




Review

A Review of Existing Ecological Design Frameworks Enabling Biodiversity Inclusive Design

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Abstract: Built environment practitioners currently seek options and opportunities to respond to the biodiversity emergency. 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. However, design projects that prioritise biodiversity are sparse and are limited to ad hoc initiatives by individual champions rather than being standard practice. Frameworks providing a structured design process to achieve biodiversity positivity already exist, but they can be difficult to find, compare and navigate. Responding to calls to further develop the concept of Biodiversity Inclusive Design, we systematically analyse 15 design frameworks compatible with BID. We explore how existing design frameworks position biodiversity as a client. For each framework, we uncover the underlying rules, ideas, beliefs, design principles and proposed structure of the design process. Through a thematic analysis, we identify re-emerging concepts and themes underpinning BID. Nested within complementary design frameworks, we conclude by positioning BID as a set of parallel processes that specifically explore biodiversity's perspectives (needs, preferences) and how they interact with the socio-ecological system to give a voice to biodiversity within the planning and design process. Our paper formalises BID as a practice and identifies three core dimensions of design action and nine design principles.

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



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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. In this publication, we 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. [15–17]. 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 (see Section 3.2). 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.

We sought to analyse academic and practice-led design frameworks that facilitate BID. Through a thematic analysis, we explore and identify key patterns in collaboration (i.e.,

who should be involved?), design thinking (i.e., what steps should guide the design team's iterative steps?) and decision-making (i.e., how should designers evaluate and choose between their available choices at each stage of the design process?). We synthesise this information to consolidate the BID approach.

The paper begins by introducing 'species as client' as a theoretical construct that is used in our analysis. We then present our methodology and the results of our exploration of the framework. For our discussion, we synthesise and consolidate the lessons learned into three core action dimensions, nine design principles, and an overarching BID process.

2. From Biodiversity to 'Species as Clients'

Stakeholder analysis is a valuable approach to finding stakeholders that might be affected by future development. The power-interest grid, a popular strategy for stakeholder analysis, organises stakeholders across the power they possess to guide or determine project priorities and their level of interest in the project [22–24]. On the right side of the grid, the matrix highlights stakeholders who have the most vested interest in the project. They may be individuals or community groups who want the project to succeed (i.e., if they will benefit from the development) or those seeking to halt a development (i.e., if they will be negatively impacted). On the top side of the grid, the matrix shows those stakeholders who can provide legal and/or financial backing to move the project forward (i.e., local council, investors, clients). These stakeholders have some level of control or influence over project decisions.

The power-interest grid also has implications for the level of engagement desired as it helps identify which stakeholders a designer should actively collaborate with (Figure 1). The matrix allocates four levels of engagement (minimal effort, keeping satisfied, keeping informed and active engagement) [24]. Figure 1 shows these four engagement categories in light grey text. The stakeholders in the top-right corner represent those whom the designer is actively engaging with, while those they aim to 'keep informed' often constitute minorities and marginalised communities with little power to influence decision-making. If a designer were to consider biodiversity, they would first need to understand the term as a multitude of non-human stakeholders and identify those species who will be affected by the project. The most probable location we would find most species is the lower-right quadrant, as powerless stakeholders highly affected by the development. However, as we can never aim to keep non-human species 'informed', they are still powerless and ignored. They are treated as a passive stakeholder in the design process [11].

Designers can also use stakeholder analysis to identify marginalised communities affected by the project to design a participatory engagement process. Participatory design is a process that gives citizens power and decision-making agency over the city they live in [25]. It effectively moves engagement from tokenistic levels of the participatory ladder to citizen-power see [25,26] for the participatory ladder]. This entails the conscious movement of stakeholders found in the 'interested but powerless' quadrant (lower right) to the 'interested and powerful' quadrant -top right.

In Figure 1, we argue for positioning the species most impacted by a project alongside human clients. This argument is not exclusive to this publication; it has been advocated for in research, teaching and design [27]. The type and level of impact, positive or negative, varies depending on the species. The design team should evaluate each species' response separately. For instance, species requiring very specific conditions to survive, i.e., catbirds [28], are displaced by urbanisation, while exploiters thrive, i.e., racoons [29]. Those species most affected by a project or with known potential to act as surrogates for other species are explicitly integrated into the design process.

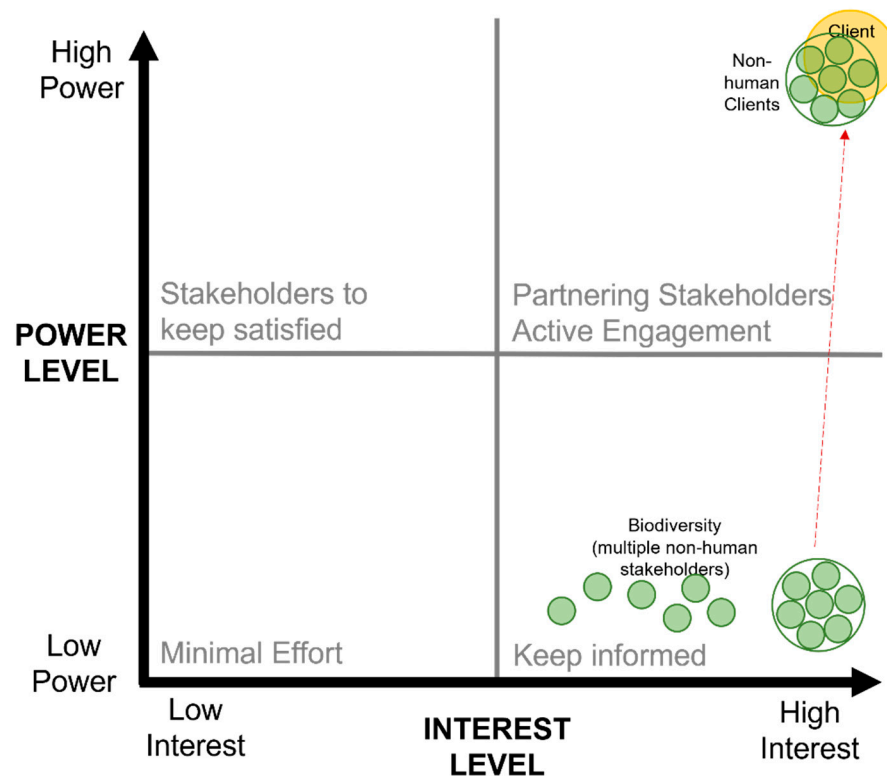


Figure 1. Power-Interest Grid. Adapted from Gardner, Rachlin [24] and Mendelow [22] to incorporate the construct of ‘species as clients’. The power-interest grid organises stakeholders depending on the level of interest and power they possess for any given project. While organised as a grid, it is also a continuum, with the black arrows showcasing the increase of interest and/or power. The grey text shows the level of engagement desired for each quadrant based on Gardner, Rachlin [24] and Mendelow [22]. We’ve incorporated ‘biodiversity’ as multiple green circles (with each species acting as a different stakeholder). In a tight circle on the right, those species are most impacted by the project. ‘Clients’, with the most power and interest, are in the top-right corner. The ‘species as clients’ construct argues for positioning biodiversity alongside human clients by intentionally prioritising the delivery of features and natural assets that enable client species’ survival within the urban landscape. The intentional shift of non-human stakeholders’ position in the grid is represented with a thin red arrow shifting the species within the circle to the top-right corner as ‘non-human clients’.

BID seeks to deliver developments that are ecologically functional and biodiverse. It seeks to support species viability by providing the resources they need, mitigating urban threats, and enabling healthy relationships between people and nature. It begins by consciously placing individual species as non-human stakeholders and strategically shifting them from a passive or incidental role to an active role as a stakeholder [11]. In other words, it is the act of designing a participatory process to give non-humans a voice within the design process. While non-humans do not speak on ‘human’ terms, we have the knowledge and skills to understand the requirements individuals, populations and communities have that set their conditions for a generative life. Even if they are not able to participate through their advocacy, we can advocate for them in a way that is analogous to ‘advocacy planning’ [30].

Locating them at the top right corner, among the most influential stakeholders, as the ‘non-human clients’ provides an ethically robust response [27]. Clients hold powerful positions within the design process as they possess the resources (money and decision-making power) that drive projects forward. A designer must actively engage with and keep clients satisfied with the proposed development or risk losing their business. Designers are accountable to their clients.

For the purpose of provocation and distinguishing the bespoke solutions required of Biodiversity Inclusive Design, we have concluded the preference for ‘species as clients’ as a metaphor for BID. This enables designers to use this new language to consciously shift their mindset in identifying species to design for and then positioning them as distinct stakeholders with decision-making power. Selecting one or a small number of species is an effective conservation strategy that design frameworks aligned with BID are employing [31–33]. It helps gather public interest, as well as focus design and or management actions under concrete banners [33]. It is also a useful pedagogical [27] and conservation tool [34]. Conceptualising these species as ‘clients’ of the design process awards individual species one of the most powerful positions amongst the different stakeholders. It strategically shifts species from *voiceless and powerless* to *powerful* and implies that designers should be equally accountable to selected species as they are to the stakeholders who pay the bill.

3. Materials and Methods

To synthesise and further develop BID, we undertook a systematic analysis of academic and practice-led design frameworks aligned with the concept of species as clients. The systematic analysis categorised the different characteristics of each framework. Then, we conducted a thematic analysis investigating the core components of BID: collaboration, design thinking and decision-making.

3.1. Scoping Relevant Design Frameworks

We build upon the results in Hernandez-Santin, Amati [11] and, through our selection criteria (Table 1), choose eight frameworks for detailed analysis. These frameworks (1) provide a decision-making structure for at least one phase of the design process (see analysis), (2) call for evaluation processes to identify impacts on local biodiversity (selected species) and/or local ecosystems, (3) ask for design decisions to minimise impacts for selected species and ecosystems, and (4) generate habitat opportunities for species survival through planning and design. These frameworks were used as a parting point to scope design frameworks for analysis.

Table 1. Selection Criteria to find relevant Frameworks for analysis.

Selection Category	Selection Criteria and Definition
Framework	- Framework components are readily available: ideas, beliefs, rules, principles and structure (see Analysis, Section 3.2).
‘Design’	- The framework provides a design thinking and/or decision-making structure suitable for design practice. - Applicable to one or more stages of the design process: pre-contract, site-analysis, design, build and post-occupancy [35].
Biodiversity Inclusive	- The framework seeks to enable species’ persistence within urban areas. - The framework suggests actions to help designers understand the habitat and/or species’ needs within the urban landscapes (ecological requirements) and design for these non-human stakeholders. This could include opportunities for designers to learn about the local biodiversity, identify one or more ‘species as clients’, and determine and design for the needs of the non-human clients of built environment projects.

However, the Hernandez-Santin, Amati [11] review was limited to peer-reviewed publications, missing design frameworks proposed by professionals. With a snowballing methodology, we explored the reference list of selected publications, performed a Google and Google Scholar search, and sought guidance from peers in academic and professional settings. Our search included terminology such as ‘designing for biodiversity’ and ‘multi-species design’, as well as searching directly for frameworks recommended by our peers. We incorporate non-academic frameworks by reputable organisations such as architecture and landscape architecture societies within English-speaking countries such as societies and institutes within the United States of America, the United Kingdom, Australia and New Zealand. We also incorporated the ecological and biodiversity-focused frameworks within sustainable building certification schemes such as SITES, Living Building Challenge, Building with Nature and the Green Building Council.

3.2. Analysis

The Cambridge Dictionary defines a framework as “a system of rules, ideas, or beliefs that is used to plan or decide something”. Within design practice, a framework often includes principles and a basic structure to guide designers’ thinking and decision-making processes. We define design frameworks as a system of rules, ideas, beliefs, principles, and basic structures to design thinking and decision-making processes. We conducted a systematic review of selected frameworks to identify the explicit and implicit components of each framework. We annotated general information determined by our definition of ‘framework’ (ideas, beliefs, rules, principles, structure) as well as the frameworks’ implications for BID (Table 2).

Table 2. Systematic review for each framework, including framework components, a description of those components and the variables analysed.

Framework Components	Description	Annotated Variables
General information	A summary of the framework’s strategy for designing for biodiversity and its creators.	<ul style="list-style-type: none"> - Name - Description - Authorship - Affiliation (Academic-led or Industry-led)
Formalisation status	Categorisation of frameworks based on the extent to which original authors defined the guiding principles and basic structure expected of the design process. FF represents formalised frameworks; IF represents inferred frameworks where some components were implied by authors rather than explicitly established.	<ul style="list-style-type: none"> - Status (FF or IF)
Ideas	Key theories and academic concepts that ground the strategy.	<ul style="list-style-type: none"> - Ecological concepts
Beliefs:	Implicit or explicit philosophical understandings and assumptions that ground or support the strategy.	<ul style="list-style-type: none"> - Valued biodiversity - Assumptions
Rules	The ‘rules’ of when to use this framework and what for. This includes enhanced clarity of the framework’s function (what is it for?), identification of the design stage that this framework can be used for, and our understanding of the key priorities guiding decision-making processes.	<ul style="list-style-type: none"> - Aim - Design Stage - Priorities - ‘Species as clients’ eligibility

Table 2. Cont.

Framework Components	Description	Annotated Variables
Principles	Design principles are established by authors to guide design thinking and decision-making. This includes principles established directly (formalised frameworks) or indirectly (inferred frameworks).	- Design Principles
Structure	Interpretation of who should be involved in the design process and expectations on what they need to achieve across each stage of the design process. Aligning with Felson, Pavao-Zuckerman [33], stages of the design process were deconstructed into five stages: contract, evaluation or site analysis, design, construction and post-occupancy or management.	- Design Team - Design Activities
Implications for BID	Identification of key themes to categorise each framework based on the characteristics of the design process (alongside three components: collaborative process, design thinking and decision-making) and the specification of the principles and factors for consideration and processes for design.	- Collaborative Process - Design Thinking - BID Principles and considered factors - Decision-making - Processes for design

We conducted a thematic analysis to categorise frameworks based on the characteristics of the design processes represented and the key functions they achieve within the design process. Thematic analysis is a well-established methodology commonly used to identify underlying patterns (or themes) grounding a particular concept [36,37]; in this case, ‘Biodiversity Inclusive Design’. Our thematic analysis used inductive coding [38], teasing out the common components and characteristics of the frameworks to identify the core ideas and characteristics of Biodiversity Inclusive Design.

3.3. Study Limitations

In this publication, we drew upon academic-led and industry-led frameworks aligned with Biodiversity Inclusive Design. As a starting point, we relied upon frameworks previously identified by Hernandez-Santin, Amati [11] and expanded the search-seeking advice from our peers and conducted Google searches to identify frameworks outside of the scope of the original literature review. As such, we did not follow a systematic strategy to identify the analysed frameworks and are limited to those available in the English language, potentially missing frameworks that are available in non-English speaking countries. However, this narrow scope was determined as English is the only language spoken by all authors, and it enabled our discussions about what each framework entailed. Furthermore, they are limited to ‘design’ frameworks, potentially missing out on opportunities to incorporate frameworks from conservation and urban ecology that are not yet linked to planning, design, and other urban disciplines. As such, this study does not comprise a comprehensive analysis of all frameworks that are relevant to Biodiversity Inclusive Design. Further research could address this limitation by identifying frameworks in different languages or nominating new frameworks to incorporate into the analysis.

While the selection criteria did consider the quality of the frameworks to infer credibility, analysis of the frameworks’ ability to deliver biodiversity-enhancing solutions in real-world professional design practice was beyond the scope of this publication. Future research opportunities in this area include but are not limited to: (1) the identification of the different strategies and tools available for the design team to complete the different activities needed within the proposed design structure and (2) an evaluation of biodiversity-enhancing actions in practice.

Lastly, the analysis and write-up of this publication are influenced by the authors' lived experiences and disciplinary backgrounds. We are a multidisciplinary team of specialists in ecology, urban planning and environmental engineering who work as educators. Future research and analysis of BID will benefit from additional perspectives from the disciplines of environmental ethics and environmental justice to further strengthen the terminology and incorporate concepts that are critical to the advocacy of biodiversity as stakeholders within urban areas and their ongoing development.

4. Results

A total of 15 frameworks were selected for analysis (Figure 2). This included nine 'formalised frameworks', where the original authors directly presented a set of principles and basic structure for the design process, and six 'inferred frameworks', where either the design principles or generic design process structure are not explicitly stated. Examples of frameworks considered but which did not meet all the selection criteria include (1) frameworks with a broader scope than built environment professions, such as the Post-Global 2020 Framework by the UN Convention on Biological Diversity and the Biodiversity Knowledge Framework by the Victoria State Government; (2) frameworks and rating schemes where we were unable to identify a specific component on which to evaluate biodiversity as stakeholders being design for; (3) academic concepts such as multispecies design, i.e. [27,39–41] where the concept was not yet developed as a framework with clear guiding principles and the basic structure of the design process.

4.1. Framework Typologies by Function

The design frameworks to deliver BID analysed here span from broad biodiversity-enhancing actions to species-specific approaches. One avenue relies on the restoration and/or habitat creation to provide functional ecosystems within urban areas, i.e. [21,42]. Another avenue takes on a distinct 'species as clients' approach, encouraging designers to select a small number of species to spearhead the biodiversity-enhancing strategy of their project. The strategy is similar in conception to using a surrogate species in conservation ecology [34]. In other words, they purposefully select species to design for. One framework specifically explores strategies to select species within the design process [43]. The final framework typology identified seeks to mitigate common threats to biodiversity or generate opportunities for biodiversity through built infrastructure [44–46]. The boundaries between these three avenues to BID are variable. Some frameworks belong to more than one category.

4.1.1. Frameworks That Protect or Restore Remnant Habitat

Six out of the 15 frameworks we evaluated approach designing for biodiversity at a habitat-scale. These frameworks are useful examples of ecosystem-scale management and conservation strategies [47,48] adapted to design. The list includes Building With Nature [20], Ecology of Place Petal [21], SER Restoration Framework [42,49], SITES V2 [19], Designing for Native Grasslands [45] and Biodiversity Sensitive Urban Design [50]. Frameworks in this category intend to ensure that areas of high-quality habitat are protected, and degraded habitat patches are brought back to health. By using the 'client' construct, these frameworks chose 'habitats' and/or 'natural cycles' as the clients rather than 'species' encompassing all living organisms within that habitat or reliant on that cycle as the organisms to design for.



Figure 2. Frameworks developed between 2000 and 2020 that were evaluated in our research, categorised by their association to industry or academia * Denotes frameworks with inferred characteristics.

The frameworks with ‘habitats and natural cycles as clients’ begin by conducting baseline assessments of the ecosystem. They seek a biodiversity net gain between the pre-construction and post-occupancy stages of the design process. They ask designers to protect the natural assets of value by zoning their designs and limiting development to pre-developed areas (brownfield developments) or devoting the healthiest land to conservation and farming as appropriate. However, the underlying understanding of nature-positive and net-positive design paradigms is understood as ‘leaving the site better than it currently is’ and stopping there. This understanding of nature-positive design does not align with Birkeland’s definition of the term, the creator of Positive Development Theory. Birkeland has consistently advocated for socially and ecologically net-positive where net-positive values extend beyond the timeline of a single project [9,10,51]. The ‘baseline’ for nature-positive development is not a ‘single’ project’s pre- and post-development comparison.

Aligning themselves with restoration science, frameworks such as the Ecology of Place Petal [21] ask development projects to establish reference ecosystems that provide a series of ecological measures to design for. Here we brought in the SER Restoration framework by the Society of Ecological Restoration (SER) [42,49] as a relevant framework for analysis as it sets the current best-practice standards for restoration. While the SER Restoration Framework is not built-environment specific, it can be embedded into the Ecology of Place Petal to delineate a clear process to achieve habitat restoration. SITES V2 links biodiversity restoration to soil health and integrates multiple strategies and opportunities to evaluate and aim to design healthy soil systems [19]. While restoration is used to protect remnant habitats, areas chosen for development are encouraged to create habitat opportunities through green infrastructure. Unfortunately, clear guidance on how to do so is sparse.

All frameworks asked designers to think about how the site will be managed and advocate for established management plans early on in the design process. This helps designers deliver functional ecologies that will remain functional for a long time. Bringing forward a habitat-specific framework, Marshall [45] puts forward a framework to protect grassland habitats embedded within urban areas through design. It asks designers to carefully think about habitat-nature interactions to deliver grasslands that are perceived as beautiful. Meanwhile, the SER Restoration Framework and Biodiversity Sensitive Urban Design ask for designers to explore species-species interaction to design a habitat that will encourage fauna to actively visit. For SER, the species-species interactions constitute critical metrics to evaluate the function of the framework. Meanwhile, Biodiversity Sensitive Urban parts, from setting biodiversity targets to designing for and thinking about species-species interactions relevant to those targets. It puts forward a design process that can establish habitats, natural cycles and/or species as clients of the design.

4.1.2. Frameworks That Guide Design for ‘Species as Clients’

Six out of the 15 frameworks evaluated have a species-specific approach. These are Biodiversity Sensitive Urban Design [50], Animal-Aided Design [32], Wildlife Inclusive Design [31], Mobile-link [33], Target Species Selection [43] and Urban Habitat as Islands [52]. These frameworks intend to enable species’ survival within urban areas by providing the resources they need to survive. In using the ‘client’ construct, these frameworks establish one or more species that can guide designers’ design thinking and decision-making.

Critical to this process is the act of identifying which species are best positioned to act as design clients. The non-human clients should help bring benefit to many other species, people and cultures. The underlying assumptions of each framework have clear implications for what species are eligible as ‘target species’ for design. For instance, Wildlife Inclusive Design and Animal Aided design imply that eligible clients for the project are animals able to move across the urban landscape. Both frameworks state that plants could also be targeted; Wildlife Inclusive Design implies the value of wildlife specifically as ‘clients’, while Animal-Aided Design would be equally useful in designing for pets than wildlife. Conversely, Biodiversity Sensitive Urban Design provides opportunities for plants, natural cycles, or even habitats to be selected as ‘clients’ for a project.

The importance of carefully selecting conservation surrogates is well documented, with several frameworks available to identify species with key roles to play [34,53]. Species in conservation may be selected for being a keystone species within the local ecological system, an indicator of ecosystemic health, being an umbrella species, delivering sought-after ecological functions or because they are important for cultural reasons. Strategies to select relevant species are embedded within each framework. For example, the ‘mobile-link’ framework selects as clients highly mobile species with an important ecological role [33]. Meanwhile, the BSUD framework was originally tested on threatened species and ecosystems [50].

To unify the process, Apfelbeck, Jakoby [43] put forward a framework that can be used at the start of the design process to identify relevant species. It asks ecologists and designers to work together to identify the regional pool of species, assess access and resources available, identify species with social or cultural value, consider people-nature interactions and then use this information to identify specific targets. This framework was created to specifically identify wildlife species that can act as clients for design, but it can be expanded to make other organisms eligible as clients. Pairing the Apfelbeck, Jakoby [43] framework with ecological analyses (i.e., species interaction analysis, trophic chain) as well as community consultation can be effective strategies that make habitats, natural cycles, plants, and animals all eligible to identify critical habitats, ecological processes, plants and animals that could be selected as targets.

The ‘species as clients’ frameworks call for specificity, replicability of the process and rigorous assessment of how different species will be impacted by a project to justify design decisions. Once the non-human clients are established, these frameworks ask for the design team to gain detailed knowledge of the non-human clients. The Urban Habitat as Islands, a site analysis framework to evaluate connectivity, suggests that the analysis should understand how selected organisms spatially use the urban landscape [52]. Animal-aided design and Wildlife Inclusive Urban Design add in the specific plea that the information should include considerations about how needs shift across the life cycle of the organism [31,32].

Species information delivers species-specific design guidelines or identifies biodiversity-enhancing actions that can be implemented in the design. Examples of biodiversity-enhancing actions include incorporating habitat analogues, sound barriers to mitigate noise pollution, guidelines for buffer provision, dispersion infrastructure, guidelines for street design as connection pathways, pet containment programs, and more [31,50,52]. Additionally, designers are asked to consider people-nature relationships and identify opportunities to improve communities’ nature experience within urban landscapes.

4.1.3. Frameworks That Mitigate Biodiversity Threats

Three out of the 15 frameworks evaluated showcase a threat-mitigation approach. These are: Designing for Native Grasslands [45], Biodiversity Sensitive Roads [54] and Green Infrastructure for biodiversity [46]. Urbanisation impacts biodiversity by altering the conditions and features in the landscape. Common impacts include fragmentation, altered micro-climate, noise pollution, light pollution, soil contamination, and introduced species [55]. Some reasons for these impacts can be traced to the lack of appreciation shown towards natural capital and poorly designed infrastructure such as roads, parks, and green walls. These frameworks intend to minimise the extent of impact caused by urban areas through intentional design. Across the three frameworks, a total of six impacts are addressed: lack of appreciation, fragmentation, noise pollution, dispersion barriers, species homogenisation and plant survivability (Table 3).

Table 3. Threat mitigation frameworks for minimising the impact of development on target species or ecosystems.

Framework	Threat Mitigated	Strategy of Mitigation
Designing for Native Grasslands [44]	Lack of appreciation (undervalued ecosystem)	<ul style="list-style-type: none"> - Inviting people's interaction with an undervalued ecosystem - Showcasing ecological knowledge and value in action (through care) - Promoting positive attitudes and behaviours to currently undervalued grassland ecosystems
Biodiversity Sensitive Roads [49]	Negative impacts caused by roads (fragmentation, noise pollution, and dispersion barriers)	<ul style="list-style-type: none"> - A design process for transport engineers - Sharing ecologist's perspectives - Incorporating biodiversity-enhancing actions (biodiversity tunnels and bridges) early on
Green Infrastructure for biodiversity [45]	Species homogenisation and Plant survivability in green infrastructure	<ul style="list-style-type: none"> - Design for connectivity - Integrating native species - Maximising species richness within plant selection of green infrastructure - Deliver constructed ecologies

4.2. Framework Design Process Components

Our thematic analysis identified a total of seven themes characterising the Biodiversity design process as represented by the design frameworks analysed. These include collaborative processes that are transdisciplinary, participatory and culturally appropriate, design thinking that is iterative and applies rigorous systematic strategies, and decision-making, evidence-based decisions and transparency. Aligning with the definition of BID [11], we synthesise our thematic analysis alongside the three main components of BID (Figure 3):

- 'collaborative process' indicating that it should not be done in isolation,
- 'design-thinking' through which creative thinking, innovation and design are placed in service of the non-human users of place, and
- 'decision-making' where the process followed has clear implications for decisions made at each stage of the design process.

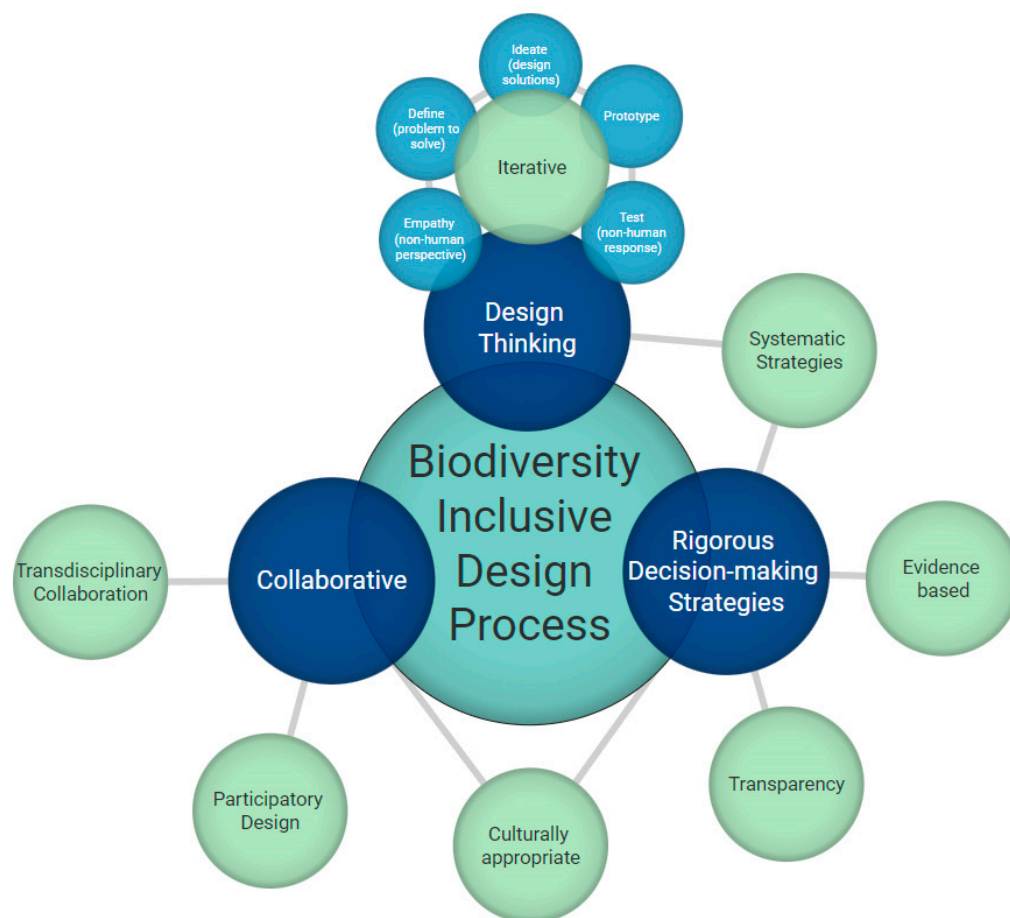


Figure 3. Thematic analysis of BID. The size of each bubble stands for the level of thematic categorisation. At the centre, the overarching topic of this research is the BID process. The next size down, in dark blue colour, are BID's three core components: collaborative process, collaborative thinking, and decision-making. The next size down, in light green colour, are the seven themes found: transdisciplinary collaboration, participatory design, culturally appropriate, iterative, systematic strategies [do design], evidence-based [design decisions] and transparency. The lines denote the association between the themes and components of BID. Lastly, the smallest bubbles, in light blue colour, correspond to the five phases of the iterative design cycle. This figure was created using 7vortex.

4.2.1. Collaborative Process

To achieve BID, collaborative approaches that are transdisciplinary, participatory and inclusive of local communities are necessary. Where applicable, incorporating the views and values of Traditional Owners of the land is critical for inclusive, participatory engagement.

Transdisciplinary collaboration is integral to the BID process, and ecologists can aid in setting targets and holding designers accountable for achieving biodiversity targets. Transdisciplinary collaboration between designers and ecologists throughout the entirety of a design process is advocated for by most biodiversity-inclusive design frameworks [31,50,56,57]. Ecologists can support evidence-based design thinking and decision-making by supporting community and designers to understand the ecology of place [57], selecting ecological and species targets to design for [43], and evaluating the potential effect of the design on biodiversity. For instance, ecological storytelling [57] and gamification [58] helped communicate complex ecological concepts such as seed recruitment and species interactions to designers and members of the general public.

Collaboration with ecologists is critical, but best-practice BID must extend beyond the expert-led approach. Participatory design processes are critical to the uptake and success of BID. Engaging with the local community is a recurring theme where researchers see

participation as a path to pro-environmental behaviour, stewardship and/or custodianship. BID encourages designers to consider people-nature relationships by involving members of the community in the selection of target species [31,43,45,50], delivering designs that foster positive human-nature interactions such as immersive nature experiences [45,50] and spearheading environmental education programs [52].

Sensitivity to cultural values is also critical for BID. Three frameworks specifically addressed culture: SITES presents ‘culture’ as one of their guiding principles, Ecology of Place Petal mentions culture as one of the factors that must be used to assess design decisions and Apfelbeck, Jakoby [43] talk about selecting culturally important species. However, a missed opportunity within the analysed frameworks is that of incorporating First Nations’ epistemologies. The SER Framework is the only one that mentions the importance of bringing traditional ecological knowledge into restoration activities.

Recognising the value of the variety of ecological understandings, conservation practices, and management by First Nations People has important implications [59,60]. For example, the Zelandia eco-sanctuary exemplifies a design process with Māori people to establish a fully fenced sanctuary protecting birdlife [61]. Cities like Melbourne are also looking into strategies to embed traditional ecological knowledges into their city-making strategies [62,63]. The opportunities are also explored by a research hub applying the Biodiversity Sensitive Urban Design Framework in Australia [14,64].

Traditional ecological knowledges offer opportunities that should not be ignored in how we plan and design our cities [65]. BID that incorporates these approaches will, therefore, not only be more practicable but can provide a pathway for cultural reconciliation between First Nations People and the colonisers. Further research on strategies and integration into BID is required as it was beyond the scope of the reviewed frameworks. Texts such as Traditional Indigenous biodiversity-related knowledge [59], Biodiversity and Traditional Knowledge [60], and Our Knowledge, Our Way in caring for country [62] can offer strategies to integrate First Nations epistemologies within BID.

4.2.2. Design-Thinking

BID acknowledges design thinking as a problem-solving strategy for complex problems. Design thinking is an iterative loop where creative thinkers define a problem, develop potential solutions and iteratively evaluate and refine these solutions to identify the best path forward [66]. There are different versions of the iterative loop that are problem-focused, i.e. [67,68] or user-focused [69]. The user-focused version begins the iterative design thinking cycle by developing ‘empathy’ towards the clients and/or future users. This is done to identify the needs that should be fulfilled by design.

Empathy, the process of learning about the intended audience and ‘walking in their shoes’ [66], is critical to design practice [66,69]; it is even more important for BID. Almost half of the analysed frameworks have a species-specific approach where each species represents a non-human stakeholder. After establishing which species will act as non-human design clients, these frameworks ask for a detailed curation of ecological information to get to know each species and its ecological requirements. Beyond gathering information, designers should attempt to experience the world at the non-human client’s scale, exploring how every non-human client selected interacts with the world. A rich scholarship exists in the idea of non-human personhoods among both traditional ecological knowledges and Western knowledges, such as environmental ethics and environmental justice, i.e. [70–73]. Species’ personhoods are a less technocratic approach to the gathering of ecological information to evoke an emotional relationship with biodiversity and nature. Further articulation of the ecological information into non-human personas [15–17] is an effective strategy to reduce the divide between human-nature relationships within the design process.

We equate a BID approach to design thinking with Stanford’s design thinking bootleg (Empathy, Define, Ideate, Prototype, and Test [69]). This design thinking cycle emphasises the concept of ‘empathy’. With habitats, natural cycles or species as clients, the design thinking iterative cycle begins by challenging designers to analyse the study area from the

perspectives of these non-human personas. In the Define step, the designer identifies one or more key issues compromising each client's survival and persistence within urban areas. During the third step—ideate—community, ecologists and designers can collaborate to design potential design solutions and either physically or hypothetically test how well these ideas might work to support and attract desired species. Design thinking also stimulates action [66]. As such, design thinking leads to decision-making.

4.2.3. Decision-Making

BID comprises a call for rigorous processes to design for biodiversity. The design frameworks evaluated provide strategic processes through which designers can evaluate design alternatives and justify design decisions. Evidence-based decision-making and transparency were recurrent themes associated with decision-making. The use of best-available ecological evidence as a strategy to identify and justify decisions is an important characteristic of the BID process.

BID assumes that designers who gain access to urban ecological knowledge relevant to the local context of their project will be well-positioned to make a design decision that enables species survival within urban areas. This indicates that the process is constrained by scientific and technological advances and the best available knowledge. It is also limited by designers' access to said ecological knowledge and their ability to understand it.

Transparency represents the last theme that emerged throughout this process, with various frameworks advocating for the active sharing of the design journey: advocating for research partnerships [52] and/or generating environmental education programs that share the stories of the local ecology or the design decisions made [21,52]. The call for transparency acknowledges 'place' as contested spaces where multiple identities are entangled and where power struggles ensue [74]. BID is constrained by the time and place in which it occurs. The available knowledge, existing technology, and competing priorities of a project all bring forward tensions between the intent and reality of BID practice. By characterising the projects' constraints and their role in the deliberative decision-making process, designers can explain and share their thinking, bringing evidence of the barriers that prevent a project from moving further.

5. 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. Our exploration of design frameworks aligned with BID has clear implications for our understanding of this practice. Here, we present the synthesis of our design framework analysis as relevant to BID practice (Figure 4). We begin by presenting the three core dimensions for design action (Figure 4, inner circle), and then we discuss nine principles (Figure 4, outer circle) and their factors for consideration in BID. Last, we acknowledge the evaluated design frameworks as different yet valid strategies for BID and discuss the BID process.

5.1. 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 2, the inner circle represents these three dimensions as a circle surrounding the design aim.

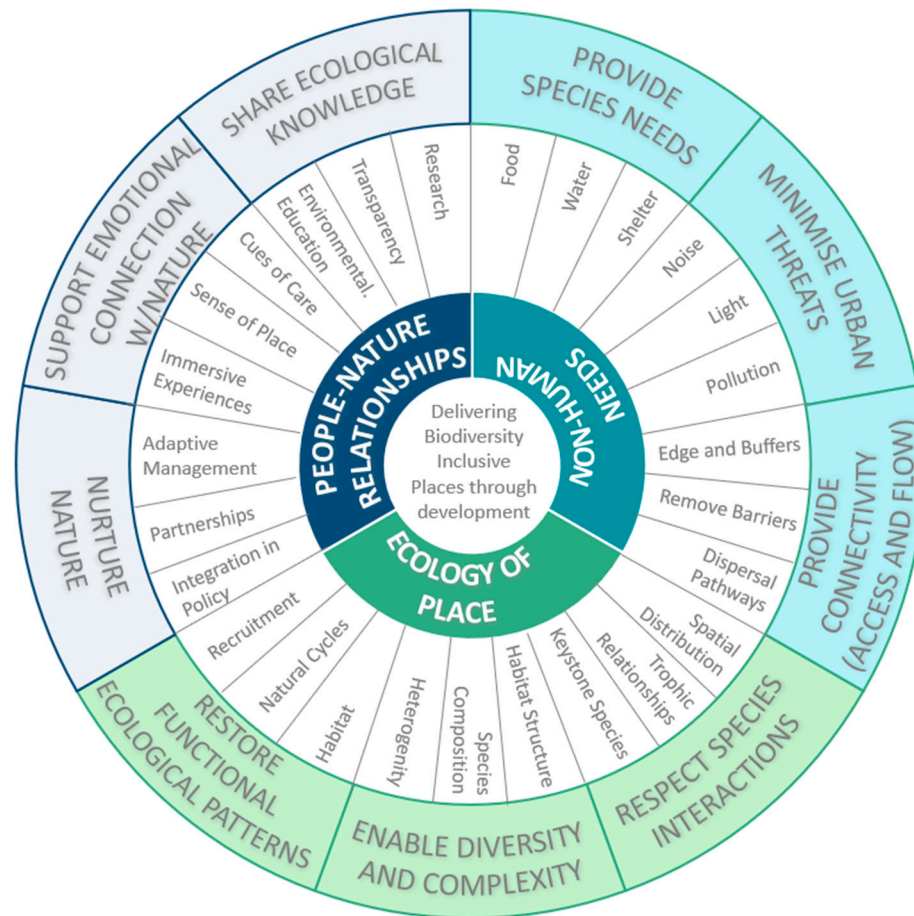


Figure 4. Dimensions, design principles and factors considered in BID Practice. In the middle is the overarching aim of BID as a design approach. Directly surrounding the aim, three core dimensions of BID design practice (the inner circle), the outer circle shows the BID nine design principles and the factors for consideration in BID are found between both circles.

5.1.1. Design for a Functional Ecology of Place

The concept of ‘place’ is simultaneously a geographical location, physically bounded and a relational entity [75], shaped by the people–people and people–place relationships [75,76]. ‘Place’ has physical (location) and emotional (meaning) aspects to it [76].

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, [75]).

Nature is critical for our shared sense of identity and sense of place [77]. 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 [78,79]. This made ‘place’ one of the three imperatives of ecological design [80,81]; 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 (See Section 5.1.2). 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.

5.1.2. 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 [8,35]. 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 [43] suggest potential species be selected from a 20 km radius of the site. Meanwhile, Lundberg and Andersson [33] 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 [82]. 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 [83]. 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 [50] and/or animals [31,32,50,52], groups of species (i.e., avifauna) [52] or even habitats encompassing all the different species that are critical for the ecological function of said habitat [45,50]. 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 [31]. This is aligned with nature-positive thinking, which makes built environment disciplines accountable for the ecological deterioration of the past [51].

5.1.3. 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.

5.2. 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 2, 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:

1. **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.
2. **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.
3. **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.
4. **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.
5. **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.
6. **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.
 7. **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.
 8. **Support emotional connection with nature:** Designers could draw from nature-connection literature and use concepts such as biophilia see [2] and regenerative placemaking [65] 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.
 9. **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).

5.3. 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 [66]. Our 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 5). 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.

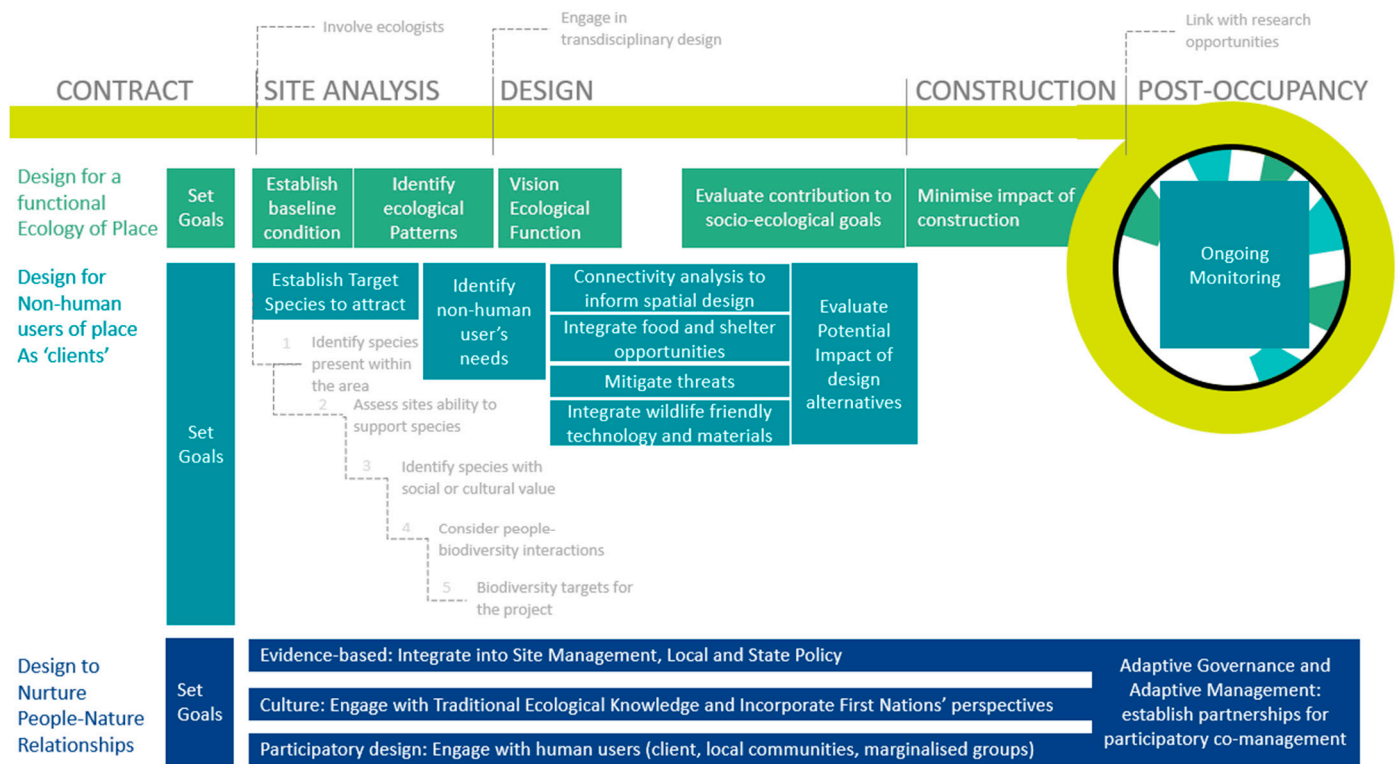


Figure 5. Synthesis of the Biodiversity Inclusive Design Process. The yellow-green loop at the top represents a typical design process with five key stages: contract, site analysis, design, construction, and post-occupancy design phases. The circle at the final stage is used to represent the iterative 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 we 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. Our 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. Our 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. Our analysis suggests that, 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. Our 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 6).

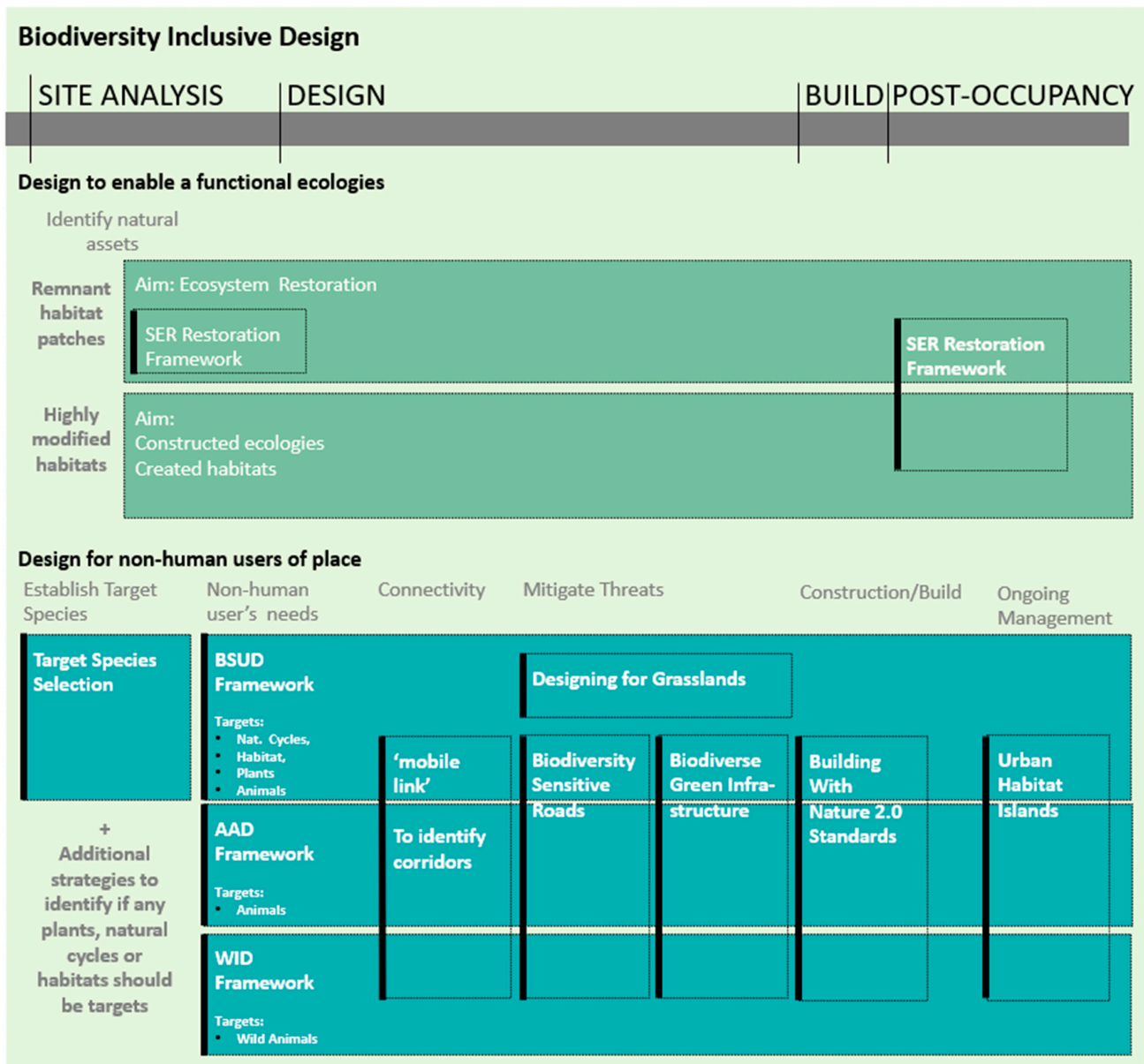


Figure 6. A multi-framework nested approach to enabling non-human perspectives within the design process. The grey box at the top presents four out of the five stages of the design process. The light grey text highlights key activities for the design team to complete. The boxes with a thick black line 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.

5.4. 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 [84],

single public spaces such as a park [82], whole neighbourhoods [14,64] or at the city scale [1,43].

There is a healthy academic discourse on how to integrate biodiversity consideration at a planning level, i.e., [53,85]. For example, ecological design often uses various mapping layers and ecological information to understand the natural processes at play and identify suitable land use [78]. More specifically, large regional-scale maps can help identify priority areas for conservation within urban landscapes [86] or identify existing and potential ecological networks for connectivity [87]. 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 [88] found that beetle diversity within urban areas is influenced by habitat characteristics, while Mayorga, Bichier [89] 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.

5.5. 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 [51].

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 [31,32,43,50]. 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.

6. Conclusions

Designing biodiverse cities—where people and biodiversity co-exist—is essential to nature-positive development that does more than simply offset ecological and biodiversity values. Biodiversity Inclusive Design (BID) has organically emerged as a design approach enabling designers to transform ‘biodiversity’ into multiple more concrete targets to design for. While already practised under various names, BID should be formalised as a design approach to yield replicable results for biodiversity.

BID is not an all-encompassing design process. At its core, it is a process designed specifically for biodiversity. It was created as a synthesis of leading academic and industry-led frameworks. These frameworks are variable in quality and public recognition, but they offer valuable lessons on what is currently considered best-practice design processes for

biodiversity. We explored fifteen design frameworks that represent alternative approaches compatible with BID. We categorised each framework based on the key drivers of the framework (restoration, species as clients, threat mitigation) and developed three key insights for BID practice:

1. BID requires that design practitioners act across three different dimensions of thinking and design action: to design for a functional ecology, to design for non-human users of place as clients and to design to nurture people-nature relationships. These three dimensions are complementary and highlight the importance of a collaborative design process for BID. In working with ecologists, the local community and decision-making organisations are critical to enabling long-term outcomes for biodiversity.
2. We identified nine design principles and 28 factors as recurrent themes across the evaluated frameworks. These principles and factors are deemed critical for BID best practice.
3. We map out the Biodiversity Inclusive Design process. Each framework analysed proposed a basic structure for the design process; we synthesised the recurrent recommendations and compiled this into a single design process. The proposed design process brings rigour to the design process and uses the ‘species-as-clients’ construct and asks designers to be as accountable to biodiversity as they are to the clients who pay the bills.

The variety of frameworks analysed is recognised as a variety of methodologies suitable for BID practice. Our analysis suggests that, while similar, these frameworks offer nuanced differences that make them suitable for application under different circumstances. As such, designers should 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. This paper, and the Supplementary Materials summarising each framework (Table S2), can provide designers with the relevant tools to identify what frameworks is most relevant to their project.

One missed opportunity within the frameworks analysed was that of integrating First Nations epistemologies within the process. Further research is required to explore strategies to engage with and integrate First Nation Peoples’ perspectives into BID.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/urbansci6040095/s1>.

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