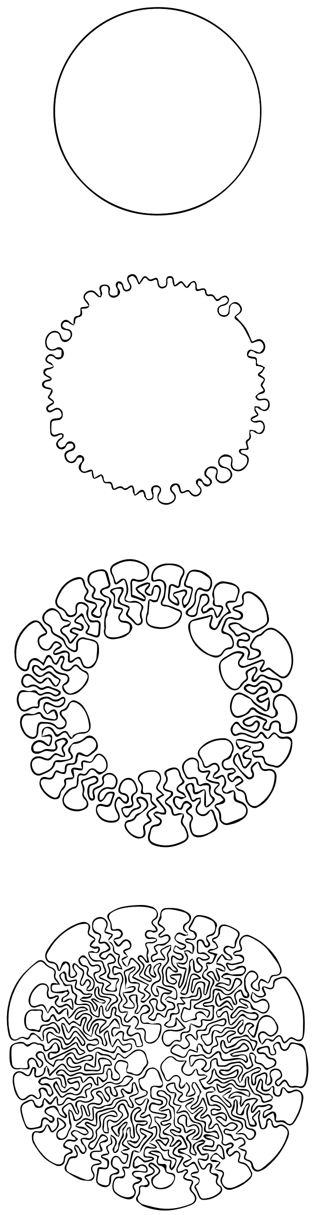


Figure 43
Stages of differential curve growth.

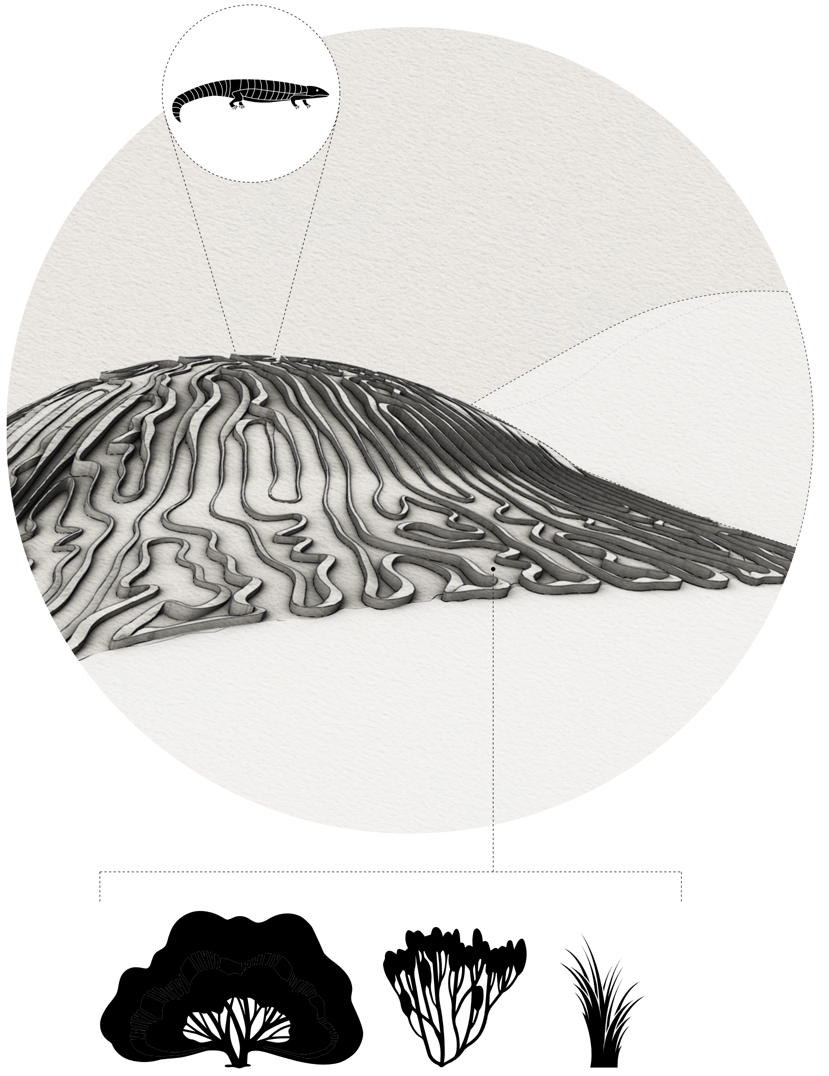


Figure 44
Collage of spatial habitat parameter translation.

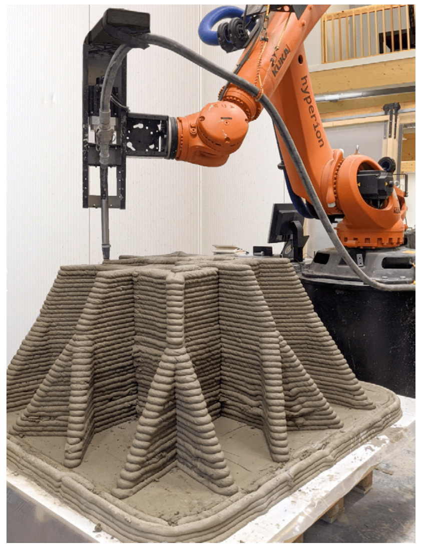


Figure 45
3D printing with recycled materials
© Hyperion Robotics

Figure 46
3D - printed artificial coral reef structure
© Hyperion Robotics

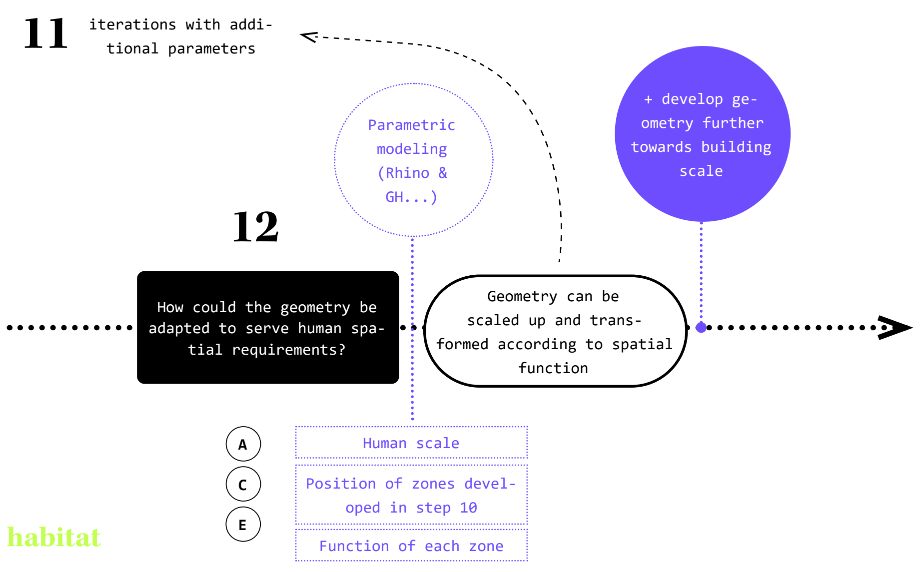
How could the geometry be adapted to serve human spatial requirements? (Fig 47)

One of the main challenges of the foci-geometry is to protect the sand lizard, particularly the nesting and hibernation areas, from human interference. However, due to the set goal of creating spaces of multispecies encounter, the human and non-human spaces should not be entirely segregated. Therefore, the core habitat should be in human sight but untouchable. To achieve this, I developed a ruleset to achieve a difference in altitude for foci- and observation areas. The differing size of lizard and human provides an interesting potential for a two-scale pathway system that structures the site in shared and protected areas. Adapting the habitat geometry to human scale was achieved in three steps. Firstly, the curve density was reduced by increasing the line segment and sphere collider size towards the human space (Fig 48).

Secondly, the curve extrusion height was adapted to the zones, for the lizard, a curve height of 1.7 m ensures enough sunlight. This height also elevates the lizard's habitat to human eyelevel, creating possibilities of species encounter. In the shared and the shading zone a curve height of 50 cm creates seating elements, and on the human path the curve merges with the ground (Fig 49). Thirdly, the structures curve thickness is gradually adjusted to the human zone (Fig 50).

The transformation of the geometry according to its spatial function leaves room for design elaboration and further investigation of an adaptation to building scale. However, the use of computational tools for artificial habitat design proved to be a promising topic to be explored in the future.

The spatial articulation of the zones developed in the previous chapter transforms the additional roof space of the building site into a shared space providing habitat and maintaining the corridor function of the site for the sand lizard as well as creating an urban green space with the possibility to experience urban wildlife for the human users (Fig 51).



Disciplines

- A Architecture
- C Computational design
- E (Urban) Ecology

Figure 47
Question 12, tools, data, disciplines, answer, findings and feedback loop

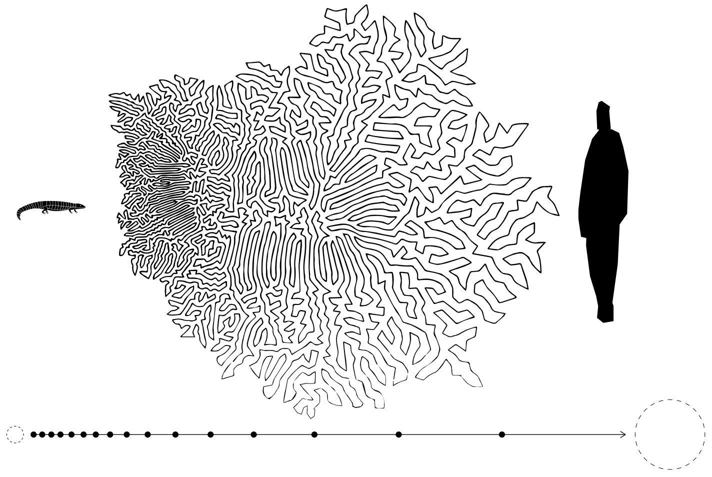


Figure 48
Adaptation to human scale. Step 1: Decreasing curve density through larger line segments and collision spheres.

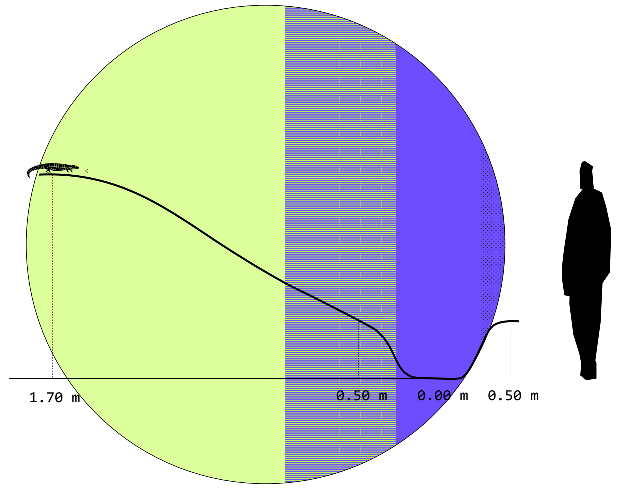


Figure 49
Adaptation to human scale. Step 2: Curve height.

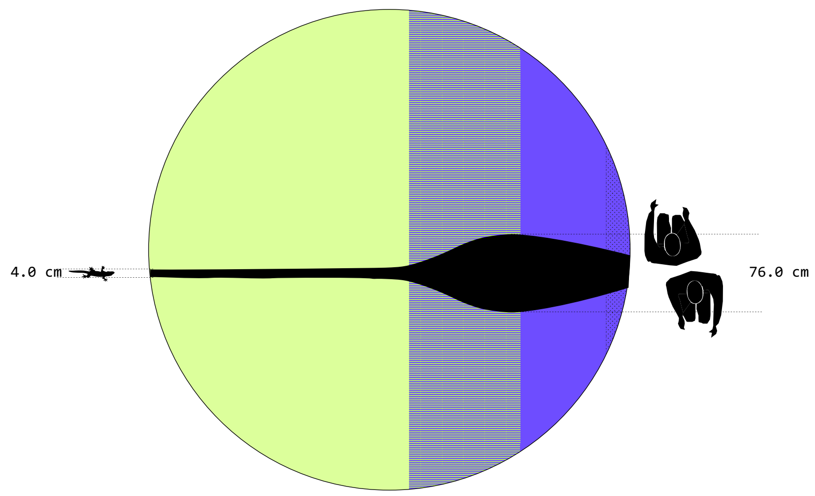


Figure 50
Adaptation to human scale. Step 3: Curve offset width.

Figure 51
Collage of a multispecies scenario. Public space landscape on the roof.

3.3 Conclusion

3.3.1 Framework summary

The methodology developed for the multispecies design framework can be divided into four parts (Fig 52). The first part provides the basic information layer the design is based on. The production of this layer begins with a multiscale geospatial analysis. Berlin proved to be a suitable case because it is pursuing the implementation of a biotope network strategy and therefore acquired valuable species occurrence data. On city scale, the analysis illustrates the conflict between the development of urban wasteland and the continuity of the biotope network. Secondly, the neighborhood scale analysis determines the site for the design proposal by zooming into one area of the Berlin densification strategy and highlighting potential areas of conflict. Finally, an in-depth site investigation provides the foundation for choosing a target species from the biotope network strategy and creating a species profile.

The second, third and fourth phase of the framework aims at translating and simplifying the gathered information into parameters and integrating those into the design process. This is done through an iterative computational design process by intuitively applying Grasshopper and various simulation plugins on three scales. Firstly, defining the multispecies building boundary, secondly, determining core areas of human and non-human territory and the space in between through zoning and finally, developing a spatial articulation of these zones through an adaptive habitat geometry.

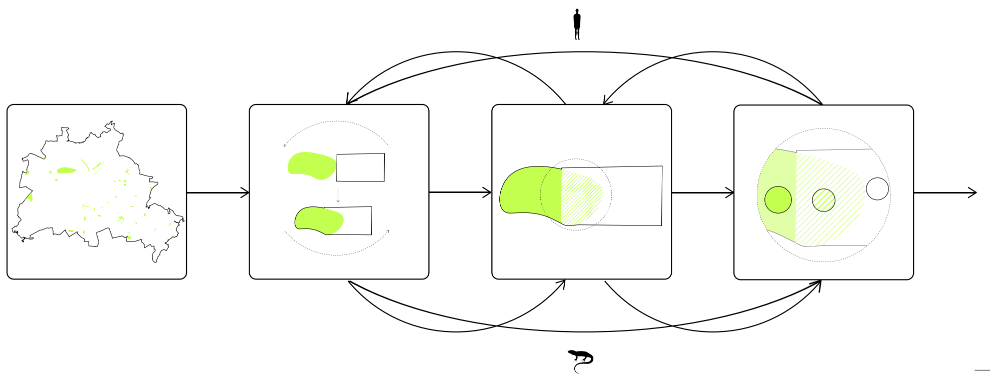


Figure 52
Framework structure.

To converge the contrastive goals of urban development and nature conservation, my thesis explored how a paradigm-shift towards multispecies design could be further articulated and implemented in the urban planning and architecture context. The aim was to increase the understanding of how ecological species-specific requirements could be integrated into the redesign of urban wasteland to counteract habitat fragmentation and biodiversity loss.

The literature review showed that even though the planning process in most western countries includes the assessment whether development impacts protected species (Apfelbeck et al., 2020), no general framework has been developed to strategically create or reconnect habitats in urban areas. Classical animal ecology tools of spatial planning usually aim at conservation and minimizing the worsening of the status quo, leaving the question how to implement biodiversity strategies focusing on animals into urban planning and architecture practice unanswered (Hauck & Weisser, 2021). In the urban planning discourse, the importance of wastelands for urban biodiversity is widely acknowledged (Gandy, 2013). However, the high pressure on building land often leads to a destruction of these sites and the loss of their function as habitat or habitat corridor. Strategies to protect valuable urban wasteland exist, however, they are place bound and seldomly take their ecological network function into account. Their multilayered significance and place in urban habitat networks are not integrated into the redesign of wastelands, and hence these biodiversity hubs gradually disappear.

I see potential in multispecies design to converge urban development and nature conservation goals by integrating ecological knowledge and perceiving the city, especially urban wasteland, as part of natural ecosystems. The vagueness of urban biodiversity strategies as well as the necessary feasibility of multispecies design was addressed by developing a step-by-step design framework in a concrete setting based on concomitantly articulated questions.

One of the main insights I gained throughout this process is that built environment professionals are not equipped with sufficient ecological knowledge to face the ongoing biodiversity crisis. Incorporating and conserving biodiversity in urban landscapes requires input from a wide range of disciplines (Ahern, 2013). Planners, architects, landscape architects and urban designers play a major role in the persistence of urban biodiversity because of their direct influence on the evolving form and fabric of the urban environment. To successfully implement multispecies design, the affected professionals need to augment their knowledge palette and work closely together with specialists from the field of urban ecology. The multispecies design framework could provide a first basic structure to cross disciplinary boundaries by clearly determining required knowledge and tools in the process. In the beginning of each iteration level, building mass distribution, zoning, and habitat geometry, the knowledge of urban ecologists and species specialists is needed to achieve a meaningful and effective outcome.

Approaching the more-than-human paradigm shift through design exploration provided valuable insight into the shortcomings of contemporary building typologies in the context of urban biodiversity loss. These shortcomings, apparent in a separation of landscape and building, exist inter alia because of the present dichotomic view on nature and human territory and on built environment and ecology. Based on the research and simulations conducted throughout the process described in chapter 3, I argue in favor of a new urban typology which is articulated through the integration of ecological systems into several layers of the design process.

3.3.3 Challenges and further developments

The step to take from the abstract idea of multispecies design to the implementation of this paradigm shift requires to include the lived experiences of urban decision makers. The multidisciplinary urban planning and design studio Animal Aided Design (AAD) provides an information basis in the German planning context. The method, developed by Prof. Dr. Thomas Hauck and Prof. Dr. Wolfgang Weisser, combines architecture, traffic planning, general city planning, landscape architecture, urban ecology, and nature conservation with the goal to increase urban biodiversity. The approach is to include habitats of target species into early stages of the planning process with a focus on landscape architecture. Their insights and practical experience of working at the intersection of urban ecology and planning were immensely valuable for the realistic contextualization of this thesis.

Many insights gained throughout the framework development process coincide with AAD's findings. Firstly, the public species databases for choosing target species are indispensable (Hauck & Weisser, 2021). In Germany only the cities Bremen and Berlin do not have a central database and therefore initiatives like the biotope network strategy are of high value. For their projects AAD developed regional species pools for major German cities, based on their bio-geographic information.

Secondly, the challenge to implement a network understanding of building sites requires to take the surrounding environment into account. In this thesis this is addressed through incorporating the biotope network data into the site analysis. The author agrees with studio AAD that, to establish this network understanding, common management strategies of the owners of adjacent sites would be beneficial.

To implement multispecies design means to ensure the accessibility of the project area through diminishing or overcoming barriers in the surrounding (Hauck & Weisser, 2021), depending on the species dispersal capacities (Edgar & Bird, 2006b).

According to studio AAD, the design of habitats should consider management and maintenance effort to avoid early decay and ensure consistent habitat quality. In my thesis, the focus was on finding spatial articulations of integrating one animal species into the initial building design rather than placing habitat elements in a landscape design or in the exterior space of a building. The question of maintenance and management is therefore more complex and requires further elaboration.

According to AAD the acceptance and integration of animals in urban environments increases with early involvement of stakeholders like planning experts, nature conservation authorities, clients, and residents in the target animal selection procedure. In their projects the level of participation ranges from information, consultation to codetermination while final decisions in residential projects are usually done by the client. I believe that the elaboration of biotope network strategies could function as decision-making aid in the early project phases. The biotope network strategy of Berlin chose species according to their habitat's functions for other species and chose the most far reaching. Even though some species might be neglected this way, the incorporation of curated species data could support well informed choices with the highest impact possible. The goal of my thesis was to develop an approach for strategical implementation of MD to strengthen habitat networks. I therefore think that a preselection of suitable target species should be done by the planner in close collaboration with urban ecologists, and specialists of the biotope network strategy, before opening the process up for participation. Additionally, AAD mentions the importance of a correct translation of the design into practice throughout the implementation and construction phase. To achieve this, specialized and trained construction workers who consider the protection of species and implement respectful conservational working methods are needed. The monitoring and evaluation of Multispecies Design is crucial to produce best practice examples. Studio AAD refers to ecological, social, and economical aspects to include in the evaluation phase. The research around artificial habitats in the context of animal conservation adds the element of long-term evaluation (Firth et al., 2020) to the implementation process of multispecies design. As the field of multispecies design is only just emerging, learning about effective employment and management of artificial habitat structures is key. Design experimentation, and field or laboratory studies can provide tools to identify reasons and patterns of an animal's habitat choice (Cowan et al., 2020), thereupon informing the design of artificial habitat structures. Drivers of habitat selection adapted in the multispecies design framework include the position of the structure within the landscape, its orientation, structural complexity, and physical dimensions. Additional parameters to investigate are color, microclimate dynamics, hardness, porosity, or surface chemistry (Watchorn et al., 2022). Careful experimentation and testing before applying artificial habitat structures is needed to minimize the risks of producing ecological traps and unsuitable microclimates. Poorly designed structures could lead to higher predation pressure, disease spread, and food scarcity (Battin, 2004). In the urban context the risk of artificial habitats being misappropriated for greenwashing purposes is high and could even facilitate environmental damage when used as biodiversity offsets (Lindenmayer et al., 2017) to compensate negative environmental impacts (zu Ermgassen et al., 2019). The recompense is not guaranteed and could even facilitate environmental damage (Firth et al., 2020). Therefore, a careful consideration of place, time and purpose of those interventions is a condition precedent and should be further investigated in an experimental context to refine implementation strategies and techniques (Watchorn et al., 2022).

Adding to the practical implementation challenges summarized in the previous paragraph, an array of future research and experimentation possibilities emerged throughout the framework development process.

The computational design approach of manipulating building mass and space distribution based on data derived from simulation and environmental information in Rhinoceros and Grasshopper points at a new field of informed space articulation. Computational design as method and tool to incorporate and translate complex data into form and its applicability in the field of multispecies design shows great potential to make use of the more-than-human complexity. Furthermore, due to the ability to express and generate a high level of complexity, the use of computational tools for artificial habitat design is a promising topic to be explored in the future. I state that the paradigm shift towards articulated landscape as architectural typology is inherent in the multispecies design approach. The building typology adopts a unique form for every site as it is responding to an augmented palette of design drivers like the multispecies site context, its position in the habitat network, and target species parameters.

Additionally, I see great potential for exploring the application of the multispecies design framework with other target species. To further develop and test the framework for its scalability, the focus should be on incorporating more than one target species into the process. As in this case the target species are chosen based on the biotope network data, the information of other species on a project site is, though limited to only a fragment of the species inherent in wasteland's ecosystems, already available. The translation and integration of species-specific habitat requirements is a very complex task and requires intense further research and ideation. One scenario could be to develop a species parameter toolkit as guiding element for built environment professionals. In my thesis, the computational exploration of animal-human transitional spaces was limited to public space scale, producing forms usable by the sand lizard and humans. The next step following this exploration will be to investigate how the zones derived from phase 6 inform the building scale with the additional parameters of e.g., usability, light incidence, economic feasibility, and accessibility.

Animals on the development site are currently perceived as nuisance by planners and developers, as they are required to find and provide a compensation area in case rare species are found on site. The need for new approaches that incorporate the creation of wildlife habitats into the planning and design process is urgent (Garrard, Williams, Mata, Thomas, & Bekessy, 2017; Hostetler, Allen, & Meurk, 2011; Parris et al., 2018). I agree with Stanislav Roudavski, senior lecturer in Digital Architectural Design at the University of Melbourne, that the contribution of architects and urban designers to counteract biodiversity loss is inter alia to create tangible visions of multispecies cohabitation through design experiments and to develop instruments to enable better integration of nonhuman participants (Roudavski, 2020). I believe that the continuing loss of nonhuman habitats is not inevitable as through the application of a multispecies design framework the urban environment could accommodate many more lifeforms than it currently does. The more-than-human paradigm shift is already underway and will gain momentum with increasing awareness of the manifold benefits that biodiversity provides (Parris et al., 2018). It is among our tasks as built environment professionals to provide the vision, formula, and tools for a sustainable multispecies future.

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