Formalising Biodiversity Inclusive Design

Subjects: Architecture And Design

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Biodiversity Inclusive Design (BID) is an approach to design that seeks to foster functional ecological systems, enable species' persistence within the built environment and (re) connect people with nature. BID can support designers' quest toward biodiversity positivity.

Keywords: multispecies design ; ecology of place ; people-nature relationships ; socio-ecological resilience ; ecological design

1. Introduction

Built environment professionals currently seek for strategies to respond to the biodiversity emergency. Nature is multifunctional and, when embedded within urban environments, can simultaneously enhance the ecological function of our cities, provide valuable social benefits, and provide a habitat for biodiversity [1]. Nature-based solutions, in which design solutions to environmental problems are inspired by nature [2], use nature to service human needs. In a simulated streetscape design, Lähde, Khadka [3] found that a suite of nature-based solutions delivered multiple co-benefits, including stormwater management, water quality, amenity and biodiversity. Similarly, intentionally designed constructed wetlands and photovoltaic energy plants can become biodiverse ecosystems [4]. However, intentional multifunctional design is required, or functions attributed to nature may fail to manifest [5].

Built environment professionals are trained to create liveable spaces for people and also rely on human-centred design paradigms to integrate nature into the city. For instance, biophilic urbanism is justified by human affinity towards nature [6] and anticipates the integration of nature in cities to service human health and well-being [7]. Similarly, water-sensitive design, regenerative design and urban greening apply an ecosystem service approach to address environmental challenges. In these frameworks, if biodiversity is not intentionally designed for or does not demonstrate the servicing of a human need, the biodiversity-enhancing potential of a project is often designed out [8].

Nature-positive development extends beyond these human-centred design paradigms by explicitly recognising and compensating for past harms. The nature-positive concept comes from Positive Development theory, which calls for the development sector to compensate for the past, present and ongoing impacts of development [9]. The theory seeks to deliver homes, neighbourhoods and cities that increase the resources (i.e., food, energy, water, nature), carrying capacity and ecosystem services to provide healthy and safe environments to live in and move through [9][10]. This requires taking action to retain and restore natural habitats as well as to integrate new and novel opportunities to create habitats and resources for biodiversity beyond pre-development levels.

True nature-positive development must also be biodiversity-positive. Herein, the researchers understand 'Biodiversity' through a 'design lens' and equate the diversity of species (within a particular locality) as multiple non-human stakeholders. Each species is a separate stakeholder or non-human user, which may be positively or negatively affected by a proposed development.

To deliver biodiverse cities where people and biodiversity—i.e., non-human species—co-exist, designers must explicitly consider what different species living within urban landscapes require to lead a generative life. Biodiversity Inclusive Design (BID) is a "collaborative process that intentionally positions local biodiversity as the non-human users of place to inform design thinking and decision-making" (p. 25, [11]). BID offers strategies for transdisciplinary collaboration to deliver biodiversity-positive development.

The difference between design paradigms that deploy nature-based solutions and BID lies in the direction of the relationship between nature and design. With nature-based solutions, the designer uses nature to solve complex environmental problems that exist within urban landscapes [2][5][12]. Meanwhile, BID shifts the direction of the relationship using design practice to deliberately incorporate features within the urban landscapes to support species' lives as part of a

thriving ecology [11]. Prioritising non-human stakeholders within the design process continues to deliver the functional and liveability benefits that come from integrating nature within urban areas [12], but co-benefits for non-human species have become intentional.

As a design approach, BID is not novel. Some designers are seeking to design for one or more species, i.e. [13][14] and even incorporate non-human personas to guide their design thinking, i.e. [15][16][17]. However, the term was only recently defined, and requires further conceptual development. This approach to design ensures that designers explicitly establish who the local non-human users are and elaborate a strategy to fulfil their requirements. The definition also emphasises the importance of strategic collaboration, design thinking and decision-making.

In a systematic literature review, Hernandez-Santin, Amati [11] sought to understand the potential roles of biodiversity as urban stakeholders in planning and design processes. Their research process identified a total of fourteen design frameworks that establish biodiversity as an active stakeholder within the design process, eight of which are associated with BID. It is possible to find a system of underlying rules, ideas, beliefs, principles and a basic structure to guide design thinking and decision-making processes embedded within each design framework. This system provides valuable information for the further development of BID as a concept and design approach.

In addition, practitioners also offer frameworks incorporating biodiversity considerations within projects. Examples include certification programs such as SITES [18][19], Building with Nature [20], and Living Building Challenge with a new Ecology of Place Petal [21]. However, it is unclear what these frameworks can teach us about BID and the specific contexts in which these frameworks would be most useful for BID practice.

2. Formalising Biodiversity Inclusive Design

BID suggests that to deliver biodiversity-positive development projects, neighbourhoods and cities, it is necessary to actively design for biodiversity. By conceptualising biodiversity as a multitude of non-human stakeholders of place, designers can ground creative and problem-solving thinking around concrete goals and identify feasible strategies to provide for one or more species and enable their persistence within urban areas. Here, researchers present the synthesis of the design framework analysis as relevant to BID practice (**Figure 1**).

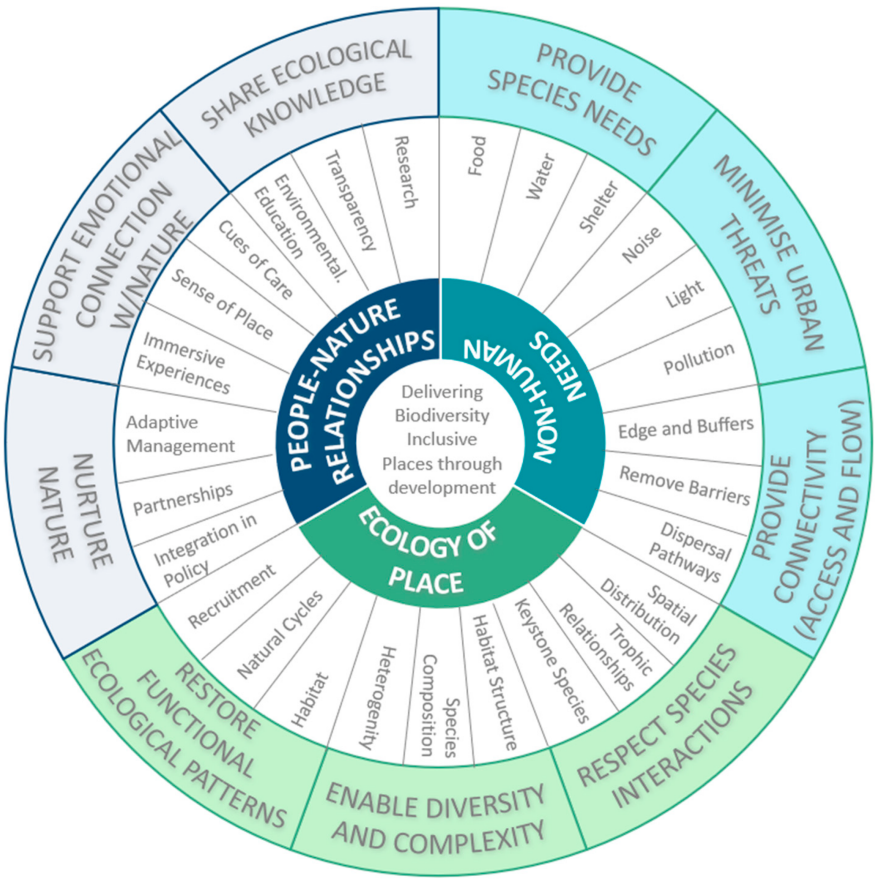

Figure 1. Dimensions, design principles and factors considered in BID Practice. In the middle is the overarching aim of BID as a design approach. Directly surrounding the aim, three core dimensions of BID design practice (the inner circle), the outer circle shows the BID nine design principles and the factors for consideration in BID are found between both circles.

2.1. Three Dimensions of Biodiversity Inclusive Design

BID aims to deliver nature-positive developments where people and nature co-exist. It requires built environment professionals to strategically act across three different dimensions: the ecology of place, the non-human users and the people-nature relationships. In **Figure 1**, the inner circle represents these three dimensions as a circle surrounding the design aim.

2.1.1. Design for a Functional Ecology of Place

The concept of 'place' is simultaneously a geographical location, physically bounded and a relational entity [22], shaped by the people–people and people–place relationships [22][23]. 'Place' has physical (location) and emotional (meaning) aspects to it [23].

Designing for 'place' is a critical imperative for built environment designers. Planners, architects, landscape architects, urban designers and other relevant professionals aim to deliver meaningful built environments. However, "conceptions of place have also been bedevilled by an anthropocentrism which disregards the many ways in which place might be created by non-humans" (p. 8, [22]).

Nature is critical for our shared sense of identity and sense of place [24]. For example, in biocultural diversity, human-nature relationships are used to explore how everyday nature experiences contribute to an individual's care and attachment to nature [4]. Beyond nature's contribution to identity, Ian McHarg argued that place-based design, grounded on a deep ecological understanding of place, is imperative to delivering healthy, liveable cities [25][26]. This made 'place' one of the three imperatives of ecological design [27][28]; it is also the first imperative of Biodiversity Inclusive Design.

Throughout the design process, the team attempts to design for non-human users of place. Design teams are asked to deeply connect with and gather knowledge about the local ecology and biodiversity. Then, the team uses this information to directly inform their design. Popular biodiversity-enhancing actions need to be adapted to the specific region, climate and biodiversity. For example, bee hotels are finetuned to native bee species of an area, modifying the types of materials used or the size of the holes drilled into the wood. Biodiversity-enhancing actions are geographically bounded by the 'locational' aspect of place.

BID also speaks towards the emotional, meaning-based aspect of place. BID shifts the direction of the human-nature relationships aiming to benefit biodiversity rather than use nature to service people. By shifting the direction of the relationship, BID uses deep ecological understanding to encourage a 'sense of place' for both humans and non-humans. Biodiversity-enhancing features delivered for an area will speak directly to the natural identity of an area, supporting biocultural diversity and positive human-nature relationships. Furthermore, BID's emphasis on delivering functional ecologies for species survival will also deliver functional and resilient systems.

2.1.2. Design for Non-Human Users of Place as 'Clients'

BID asks designers to reframe biodiversity as many non-human stakeholders and identify those species that will be most affected by the project. These selected species are then established as 'targets' for design and conservation and equalled to 'non-human clients' for each project. Establishing species to design for and clear biodiversity goals is a critical step to enabling accountability and follow-through [8][29]. These goals help communicate the sought-after experiences for the project, its implications for the ecological function of the site and its lived experience for both humans and non-humans.

The 'species as clients' construct represents the intentional decision to cater for species with the same level of importance given to design clients. There is more than one way of selecting one or more species as clients. For instance, Apfelbeck and Jakoby [30] suggest potential species be selected from a 20 km radius of the site. Meanwhile, Lundberg and Andersson [31] favour highly mobile species with important seed dispersal or pollination roles as a way of enabling connectivity and genetic diversity. As a final example, the post-2020 global biodiversity framework emphasises the importance of 'halting biodiversity extinction rates' and might prioritise the selection of threatened species.

When selecting non-human clients for any given project, it is important to keep in mind the feasibility of 'designing-in' the ecological requirements for each species within the project. This includes the resources (food, water, shelter) the species will need. It also includes how species interact with the landscape and with each other to identify potential overlaps and synergies or conflicting priorities. For example, a series of wetland parks in Seattle experienced an increase in ecological complexity and biodiversity after they were colonised by beavers [32]. Known as an ecological engineer, the beaver acted as a catalyst to create functional wetland ecosystems, but it also made it impossible for other species to colonise said parks. Some species may not be compatible because they require different types of habitats or may actively avoid each

other to avoid predation or competition for resources. For instance, two urban-adapted bat species actively avoid sharing a habitat to avoid competing [33]. Gaining awareness of the compatibility and feasibility of the species being selected as clients is critical for a project's success.

Depending on the framework selected, suitable 'species as clients' can include individual plants [34] and/or animals [34][35][36][37], groups of species (i.e., avifauna) [37] or even habitats encompassing all the different species that are critical for the ecological function of said habitat [34][38]. While the strategy selected to guide species selection might determine eligible target species, all frameworks evaluated agree that 'client' species should be carefully and collaboratively selected based on their impact on ecological function, cultural values and community preferences, attainability and feasibility of success. Once selected, the species become a non-negotiable of the project, and design decisions can be evaluated based on their ability to facilitate or hinder the 'species as clients' survival within urban areas.

Designers are also asked to gain clarity on how the site will be managed after the project is built and incorporate evaluation and management considerations as part of the design process. Understanding future management strategies enabled the ongoing improvement and adaptation to local conditions. BID asks designers to move beyond 'preserving' biodiversity but instead proactively attempt to create new environments for biodiversity [35]. This is aligned with nature-positive thinking, which makes built environment disciplines accountable for the ecological deterioration of the past [39].

2.1.3. Design to Nurture People-Nature Relationships

Nature and biodiversity play an important role in cultural identity. BID suggests that participatory design is critical to celebrate existing relationships between people and nature or (re) igniting the community's connection to nature. Built environment professionals are asked to engage with the local community and First Nations People to integrate their values and perspectives into design-thinking and decision-making considerations. For instance, while establishing target species for action, the 'people-nature relationships' dimension and the 'non-human users' dimensions overlap by identifying cultural and social values attached to different local species.

2.2. Nine Principles for Biodiversity Inclusive Design

The analysis distilled nine BID principles that could help guide built environment professionals' design thinking and decision-making process. The design principles are represented by the outer circle of **Figure 1**, while relevant factors are located within the space between both rings. Each principle remains broad enough that delivering 'restored habitats' or 'constructed ecologies' can be equally valid approaches to BID practice:

- **Restore functional ecological patterns:** Designers are asked to think about natural cycles (soil, water, gas exchange) and identify strategies to improve their health. Responding to the site condition and context also entices designers to think about the habitat scale and restore or emulate habitat characteristics to deliver urban landscapes that are structurally complex and diverse. Diversity is evaluated based on ecological function rather than restoration to acknowledge urban areas as ecosystems where some remnant habitats might require more traditional conservation techniques while other spaces welcome constructed ecologies. Factors to consider in this principle include Natural Cycles, Habitat Character and Recruitment.

- **Enable diversity and complexity:** Habitat structure and complexity are well-known factors that deliver biodiverse habitats. This principle seeks to incorporate well-tested biodiversity-enhancing actions at a habitat level to support biodiversity as a whole. Factors to consider in this principle include Habitat Structure, Species Composition, and Heterogeneity.

- **Respect species interactions:** This principle asks designers to gain deeper knowledge about how the ecology of the site works and the role that different species have in delivering a functional ecosystem. Having a clear understanding of how the local species relate to each other (i.e., predator-prey interactions) can help deliver designs that foster desirable species. Factors to consider in this principle include spatial distribution, trophic relationships, and keystone species.

- **Provide species needs:** In using the 'species as client' construct, this principle seeks for designers to get to know the species that they are designed for. Each species, just like people, need different things from the place they live in. This process enables designers to understand the needs of non-human clients (their ecological requirements) and to identify potential strategies to support conservation through design. Factors to consider in this principle include Food, Water, and Shelter. Shelter includes the resources needed to find or build a shelter as well as considerations of the minimum area required for species to conduct their daily activities.

- **Minimise urban threats:** This principle seeks to enable designers to identify common features within the urban form that are known to affect biodiversity. Having an awareness of how they affect different organisms can help a designer identify existing biodiversity-friendly technologies (e.g., wildlife-friendly lights). When a solution does not yet exist, it offers opportunities for designers to use their design thinking skills in the service of non-human species. Factors to consider in this principle include Noise, Light, and Pollution.

- **Connectivity:** This principle asks designers to think at multiple scales and deliver interconnected habitats. This includes planning for connectivity (at large-scale projects), identifying where your project fits within existing connectivity plans (for small-scale projects) and incorporating features within their projects that support species' ability to move across the urban landscape. Factors to consider in this principle include Edge and Buffers, Removing Barriers, and Dispersal Pathways.

- **Share ecological knowledge:** This principle seeks the implementation of design and site management processes that elicit ongoing learning and awareness of the local ecosystem and its functions. Supporting ecological research for the continuous gathering of evidence is critical to maintaining up-to-date information. This keeps BID place-specific, relevant and aligned with advances in the field. Environmental education programs are encouraged to transfer knowledge about local species, implement biodiversity-enhancing actions and communicate the rationale behind them. Factors to consider in this principle include Research, Transparency, and Environmental Education.

- **Support emotional connection with nature:** Designers could draw from nature-connection literature and use concepts such as biophilia see [2] and regenerative placemaking [40] do deliver opportunities for communities to connect and reconnect with their local environment and local species. Factors to consider include enabling Immersive [nature] experiences, a Sense of Place and Cues of Care which indirectly communicate that local species are valued.

- **Nurture Nature:** This principle seeks the implementation of design and site management processes that elicit active citizenship to protect local biodiversity and ecological functions. There is an overlap between this principle and principles seven and eight. 'Nurturing Nature' calls for action, but this action is built upon the community's knowledge of and emotional attachment to the local environment to elicit participation. The act of nurturing nature should cross boundaries between organisations and communities. For instance, Citizen Science is an opportunity that some projects can find suitable to integrate the community in the act of research as well as ongoing management of the BID practices established in a project. Developing partnerships to enable the community's participation in the ongoing monitoring and management of the project is a great step to maintaining long-term emotional bonds between the community and their environment. Factors to consider in this principle include Adaptive management, Partnerships, and Integration into the policy (site-specific policies or legal requirements).

2.3. A Strategy for Integrating Biodiversity Inclusive Design

Built environment professionals (planners, urban designers, architects, and landscape architects) can use ecological information and species-specific characteristics to support their design processes [41]. The exploration of 15 design frameworks unveiled a series of activities common among the different frameworks that designers and transdisciplinary collaborators can apply to integrate biodiversity perspectives into built environment projects (**Figure 2**). While there are nuanced differences in each, all frameworks recommend a comprehensive site analysis of the local ecology, the identification of key species to design for and engaging with a variety of non-designers to explore the relationships between people and nature.

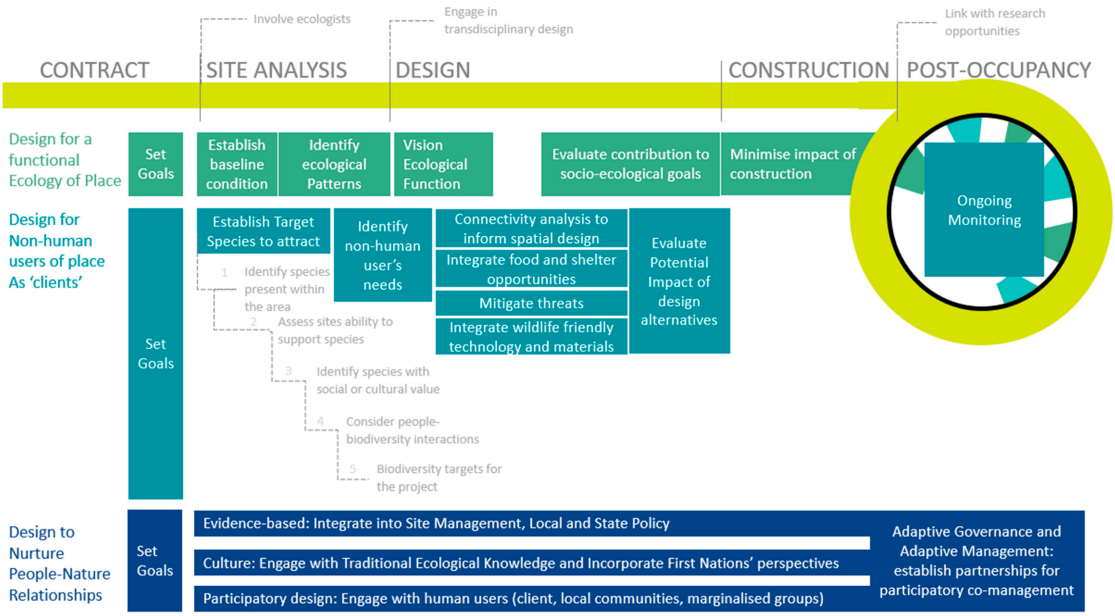

Figure 2. Synthesis of the Biodiversity Inclusive Design Process. The yellow-green loop at the top represents a typical design process with five key stages: contract, site analysis, design, construction, and post-occupancy design phases. The circle at the final stage is used to represent the iterative and ongoing nature of design processes; the post-occupancy stage is under constant evaluation. The three categories of the *y*-axis represent the three core dimensions of action: design for a functional ecology of place, design for non-human users of place and design to nurture people-nature relationships. The coloured boxes stand for the recurrent activities that design teams should complete at different stages of the design process by the analysed frameworks. The colour of the boxes represents the dimension of action to which they are aligned. The green colour represents actions that will help designers deliver a functional ecology of place; the turquoise colour represents actions that will help design for non-human users of place; and the deep blue colour represents actions and partnerships that should be developed to nurture people-nature relationships. Lastly, in light grey text researchers find opportunities for collaboration across whole phases of the design process, or specifically as sub-steps to identify target species for the project.

The BID process begins when the design team (including consultants) intentionally position local biodiversity as the non-human users of place. Designers may be motivated by personal values, respond to the interests of the local communities or be dictated by the government and/or 'human' clients of the project. As represented by the design frameworks analysed for this body of research, BID can apply a variety of methodologies to engage in meaningful conversation about the relationships between the three different dimensions of Biodiversity Inclusive Design. This includes exploring and understanding the ecological systems (ecology of place), selecting the non-human clients (habitat, natural cycle, plant species, animal species or a combination), and investigating the relationship between human and non-human neighbours.

During the site analysis, the design team gathers information about the local ecosystem and local biodiversity. From an ecological perspective, the analysis should help identify key patterns that keep the ecosystem functioning. This may include mapping out areas that have remnant natural habitats or identifying natural cycles and ecosystem services that were compromised with urbanisation. This is used to establish specific clients to design for. For best results, the 'clients' should be selected in collaboration with the local community and, when applicable, with First Nations Peoples.

The process provides non-human participation within the design process. The client species are investigated, creating a 'knowledge pool' of species' requirements. The designer can use this information to purposefully incorporate a biodiverse user's needs in the design. Ecologists are invited to the design table to act as species' voices keeping designers on track and accountable. Through their knowledge and work (i.e., completing technical analyses), ecologists can evaluate and communicate which design decisions will negatively affect non-human clients. Finally, having clear and feasible evaluation and management strategies is critical to contribute to ongoing growth in this field of knowledge.

The frameworks analysed place non-humans at the centre of the design process asking designers to collaborate with ecologists knowledgeable about the local ecology to guide how to design for the non-human experience. The main task of these frameworks is to bring rigour and accountability to their design and decision-making processes to incorporate biodiversity.

There is more than one strategy that offers a valid design process capable of delivering projects filled with features that can support biodiversity within urban areas. Analysis suggests that, while similar, the frameworks offer nuanced

differences that make them suitable for application under different circumstances. As such, designers must develop an awareness of the underlying assumptions, implications and limitations of different frameworks to select the one that is more suitable for their project on a case-by-case basis.

Simultaneously, some frameworks can co-exist within the same design process as they have different yet complementary priorities. The analysis identified frameworks with three different functions: to provide ecosystemic perspectives (habitat-scale), to provide species-specific perspectives (species as clients), and to provide threat-mitigation perspectives. These three perspectives offer an opportunity to nest frameworks within each other.

A Decision-Matrix for Integrating Biodiversity Inclusive Design

The frameworks place non-humans at the centre of the design process. They ask designers to collaborate with ecologists who are knowledgeable about the local ecology to guide how to design for the non-human experience. The main task is to bring rigour and accountability to design thinking and decision-making processes to incorporate biodiversity as non-human clients of design.

Multiple frameworks offer valid strategies for BID. These frameworks are capable of delivering projects filled with features that can support biodiversity in urban areas. While similar, these frameworks offer nuanced differences that make them suitable for application under different circumstances. As such, designers must develop an awareness of the underlying assumptions, implications and limitations of different frameworks to select those that are most suitable for their project on a case-by-case basis.

Simultaneously, some frameworks can co-exist within the same design process as they have different yet complementary priorities. The analysis identified frameworks with three different functions that adapt popular conservation strategies to design practice: habitat or natural-cycle as clients (ecosystem-scale conservation), species as clients (surrogate-based conservation), and threat-mitigation (minimising threats to biodiversity). These three approaches can be nested. For example, the Biodiversity Sensitive Roads framework can be embedded in an overarching Biodiversity Sensitive Urban Design process to provide advice to specifically mitigate the threats of roads acting as barriers for some of the species selected as clients. Similarly, ecosystem-scale conservation can benefit from ‘species as clients’ frameworks to support local-scale biodiversity-enhancing actions. Furthermore, nested with other overarching ecological design frameworks, BID offers a replicable and rigorous strategy to intentionally design for the coexistence of people and biodiversity (**Figure 3**).

Figure 3. A multi-framework nested approach to enabling non-human perspectives within the design process. The grey box at the top presents four out of the five stages of the design process. The light grey text highlights key activities for the design team to complete. The boxes with a thick black line on the left represent different design frameworks; their location indicates the dimension of action (design to enable functional ecologies or design for non-human users of place) and the activities that they are associated with. A single design process could use multiple frameworks simultaneously.

2.4. The Scalability of Biodiversity Inclusive Design

This publication has focused on exploring the concept of Biodiversity Inclusive Design as informed by a series of 'design frameworks'. While BID was explored through a design lens, it is a scalable concept that could be equally applied to ecosystems, habitats or micro-habitats.

BID provides a tangible approach for designers to interact with and design for non-human stakeholders. Each project, small or large, should be seen as part of a nested system. While grounded in a geographic location, the concept of 'place' does not have specific boundaries. Instead, the extent of the physical boundary is negotiated on a project-by-project basis. Similarly, BID can be applied to projects of all sizes: single dwellings [42], single public spaces such as a park [32], whole neighbourhoods [14][43] or at the city scale [1][30].

There is a healthy academic discourse on how to integrate biodiversity consideration at a planning level, i.e., [44][45]. For example, ecological design often uses various mapping layers and ecological information to understand the natural processes at play and identify suitable land use [25]. More specifically, large regional-scale maps can help identify priority areas for conservation within urban landscapes [46] or identify existing and potential ecological networks for connectivity [47]. These provide a systematic strategy to understand the ecological patterns at a 'macro-scale'.

Even working with a single species, built environment professionals can be challenged to figure out the 'scale' of their work. For some species, local characteristics of their immediate environment are critical for their survival, while highly mobile species need designers to act at a landscape-scale. For example, Kyrö, Brenneisen [48] found that beetle diversity within urban areas is influenced by habitat characteristics, while Mayorga, Bichier [49] discusses an array of local and landscape characteristics that influence bird assemblages. As such, the 'physical boundary' at which BID acts is set up on a project-by-project basis and responds to the needs of human and non-human clients.

2.5. Biodiversity Inclusive Design within Positive Development

Positive Development offers a holistic theory for the development of the built environment to maximise socio-ecological benefits. Thinking about development through an ecological mindset offers a set of principles and processes to protect and enhance social capital, economic capital, natural capital and more [9]. It challenges the traditional understanding of development as an opposing force to biodiversity conservation by seeking opportunities for co-benefits. As a holistic practice, Positive development asks designers to act across various socio-ecological considerations, including local ecology, social, economic, democratic and governance, with sustainability at the core of the process [39].

In contrast, BID offers only a small subset of these considerations as issues around democracy and governance of the system are specifically related to human-nature relationships. For instance, BID advocates for adaptive governance strategies for the ongoing monitoring and maintenance of biodiversity within an area. Meanwhile, Positive Development would include the aforementioned governance as well as the governance of other topics associated with sustainability. However, BID provided an added level of specificity in grounding design thinking and decision-making for biodiversity through the purposeful selection of non-human clients. Many of these frameworks call for a multitude of individual species, clearly selected for their critical roles for conservation, including [30][34][35][36]. This can include a role as an advocate (i.e., species with social or cultural value), species being displaced by urban environments (i.e., threatened species), or species with important ecological roles that signal a healthy ecosystem (i.e., keystone species, indicator species, ecological engineers, etc.). That said, there is a clear overlap between the principles advocated by positive development and BID. This overlap highlights synergies and alignment between the two concepts that require further investigation.

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