From Urban Greening to Ecological Accountability: A Critical Review of Biodiversity-Sensitive Urban Design

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ABSTRACT

Urban greening does not necessarily produce sustained improvements in native biodiversity. This critical integrative review examines the relationships among urban ecology, habitat connectivity, and Biodiversity-Sensitive Urban Design (BSUD), and proposes an approach to strengthen ecological accountability. Kirk et al. (2021) serves as the anchor publication, complemented by a supplied corpus of 72 bibliographic records classified into eight thematic groups. The synthesis distinguishes conceptual frameworks, spatial simulations, empirical observations, and review findings. The evidence indicates that green-space area and canopy cover alone are insufficient proxies for habitat quality. Vegetation structure, resource continuity, spatial configuration, taxon-specific movement requirements, and long-term governance jointly shape ecological outcomes, although their effects remain context-dependent. Modelled connectivity should not be interpreted as population recovery without field validation. Accordingly, the review proposes a six-stage BSUD decision framework and four provisional evidence-status labels: projected, installed, used, and persistent. These labels are recommendations rather than externally validated performance standards. Sustainable urban planning should connect measurable conservation objectives with multispecies monitoring, long-term evaluation, and clearly assigned implementation responsibilities. The review identifies the need for more transparent reporting, longer-term multi-taxon evaluation, and explicit accountability for ecological outcomes.

Keywords: Urban Ecology; Urban Biodiversity; Ecological Connectivity; Biodiversity-Sensitive Urban Design; Nature-Positive Development; Urban Planning; Ecological Accountability

INTRODUCTION

Cities are no longer defensible as spaces outside conservation responsibility. Species occupy, traverse, breed within, and sometimes depend upon urban landscapes, while residents receive climate, recreational, psychological, and cultural benefits from contact with nature. The foundational BSUD application in Fisherman's Bend translated broad aspirations into target-species resource requirements, spatial scenarios, and a practical sequence of design actions (Kirk et al., 2021). Its most important intellectual move was to make biodiversity a primary client in planning rather than an amenity added after infrastructure decisions. The contemporary challenge is to determine whether that promise translates into durable, demonstrable ecological improvements.

Newer studies considerably sharpen this challenge. Urban tree benchmarks illuminate canopy deficits but do not alone measure ecological habitat (Croeser et al., 2024a). Vegetation assessments now characterize structure, floristic diversity and connectivity (Visintin et al., 2026), while an everyday-nature index likewise argues for biodiversity dimensions beyond canopy (Croeser et al., 2026). More stringent questions concern which species benefit, whether those benefits persist, how disturbance and maintenance alter them, and who is accountable when predicted improvements do not materialize.

Urban expansion can also place pressure on protected ecosystems, showing why site-level design must be considered alongside the wider effects of urban development (Sobhani, 2024). The urgency is material rather than rhetorical. Local redevelopment can remove private garden cover despite citywide greening ambitions

(Davies et al., 2026); expanding transport systems can sever habitat connections outside their immediate footprint (Kaszta et al., 2024); green-infrastructure decline can compound across decades of urban growth (Busari & Adedeji, 2026). Consequently, aggregate green-area gains may coexist with losses in ecosystem integrity. The relevant ecological unit is not merely the planted parcel, but a nested hierarchy of organisms, resources, patch networks, demographic processes and social institutions.

This review develops five propositions. First, native biodiversity must be specified as measurable outcomes rather than presumed from planting. Second, habitat quantity, structure and spatial configuration operate together but differently for each organism. Third, ecological performance depends on maintenance and life-cycle decisions as much as initial construction. Fourth, ecological evidence must be linked to enforceable planning and economic arrangements. Fifth, justice and stewardship belong in performance evaluation, without displacing ecological measures. The synthesis draws on the explicitly supplied source set and acknowledges that highly diverse study designs limit quantitative aggregation (Hernandez-Santin et al., 2022; Russo et al., 2026).

METHODOLOGY

2.1. Review Design and Research Approach

This study adopted a structured integrative literature review to examine the development of biodiversity-sensitive urban design and its relationship with urban ecology, ecological connectivity, nature-based solutions, and sustainable urban planning. An integrative approach was considered appropriate because the research field encompasses heterogeneous forms of evidence, including empirical ecological studies, spatial modeling, conceptual frameworks, design-based research, and governance analyses.

The review was anchored in Kirk et al. (2021), which presented a real-world application of the Biodiversity-Sensitive Urban Design (BSUD) framework in the Fishermans Bend urban renewal project in Melbourne, Australia. This study served as the conceptual reference for identifying subsequent developments in biodiversity-inclusive urban planning and design.

2.2.Literature Identification

Literature identification was organized around backward and forward citation searching. Backward citation searching involved examining the reference list of the anchor publication to identify foundational studies related to urban biodiversity, ecological processes, habitat requirements, and biodiversity-sensitive design. The reference list of Kirk et al. (2021) contained 114 bibliographic entries. These entries constituted the initial historical reference pool; however, their individual Scopus indexing status and eligibility for inclusion required separate verification.

Forward citation searching was designed to identify subsequent publications citing the anchor article and to trace the evolution of BSUD-related research. The supplied Scopus export, dated 11 October 2026, contained 72 bibliographic records covering publications from 2021 to 2026. These records were used as the contemporary literature dataset for the present thematic synthesis. Because the available export did not preserve explicit cited-reference relationships, the 72 records were not independently treated as a verified exhaustive set of forward citations.

2.3.Bibliographic Screening and Relevance Assessment

The bibliographic dataset was examined using publication titles, author information, publication years, DOI identifiers, and available abstracts. Duplicate assessment was based primarily on DOI matching, supplemented by normalized-title comparison and manual examination of author and publication-year information when DOI data were unavailable.

The supplied RIS file contained 72 records, of which 71 included DOI information and one did not. Abstract

information was available for 70 records in the RIS export. The two records without abstracts were retained in the initial bibliographic inventory but require additional examination before their substantive relevance can be considered fully established.

For relevance assessment, publications were conceptually organized into three groups: core literature, supporting literature, and contextual literature. Core literature addressed biodiversity-sensitive urban design and direct ecological outcomes; supporting literature examined related mechanisms such as habitat connectivity, vegetation structure, and ecosystem services; contextual literature addressed associated social, governance, and sustainability dimensions.

The inclusion and exclusion criteria were based on the relevance of each publication to urban ecological processes, biodiversity conservation, habitat quality, urban design, and the implementation of sustainable urban development. Records without sufficient information to establish their relevance were identified for further verification rather than being assigned an unsupported eligibility status.

Critical Evaluation and Evidence Synthesis

The publications were evaluated through four analytical dimensions: ecological relevance, methodological robustness, ecological outcomes, and planning and implementation relevance.

Ecological relevance concerned the extent to which studies addressed biodiversity, habitat requirements, species persistence, or ecosystem processes. Methodological robustness considered the appropriateness of research designs, ecological surveys, spatial analytical techniques, and modeling approaches in relation to the stated research objectives.

Ecological outcomes were examined by distinguishing empirically observed biodiversity responses from model-based predictions and proposed design benefits. This distinction was important to avoid interpreting simulated improvements in habitat connectivity or theoretical design potential as demonstrated ecological recovery.

Finally, planning and implementation relevance assessed whether research findings could be translated into practical design recommendations, institutional arrangements, monitoring strategies, and urban development policies.

The synthesis was conducted comparatively and thematically, focusing on areas of convergence, methodological limitations, research gaps, and opportunities for integrating ecological principles into sustainable urban development.

Methodological Transparency and Limitations

The review was based on the anchor publication and the bibliographic records and abstracts supplied in the Scopus export. The available files established the number of reference-list entries and contemporary bibliographic records but did not provide a complete search history, the initial Scopus search query, record-level citation provenance, or a documented exclusion log.

Consequently, the 72-record dataset was treated as a supplied literature corpus for thematic analysis rather than as a fully reproducible systematic-review sample. Likewise, the complete backward–forward citation overlap and the final number of unique eligible publications require verification against separately identified citation-search exports.

These limitations were explicitly considered when interpreting the findings and formulating the review's conclusions.

2.6. Analytical Procedure and Limits of Inference

Each record was examined for its relevance to urban biodiversity, habitat and taxon requirements, ecological connectivity, nature-based interventions, performance indicators, governance, and human–nature interactions. The records were assigned one primary theme for descriptive counting, while cross-thematic contributions were considered in the narrative synthesis. The eight themes cover ecological networks; vegetation and habitat; biodiversity-inclusive and regenerative design; nature-based solutions; governance; human–nature relationships; spatial assessment; and cross-sectoral urban systems. The primary-theme rule prevents double counting in the thematic matrix, but it does not imply that a publication contributes to only one field. The classification describes the distribution of topics, not the relative quality or effectiveness of the interventions. Evidence was interpreted according to the type of contribution reported: conceptual proposal, modeled scenario, empirical observation, or review finding. Where only abstracts were available, the assessment was limited to the information reported in those abstracts and was not treated as a full methodological appraisal or causal verification. Given the heterogeneity of study designs, geographical settings, taxa, and indicators, findings were synthesized narratively rather than pooled as quantitative effect estimates. For each record, the extraction database captured the publication year, study location where reported, analytical method, research focus, and principal findings. Conclusions were restricted to the level of inference supported by the supplied sources.

Based on the results of the classification, eight research themes are obtained as shown in Table 1; the results organize eight main themes covering ecological networks, vegetation and habitats, inclusive and regenerative design that is inclusive of biodiversity, nature-based solutions, governance, human–nature relations, spatial assessment, and cross-sectoral urban systems. One main theme is provided per record for descriptive accounting, while cross-sector contributions form a narrative synthesis. Analytical discussions distinguish

Table 1. Thematic classification of the 72 supplied bibliographic records

Theme Group	**Main Scope**	**Number of articles**
Ecological Connectivity and Landscape Networks	Habitat connectivity, ecological corridors, fragmentation, animal movement barriers, ecological network models	8
Urban Vegetation Structure and Habitat Quality	Vegetation structure and diversity, urban habitats, urban forests, residential parks, flora-fauna communities	20
Biodiversity-Sensitive and Regenerative Urban Design	BSUD, species-inclusive design, restorative planning and regenerative urban development	10
Nature-Based Solutions and Ecosystem Services	NbS, blue-green spaces, ecosystem service benefits as well as ecological-social compromises	9
Governance, Planning Policy, and Institutional Instruments	Spatial policy, impact assessment, certification, governance, institutional implementation	10
Human–Nature Relationships and Community Participation	Health, well-being, education, participation and environmental stewardship	11
Urban Greening Indicators and Spatial Assessment	Canopy cover benchmarks, vegetation indexes and spatial assessment tools	2
Cross-Cutting Sustainability and Urban Systems	Energy, infrastructure and resource systems with ecological implications	2
TOTAL	**Initial classification, one primary category per record**	**72**

RESULTS

2.4. Evolution of BSUD: From Design Principles to Ecological Accountability

The five original BSUD principles are to maintain and introduce habitat; facilitate animal and plant dispersal; minimize threats and anthropogenic disturbances; support natural ecological processes; and improve positive

human–nature interactions (Kirk et al., 2021). These principles are complementary but non-substitutable. A planted corridor without safe crossings may fail connectivity goals; a rain garden without suitable hydroperiods may fail amphibian reproductive needs; a highly accessible park without refuge and disturbance controls may not support disturbance-sensitive wildlife. Planning therefore requires an explicit chain between conservation objective, ecological mechanism, spatial intervention and measurable response.

In Fishermans Bend, co-developed goals were translated into habitat provisions, waterbodies, green links, understorey plantings, and proposed bridge or underpass structures. Using circuit-based landscape modeling, the authors reported that the biodiversity-oriented scenario generated mean connectivity values approximately 2.5 times the preliminary baseline scenario for superb fairy-wrens and eight times for growling grass frogs. These are modeled scenario comparisons, not evidence that populations actually increased: the article explicitly recognized that completed development and post-occupancy ecological responses had yet to be observed (Kirk et al., 2021).

Contemporary biodiversity-inclusive design has expanded from site-specific prescriptions to frameworks capable of recognizing nonhuman needs across scales (Hernandez-Santin et al., 2022). Nature-positive design moves from avoiding damage toward reversing ecological decline (Thomson et al., 2022), while regulatory proposals seek to incorporate opportunities for biodiversity gain into environmental assessment itself (Kirk et al., 2026). These are important conceptual developments, yet neither a framework nor an assessment pathway automatically guarantees realized species persistence. Their test lies in implementation, evidence collection and accountability.

Implementation scholarship also shows why ecological ambition is difficult to institutionalize. Dutch development cases describe knowledge, entrepreneurial risk, certification incentives and policy translation as obstacles and leverage points (Mattijssen et al., 2023). Copenhagen-based research similarly documents friction when biodiversity aspirations enter established design practice (Lund, 2022). Australian accounts of changing municipal practice emphasize long-term organizational learning rather than single project success (Bush et al., 2023). Thus, BSUD should be treated as a decision system embedded in institutions, not merely a list of plantings.

The ethical basis of this approach has broadened. Ecocentric precinct design foregrounds ecosystems early in master planning (Al Hazmi, 2026); coexistence research on powerful owls elevates knowledge of animal behavior and nonhuman interests (Parker et al., 2025); proposed multispecies planning tools combine social judgments and spatial evaluation (Edejer et al., 2024). A meaningful more-than-human approach requires transparent decisions about species selection, ecological priorities and the distribution of inevitable risks, rather than assuming that consensus among human stakeholders is sufficient. This is detailed in Table 2.

Table 2. Conceptual shift from green provision to demonstrable ecological performance

Planning domain	Conventional proxy	Ecological performance question	Recommended evidence	Principal limitation	Ref.
Habitat supply	Total green area	Do focal organisms access necessary resources?	Field inventories; resource phenology	Area is not habitat quality	(Visintin et al., 2026)
Vegetation	Canopy percentage	Are canopy, shrub, and ground layers functional?	Stratification; diversity; survival	Canopy can conceal understorey deficits	(Tobisch et al., 2026)
Movement	Mapped corridor length	Can target taxa move across barriers?	Resistance surfaces; dispersal validation	Modeled current is not dispersal	(Courtney Jones et al., 2025)

Development	Design certification	Are conservation targets contractually delivered?	Approval conditions; audit trails	Credits may not require biodiversity gains	(Kiss et al., 2025)
Coexistence	Park visitation	Are positive encounters and threats balanced?	Species monitoring; conflict records	Access can produce disturbance	(Parker et al., 2025)
Equity	Park-distance compliance	Who receives quality biodiversity access?	Building-scale distribution and use	Distance overlooks ecological quality	(Galeota Lanza et al., 2026)

Multispecies Habitat Requirements and Functional Connectivity

Studies of habitat-patch creation in growing cities likewise show that small urban sites can contribute to endangered-species conservation when habitat requirements are integrated into planning and implementation (Leino & Nieminen, 2026). The most consequential lesson from new connectivity work is taxon specificity. Structured elicitation across seven animal groups demonstrates that ideal habitat, movement barriers and threshold distances cannot be assigned universally (Courtney Jones et al., 2025). Similarly, a multispecies ecological network in Hangzhou integrates habitat condition and degradation to rank priorities, then identifies patches, corridors, pinch points and barriers for managing urban expansion (Ma et al., 2025). Planning that maximizes one movement metric without ecological differentiation risks overestimating gains for poorly represented taxa.

The geographic scale of observation changes the inferred driver. Analyses around London show avian diversity patterns shifting with grid scale and species group, with water-associated birds responding differently to the urban gradient (Dein & Tran, 2025). An independent field study in Munich finds strong associations between residential vegetation and birds, reporting vegetation-cover thresholds that depend on which diversity component is evaluated (Tobisch et al., 2026). These findings are not universal coverage prescriptions: they illustrate why spatial grain, community composition and habitat type must be specified before adopting a benchmark.

Multi-scale green-infrastructure research further emphasizes that urban biodiversity planning must connect local habitat interventions with wider landscape networks (Grabowski et al., 2023). Landscape configuration is consequential when habitat bottlenecks determine the ability of organisms to traverse the built matrix. Melbourne parking-space conversion scenarios suggest that strategically targeted greening yielded roughly twice the connectivity gain per area converted relative to less strategically targeted deployment (Croeser et al., 2024b). Conversely, mapped fragmentation in Ibadan indicates severe decline in green-infrastructure contiguity over two decades (Busari & Adedeji, 2026). Connectivity gains therefore depend on where added habitat changes network topology, not simply how much land is replanted.

Large infrastructure requires an even broader spatial lens. Movement models for Sunda clouded leopards forecast substantial impacts of projected development across Borneo and Sumatra; the modeled contribution of Nusantara infrastructure to combined predicted connectivity loss was particularly large (Kaszta et al., 2024). Site-scale biodiversity plans must therefore be nested inside regional connectivity safeguards. The Nusantara-focused BSUD design study shows a pathway for identifying target organisms and translating habitat vulnerability mapping into precinct interventions (Kurniawan et al., 2025), but design recommendations cannot undo region-wide network disruption unless the broader development pattern is also addressed.

Different habitat guilds experience the built matrix differently. Urban amphibians face breeding-water pollution, invasive predators, fragmentation and noise (Parris, 2023). Stormwater ponds may also be used for turtle nesting, demonstrating that engineered water assets sometimes create ecological opportunities, although site-specific ecological conditions still determine suitability (de Oliveira Ferronato et al., 2026). More generally, species-focused urban restoration of beaver habitats requires simultaneous assessments of physical feasibility, social conflict and multispecies needs (Edejer et al., 2024).

Birds are especially informative when their roles are correctly specified. Longitudinal observations from Shanghai were used to identify a limited suite of candidate surrogate birds associated with both regulating ecosystem services and biodiversity objectives (Liu et al., 2023). The result is a context-specific monitoring hypothesis, not a justification for treating birds as a universal proxy for insects, soil biota or aquatic vertebrates. Coexistence approaches to powerful owls stress the protection of nesting structures and reduced disturbance alongside opportunities for positive human encounters (Parker et al., 2025).

Connectivity has several distinct meanings. Structural connectivity describes mapped habitat configuration; functional connectivity expresses organism-specific movement through that configuration; demographic connectivity concerns consequences for recruitment, survival and gene flow. Circuit theory, least-cost surfaces and expert-derived resistance estimates are useful planning instruments, but outputs are conditional upon map classification, source locations and dispersal assumptions. The strong calibration but weak external validation of many urban invertebrate distribution models is a warning against confusing plausible spatial fit with dependable prediction (Morpurgo et al., 2025).

A proposed research hierarchy follows: use models to reveal competing spatial configurations, collect field movement and colonization information to test model predictions, and evaluate population responses against defensible comparison sites. Designs should explicitly address uncertainty with sensitivity analyses across dispersal ability, seasonal resource availability, and multiple feasible infrastructure scenarios. Urban networks cannot be assumed resilient merely because a simulated corridor exists (Ma et al., 2025; Courtney Jones et al., 2025).

2.5. Urban Vegetation, Blue–Green Infrastructure, and Ecological Mechanisms

Research on urban metabolism also provides a complementary systems perspective on how resource-use decisions and the engagement of urban actors shape sustainability transitions (Ahmadian & Perrotti, 2025). Vegetation architecture matters because vertical layers supply different nesting, feeding, thermal and protective resources. The recent advocacy for multi-layered urban forests reframes density as compatible with ecological richness when plant stratification is designed intentionally (Rahman et al., 2026). An Australian landscape scorecard operationalizes this proposition through eight design metrics covering vegetation structure, diversity, and connectivity (Visintin et al., 2026). A street-level index similarly incorporates vegetation structure, native composition and landscape links beyond basic canopy assessment (Croeser et al., 2026). Both tools are promising assessment devices, but validation against long-term species demography remains essential.

Empirical studies reinforce the need to distinguish habitat structure from visual greenness. Vegetation maintenance and plant complexity in Mexican residential developments were associated with greater avian diversity (Hernandez-Santin et al., 2025). Munich residential blocks showed stronger bird responses to local vegetation cover than to distance from surrounding green spaces in the sampled design (Tobisch et al., 2026). These observations challenge park-access-only planning, without proving that landscape context is irrelevant for less mobile or specialist taxa. A 2026 inventory of dye-producing plants in the green spaces of Universitas Syiah Kuala recorded 32 species across canopy, understory, and groundcover strata, illustrating how urban vegetation can also retain biocultural and educational value (Iqbar, 2026). This single-campus inventory should be interpreted as a site-specific floristic assessment, not as evidence of a general biodiversity response to urban design.

Pollinator research adds seasonal specificity. In Malmö, new green elements did not consistently outperform conventional planting for observed butterflies and bumblebees; flowering species richness and floral cover were among the more informative associations (Haaland, 2023). Green-wall evidence similarly examines how planting diversity and flower availability relate to pollinator abundance (Fischer et al., 2026). The ecological outcome therefore depends on floral resources and other requirements, not the label assigned to an intervention. Explicit pollinator-garden goal setting is recommended so projects define organisms, response metrics and expected change before planting (Dorian et al., 2025).

Conceptual work on bee-oriented botanical gardens also illustrates the need to translate pollinator perceptions and ecological requirements into planting and landscape design decisions (Yang et al., 2024). Green façades, rooftops and podium landscapes can augment scarce ground-level habitat, but vertical deployment introduces substrate limitations, maintenance demands, drought exposure and isolation from surrounding networks. Research on urban design of vertical biodiversity explores the need to treat building surfaces as habitat rather than decoration (Geropanta et al., 2023). Work on engineered soils recognizes that substrate composition and circular material use mediate green-infrastructure functioning (Minixhofer et al., 2022). Housing-market interest in exterior green walls may help finance interventions (Roffe & Trop, 2025), but willingness to pay is neither proof of ecological effectiveness nor evidence of equitable access.

Reviews and bibliometric assessments of nature-based solutions indicate that the field spans diverse definitions and applications, reinforcing the need to specify the ecological function expected from each intervention (Frantzeskaki et al., 2022b; Guo et al., 2025; Lemes de Oliveira, 2025; Zhu et al., 2023). Blue–green systems connect biodiversity to hydrological functioning. Residential garden studies describe edible, pollinator and rain gardens, ponds and roofs as complementary parcel-scale infrastructure (Sekban & Akyol, 2023). Investigations of retrofitted infiltration swales examine possibilities for improving water management and ecological outcomes simultaneously (Helmreich et al., 2024). Waterscape literature identifies plausible pathways to psychological wellbeing, including thermal moderation and restorative experience (Zhang et al., 2021). Such co-benefits should be measured in parallel, since water quality, inundation timing and accessibility requirements can conflict.

Research on urban tree composition in children's squares further demonstrates that the design and spatial arrangement of planted vegetation are relevant to the ecological character of everyday public spaces (Zibtseva et al., 2022). Urban ecology also contains negative and unexpected trajectories. Successional vegetation in abandoned Chornobyl urban sites contains expanding invasive taxa amid changes in climate and site management (Rogovskyi et al., 2023). Assessment of old arboretum trees documents diseases and deteriorating sanitary conditions that may compromise heritage vegetation (Kopylova et al., 2025). Consequently, the ecological adequacy of planted habitats cannot be inferred at project completion: survival, pest management, competitive interactions and invasive-species risks shape outcomes over decades.

Vegetation preservation can also be lost incrementally. A Sydney redevelopment study reports pronounced reductions in front gardens and canopy on replaced housing parcels, revealing how small, cumulative private-lot decisions can undermine municipal targets (Davies et al., 2026). Construction-focused landscape preservation emphasizes protection or carefully planned relocation of mature trees rather than automatically replacing established habitat with young stock (Pobegaylov, 2023). The ecological value of large old trees includes time-dependent attributes such as cavities and structural complexity that compensation plantings cannot immediately reproduce. Table 3 classifies the empirical evidence linking urban habitat attributes to ecological responses

Table 3. Empirical evidence linking urban habitat attributes to ecological responses

Setting/study	**Taxa or outcome**	**Design or observational feature**	**Reported direction/finding**	**Interpretive caution**	**Ref.**
Munich residential blocks	Bird diversity and abundance	90 blocks across cover and park proximity	Local vegetation cover strongly associated with birds; thresholds varied	Context-specific observational associations	(Tobisch et al., 2026)
Malmö green structures	Bumblebees and butterflies	20 green structure elements	Floral richness mattered; designed sites not uniformly superior	Low counts and city-specific conditions	(Haaland, 2023)
The Hague urban green–blue systems	Invertebrate occurrences	Bulk DNA and eDNA with SDMs	Vegetation and water indicators	Very few models validated well	(Morpurgo et al., 2025)

			informative in calibration		
Melbourne retrofit scenarios	Modeled ecological connectivity	Parking space conversions	Spatial targeting doubled gain per effort in scenarios	Potential movement, not observed population growth	(Croeser et al., 2024b)
Sydney housing redevelopment	Garden and canopy retention	370 residential properties	Large losses of gardens and tree canopy	Spatial sample not all housing markets	(Davies et al., 2026)
Ibadan 2000–2020	Landscape contiguity	Remote sensing and pattern metrics	Connectivity and green-landscape share decreased	Structural indices are not movement observations	(Busari & Adedeji, 2026)
Hangzhou ecological network	Six focal species	Habitat modeling and circuit analyses	Mapped 31 patches, 56 corridors, 23 pinch points	Prioritization relies on chosen species and weights	(Ma et al., 2025)
Fishermans Bend scenarios	Two focal species	Circuit-based spatial scenarios	BSUD scenario outperformed baseline in modeled connectivity	Pre-implementation model estimates	(Kirk et al., 2021)

2.6. Measurement: Indicators, Benchmarks, and the Credibility of Nature-Positive Claims

The performance-measurement problem is no longer simply a lack of indicators. Urban governments already use cover percentages, park distance, tree visibility, heat exposure, landscape indices and certification credits. The challenge is construct validity: do those variables measure ecological resources, movement, reproduction, community composition or only visually measurable proxies? Global comparison under the 3–30–300 rubric highlights widespread shortfalls in canopy provision (Croeser et al., 2024a), but the metric originated as an accessible human-nature benchmark, not a comprehensive ecological viability test.

Recent spatial indexing seeks to incorporate ecological and distributional features into canopy-and-access measures (Galeota Lanza et al., 2026). Street-scale everyday-nature assessment explicitly moves toward native vegetation, structural complexity, and connectivity (Croeser et al., 2026). Comparison scorecards for landscape designs introduce explicit resource-oriented dimensions (Visintin et al., 2026). Their main potential is to structure procurement and design review before ecological change can be observed; their main methodological vulnerability is that weighted scores may conceal trade-offs or overstate biological significance.

An effective monitoring strategy consequently needs three tiers. Tier I records inputs and compliance: land retained, trees surviving, vegetation strata planted and connectivity structures installed. Tier II evaluates intermediate ecological function: floral phenology, nesting substrate, microhabitat suitability, water quality and modeled movement permeability. Tier III measures outcomes: occupancy, community composition, recruitment, persistence and ideally dispersal or genetic exchange. Tier III evidence is more demanding but critical before claiming biodiversity uplift. This distinction responds directly to critiques of current ratings practice (Kiss et al., 2025) and model validation problems (Morpurgo et al., 2025).

Research syntheses of urban biodiversity indicators document the diversity of methods available for assessment and enhancement (Wang et al., 2023). Reviews integrating ecosystem services with wellbeing show that different stages of the ecological service cascade are inconsistently measured (Uchiyama et al., 2025). A site reporting cooling or access benefits therefore cannot automatically claim habitat benefits. Each causal pathway needs its own stated indicators, sampling intervals and counterfactual interpretation.

Stronger evaluation requires explicit baselines, comparison sites, temporal replication and uncertainty communication. Before–after evidence without a counterfactual cannot distinguish intervention effects from changing weather, regional colonization or development trends. Repeated biological observations should be aligned with seasonal life histories and survey detectability. Ecological gains also need an additionality test: would the same outcomes have occurred under existing policies and routine planting? The alternative environmental-impact pathway proposed for nature-positive development can strengthen incentives only when additional improvements are auditable (Kirk et al., 2026).

A practical dashboard should retain raw component metrics alongside any aggregate score. For instance, the loss of a mature cavity-bearing tree should not be obscured by an increase in turf or by a composite score with arbitrary compensation weights. Similarly, public access and biodiversity outcomes can be reported side by side without assuming perfect correspondence. The value of fine-scale indicators is their ability to make choices intelligible while preserving rather than erasing ecological specificity (Galeota Lanza et al., 2026; Visintin et al., 2026).

2.7. Governance, Development Economics, and Implementation Pathways

Biodiversity provision is delivered through many actors: governments set statutory standards, developers control land transformation, design teams configure habitat, contractors install it, owners maintain it, and residents influence disturbance after occupation. These responsibilities rarely align in time. Dutch real-estate projects illustrate the need for shared expertise, favorable tender incentives, and binding translation of biodiversity visions into implementation instruments (Mattijssen et al., 2023). Community-oriented regenerative housing experiments suggest that resident agency can sustain stewardship, while their preliminary fauna observations underscore the need for longer monitoring (Hernandez-Santin & Hes, 2025).

The gap between aspiration and measurable responsibility becomes especially evident in certification. A review of green-building rating schemes reports that most assessed schemes did not specify biodiversity objectives and many lacked either ecological connectivity or monitoring provisions (Kiss et al., 2025). Certification may thus reward an intention or input rather than a verified species outcome. Reform should attach biodiversity criteria to site baselines, target taxa, explicit performance thresholds, credible stewardship funding, independent checks and transparent reporting.

The case for integrating biodiversity into assessment processes is strengthened by a proposal to evaluate nature-positive opportunities as a distinct development pathway (Kirk et al., 2026). Yet the strongest principle remains avoidance of irreversible losses followed by retention, restoration and credible enhancement. An optimistic label must not obscure displacement of habitat or transfer of ecological burdens to adjacent landscapes. Planning must also acknowledge ecological risk from apparently unrelated infrastructure transitions: energy development has been examined as a possible source of non-linear biodiversity effects at large scales (Arshed et al., 2024).

Implementation may improve when ecological requirements enter the project lifecycle earlier. A proposed precinct sequence is: screen regional habitat safeguards before zoning; inventory species and habitat during strategic design; compare spatial alternatives before fixing transport layouts; include detailed habitat-resource schedules in permits; inspect ecological specifications during construction; and fund recurring monitoring after occupancy. The strategy aligns the original BSUD emphasis on early stakeholder coordination with newer evidence on governance barriers (Mattijssen et al., 2023; Kirk et al., 2026).

Governance also includes digital and organizational innovations. Distributed-ledger proposals investigate incentives for biodiversity action in cities (Li & Dounas, 2024), whereas broader critiques of data-sharing in green infrastructure emphasize incomplete stakeholder and economic information (Ruan et al., 2024). Neither technology automatically fixes missing ecological baselines or weak institutional mandates. An open, versioned evidence trail of objectives, design changes, monitoring records and responsible institutions may be more consequential than the particular database chosen.

Research on Canberra's green infrastructure and broader urban sustainability missions similarly highlights the importance of connecting socio-ecological evidence with strategic planning and institutional coordination (Frantzeskaki et al., 2022a; Mofrad & Ignatieva, 2023). Several policy scales must work together. A building parcel can contribute substrate, vegetation and refuge; neighborhoods need connected habitat mosaics; metropolitan plans must prevent cumulative fragmentation; regional planning must protect larger source populations. Conservation arguments that widen planning beyond protected-area boundaries underscore the limits of isolated site management (Lawler et al., 2025). Urban biodiversity should be embedded in transport, drainage, housing and climate policy as a cross-sector performance obligation, not a separate landscape embellishment.

2.8. Human–Nature Relationships, Equity, and Environmental Justice

Broader work on people-friendly urban places and territorial quality of life also suggests that urban design choices should be considered alongside residential expansion, densification, and the distribution of everyday benefits (Friedman, 2024; Ustaoglu & Williams, 2024). Urban biodiversity produces public benefits, but public benefit is neither uniform nor inherently equitable. The assessment exposes unequal local access and canopy performance (Croeser et al., 2024a), while composite metrics incorporating population distribution can help identify intra-urban disparities (Galeota Lanza et al., 2026). Efforts to pursue equitable nature-based regeneration also stress participation, cultural sensitivity and protections against displacement (Russo et al., 2026). A nature-positive claim should therefore be evaluated through two related but distinct lenses: ecological improvement and socially fair distribution of risks and benefits.

Health research establishes plausible connections between blue–green environments and wellbeing but also highlights contextual complexity. Urban waterscape reviews outline restoration and physical-activity pathways (Zhang et al., 2021); examination of healing-forest potential emphasizes biophysical conditions and residents' preferences (Situmorang et al., 2026); a synthesis on older adults explores how urban design and environmental conditions influence wellbeing (Mensi et al., 2026). These findings argue for attention to accessible, comfortable natural places while avoiding the simplistic premise that greater public activity always favors wildlife.

Environmental education and shared stewardship can connect people to organisms often omitted from design decisions. A project-based learning initiative documented urban species and student engagement (Oliveira et al., 2025); community-based habitat creation for an endangered bumblebee addresses local participation in targeted conservation (Shafer et al., 2025). Engagement is most ecologically credible when participants help set measurable goals, gather observations and respond to outcomes rather than merely endorse a completed landscape plan (Dorian et al., 2025).

More-than-human spatial practice reframes nonhuman organisms as relevant stakeholders, although their interests must be inferred through ecological evidence and ethically justified representation. Owl coexistence interviews demonstrate the importance of everyday knowledge and changing management relationships (Parker et al., 2025). Multispecies spatial restoration frameworks formalize human and animal requirements in comparative decision tools (Edejer et al., 2024). More-than-human placemaking and environmental storytelling explore how cultural methods can communicate ecological relationships (Boros et al., 2024); arts-based spatial inquiry adds sensory accounts that complement but cannot replace biological measurement (Grilli & De Franco, 2025).

Cultural specificity is particularly important in places shaped by Indigenous or other place-based knowledge. The Azheke village analysis highlights traditional ecological knowledge as a source of insight into human–environment relations (Wu et al., 2025). A nature-inclusive urban framework must make space for those knowledge systems, decision rights and appropriate long-term stewardship without assuming they are equivalent to generic citizen participation. In the original Fishermans Bend article, the authors themselves reflected that deeper Indigenous collaboration would have strengthened implementation (Kirk et al., 2021).

The contribution proposed here is not the invention of adaptive management: sequential planning, implementation, monitoring, and correction are well established. Rather, the synthesis adds a claim-verification

layer to BSUD by explicitly separating predicted habitat potential from constructed habitat, observed organism use, and evidence of persistence. This distinction is intended to prevent performance labels from exceeding their supporting observations.

For practical application, a baseline should document pre-intervention habitat extent and condition, focal taxa, threats, sampling effort, and the wider landscape setting. An appropriate comparison may be a matched untreated site, a before–after control–impact design, or a defensible modeled business-as-usual scenario; each has different inferential limitations. Additionality should be reported only relative to a stated counterfactual, with pre-existing legal obligations and likely background trends described. Where a counterfactual is unavailable, observed change should not be attributed confidently to the intervention.

Taxon coverage should be justified by site objectives and feasible detection methods, rather than an arbitrary universal number of species. At minimum, reporting should state which ecological groups were sampled, which were omitted, and why. “Projected” denotes model output without field confirmation; “installed” requires an inspection of habitat features; “used” requires direct or appropriately inferred occupancy, visitation, or behavior, with detection limitations disclosed; and “persistent” requires repeated evidence across ecologically meaningful seasons or generations, with a suitable comparator where causal gain is asserted. There is no universally defensible fixed monitoring duration or effect-size threshold in the supplied evidence; projects should preregister taxon-specific intervals and success criteria. Confidence intervals, sensitivity analyses, and survey effort should accompany claims wherever available.

These labels are not mutually exclusive project certifications and have not been externally validated. They should be applied to individual outcomes rather than entire developments. A site may demonstrate sustained use by one bird species while offering only projected benefits to amphibians. The term “verified nature-positive” should therefore be reserved for clearly specified, monitored outcomes and should not imply net biodiversity gain across unmeasured taxa or off-site impacts.

2.9.Toward an Outcome-Linked, Adaptive BSUD Framework

We propose an outcome-linked BSUD framework organized into six decision gates. Gate 1 establishes ecological reference conditions: existing organisms, habitat attributes, threats and relevant regional networks. Gate 2 specifies target outcomes for focal taxa, communities and ecological processes, including time horizons and potential adverse effects. Gate 3 generates competing site and infrastructure designs and evaluates their spatial, social and financial implications. Gate 4 converts chosen actions into legally traceable responsibilities and ecological maintenance plans. Gate 5 measures implementation and post-occupancy outcomes with explicit uncertainty. Gate 6 requires corrective action when ecological indicators diverge from stated objectives.

Gate 1 must combine mapped vegetation and water with taxon-specific information. Habitat quality assessed solely by remote sensing may miss breeding substrates and invasive predators; inventories and ecological expertise remain necessary (Courtney Jones et al., 2025). Gate 2 should define conservation targets that are measurable at appropriate biological and spatial scales, following recommendations for goal-oriented garden conservation (Dorian et al., 2025). Gate 3 should compare plausible pathways, including avoidance and strategic retrofit options, rather than only maximizing plantable area (Croeser et al., 2024b).

At Gate 4, biodiversity design must become a legally, operationally and financially managed commitment. The limitations documented in green-building ratings show why biodiversity targets cannot end at a certificate (Kiss et al., 2025). Gate 5 separates what was installed from what species used and from what populations achieved. Designs may improve local habitat structure without yet producing stable populations; early successes should therefore be described with their correct evidence status. Gate 6 should allow adaptive responses to drought, predators, failed plant survival, changing land use and monitored species trends.

A practical application can be illustrated with an amphibian-focused development site. At Gate 1, the project team would map existing breeding ponds, water quality, marginal vegetation, terrestrial refuge, road barriers, and nearby source populations. At Gate 2, it would specify measurable objectives such as maintaining suitable

breeding conditions, enabling movement between waterbodies, and reducing road mortality. At Gate 3, alternative layouts would be compared for pond location, hydroperiod, vegetated links, crossing structures, and conflicts with buildings or transport. At Gate 4, the selected measures would be translated into permit conditions, construction specifications, maintenance budgets, and named responsibilities for the developer, contractor, and long-term asset manager. At Gate 5, inspections would confirm that the habitat features were installed, while repeated ecological surveys would assess occupancy, breeding activity, and recruitment. At Gate 6, monitoring results would trigger corrective measures—for example, changes to water management, vegetation maintenance, predator control, or crossing design. This example demonstrates that the framework is not simply a conceptual sequence: each decision gate is connected to a responsible actor, an implementation instrument, and an evidence requirement. The indicators must nevertheless be adapted to the focal taxon and local ecological conditions.

The framework intentionally retains both ecological integrity and lived experiences. Street-scale indicators may make nature visible in daily travel (Croeser et al., 2026), while dedicated habitat refuges may require access controls. Landscape performance cannot always be reduced to a single figure because a socially favored intervention may be harmful to a specialist species. Transparent multi-criteria choices can make such conflicts legible (Edejer et al., 2024); they should not camouflage them as universal win–wins.

A further innovation is the proposed evidence-status label for every reported biodiversity claim: projected (model-based), installed (verified physical habitat), used (species occupancy or behavior observed), and persistent (longitudinal evidence supporting durable community or demographic response). These terms are recommendations of this review, not a tested index. They would help distinguish an attractive conceptual rendering from a documented ecological result and reduce ambiguity in citywide nature-positive reporting. A summary of this conceptual overview can be seen in Table 4.

Table 4. Proposed outcome-linked BSUD workflow and minimum evidence expectations

Decision gate	**Required decision**	**Minimum measurable evidence**	**Implementation responsibility**	**Evidence status/risk**	**Ref.**
Baseline	Which ecological assets and threats exist?	Taxa records; vegetation strata; water; barriers	Municipal ecology team/consultants	Incomplete detection biases targets	(Courtney Jones et al., 2025)
Objectives	Which species and functions must improve?	Species targets; resource needs; timeframe	Planning authority and stakeholders	Ambiguous outcomes undermine audit	(Dorian et al., 2025)
Alternatives	Where should investments be placed?	Scenario comparison and sensitivity	Spatial planners and landscape ecologists	Spatial model is projection only	(Croeser et al., 2024b)
Delivery	Who must build and maintain habitat?	Permit requirements; budgets; contracts	Developer; contractor; asset manager	Certification can miss biodiversity	(Kiss et al., 2025)
Monitoring	Have species responded and persisted?	Repeated field observations; comparison	Independent ecological monitoring	Occupancy is not persistence	(Morpurgo et al., 2025)
Adaptation	What happens if outcomes fail?	Predefined triggers; redesign; reporting	Regulators and owners	Long-term stewardship essential	(Hernandez-Santin & Hes, 2025)

Research Agenda: Priority Tests for the Next Decade

First, longitudinal causal studies are needed. Many urban interventions are reported as conceptual designs, model outputs or short-term observations. The emerging scorecard and index literature requires independent testing of

whether predicted habitat value corresponds to increasing occupancy, breeding, and persistence across seasons and years (Visintin et al., 2026; Croeser et al., 2026). Research designs should where feasible use before–after control–impact sampling and explicitly adjust for changes in the surrounding urban matrix.

Second, there is a multispecies transferability problem. Indicators calibrated for plants or conspicuous birds may fail for low-mobility invertebrates, subterranean organisms, amphibians and nocturnal mammals. Expert elicitation is valuable where field evidence is sparse, but its uncertainty must be transparent and empirically revisited (Courtney Jones et al., 2025). DNA-based invertebrate sampling expands observational scope, yet low predictive validation demonstrates the danger of using calibration accuracy as decision certainty (Morpurgo et al., 2025).

Third, performance needs to be evaluated over the life cycle of constructed habitats. Plant survival, horticultural changes, irrigation restrictions, pest treatment, soil quality and renovation influence resource continuity (Kopylova et al., 2025; Minixhofer et al., 2022). Studying construction as the end point underestimates these processes. Long-term ecological covenants, maintenance costs and responsible management entities require comparative investigation, particularly across private parcel boundaries.

Fourth, ecology must be connected to the cumulative urban economy. The loss of small private gardens reveals why parcel-by-parcel regulation matters (Davies et al., 2026). The ecological influence of energy and transport corridors further shows that biodiversity cannot be managed separately from infrastructure expansion (Kaszta et al., 2024; Arshed et al., 2024). Multi-scale scenario studies should jointly compare avoided habitat loss, redevelopment location, intensity, transport provision and targeted green retrofits.

Fifth, evaluation should disentangle ecological improvement from ecosystem-service enhancement. Although some bird groups can indicate regulating services in certain settings (Liu et al., 2023), services and biodiversity may diverge. A fuller ecosystem-service cascade should measure the production of ecological functions and the distribution of human benefits separately (Uchiyama et al., 2025). This is essential to detect development scenarios that improve cooling or recreation while impoverishing particular species assemblages.

Sixth, socially legitimate conservation requires careful attention to participation and justice. Inclusive governance is repeatedly identified as a barrier or enabler in NbS implementation (Zhu et al., 2023; Russo et al., 2026). Yet the quality of participation cannot be inferred from workshop attendance alone. Research should examine who controls species selection, who maintains landscapes, whose livelihoods or housing costs change, and whether affected communities can request redesign when projected outcomes fail.

Seventh, standardized monitoring must be flexible rather than universally prescriptive. Resilience depends on regional climate, invasive species, water regimes, and culturally appropriate land management; studies in Australia, Europe, China, Indonesia, Turkey, Nigeria and elsewhere already reveal strong contextual contrasts (Kurniawan et al., 2025; Sekban & Akyol, 2023; Busari & Adedeji, 2026). Common reporting categories can support comparison, while local reference ecosystems and priority taxa must govern ecological thresholds.

These priorities suggest an institutional shift in the research–practice relationship. Instead of producing a static design checklist and returning years later to evaluate its success, research programs should be embedded in iterative urban development. Models provide hypotheses; developers deliver carefully specified interventions; monitoring tests those hypotheses; and planning authorities revise standards from accumulating evidence. The objective is not to eliminate design uncertainty but to make it visible, governable, and scientifically productive. Table 5 below outlines the research gaps that remain unresolved.

Table 5. Unresolved research gaps and proposed testable designs

Research gap	Current evidence signal	Suggested study design	Key outcome measures	Policy application	Ref.
Predictive validity of scoring tools	Design metrics are proliferating	Independent multi-city longitudinal validation	Occupancy, demography, richness	Performance-based certification	(Visintin et al., 2026)

Taxon-specific connectivity	Thresholds differ among groups	Movement tagging and landscape genetics	Dispersal, colonization, gene flow	Species-calibrated corridors	(Courtney Jones et al., 2025)
Planting versus persistence	Many projects report near-term design	Repeated monitoring across maintenance phases	Survival, floral continuity, nesting	Maintenance covenants	(Hernandez-Santin & Hes, 2025)
Model generalization	Calibration may not predict new sites	Out-of-sample and temporal validation	Predictive error; detection-adjusted occupancy	Evidence grades for spatial models	(Morpurgo et al., 2025)
Site versus regional impacts	Infrastructure fragments broad landscapes	Nested city-region scenario comparison	Network permeability and habitat loss	Strategic zoning and transport	(Kaszta et al., 2024)
Equity and ecological quality	Access proxies omit habitat quality	Spatial-social ecological audits	Distribution of quality nature and taxa	Just transition and anti-displacement	(Galeota Lanza et al., 2026)
Governance implementation gap	Certificates omit ecological accountability	Comparative institutional evaluation	Compliance and post-occupancy response	Biodiversity-linked approvals	(Kiss et al., 2025)

The flowchart illustrates seven interconnected research priorities for advancing urban biodiversity conservation, encompassing longitudinal studies, multispecies assessment, habitat performance, urban development, ecosystem services, social justice, and adaptive monitoring. These priorities support an iterative research–practice framework integrating ecological models, practical interventions, continuous monitoring, and evidence-based revisions of urban planning standards.

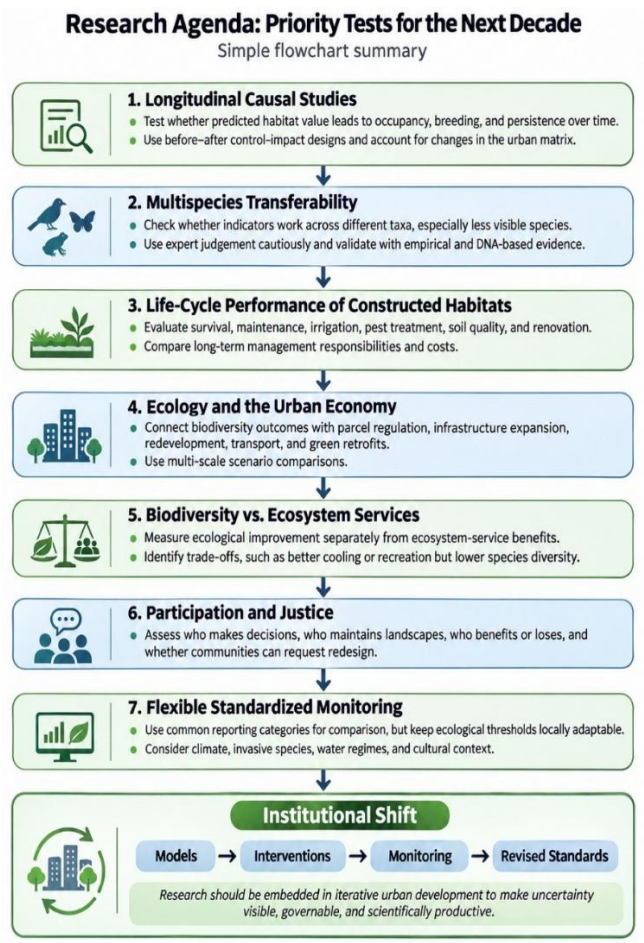


Figure 1. Research Agenda

DISCUSSION

The reviewed literature contributes different kinds of knowledge that should not be combined as though they were interchangeable estimates of biodiversity gain. Species-focused studies and field observations can identify plausible habitat mechanisms; scenario analyses help prioritize locations but require external validation; design frameworks specify decisions and responsibilities; and studies of wellbeing, economics, or digital governance provide implementation context rather than direct biological outcome evidence.

Three tensions recur across these categories. First, canopy or green-area indicators are administratively convenient but may omit species-specific resources and habitat quality. Second, spatial connectivity predictions are useful for comparing alternatives but do not establish successful dispersal, recruitment, or gene flow. Third, certification and community participation may facilitate delivery without demonstrating ecological additionality. These tensions support a narrower conclusion than a general claim that BSUD interventions already deliver durable nature-positive outcomes.

Geographic and disciplinary heterogeneity, abstract-only access for parts of the corpus, and unavailable original screening records constrain generalization. Contextual works on health, housing preferences, urban metabolism, cultural practice, and digital tools remain relevant to adoption and justice, but their inclusion must not be mistaken for independent corroboration of ecological effectiveness. Future reviews should publish database queries, eligibility decisions, deduplication rules, full-text availability, and study-level appraisal before estimating the strength or prevalence of effects.

4.1. Areas of agreement across the literature

1. The quantity of green space is an incomplete proxy for ecological quality. Canopy cover, park proximity, and total green area are useful planning indicators, but they do not reveal whether a site supplies the food, shelter, nesting substrates, breeding conditions, or seasonal resources required by particular taxa. The Munich residential-block study links local vegetation cover and vegetation structure with bird abundance and diversity, while the vegetation assessment tool developed by Visintin et al. (2026) evaluates structure, diversity, and connectivity rather than relying on a single greenness measure (Tobisch et al., 2026; Visintin et al., 2026). The proposed Everyday Nature Index similarly seeks to incorporate vegetation structure, nativeness, diversity, and connectivity into street-level assessment (Croeser et al., 2026). These contributions converge on a central point: urban nature should be evaluated by the ecological resources it provides, not solely by its visible extent.

2. The importance of ecological connectivity, although the relevant form of connectivity is taxon-specific. The BSUD case study showed that alternative spatial arrangements could improve modelled movement opportunities for two focal species (Kirk et al., 2021). More recent work has sought to estimate habitat connectivity requirements for multiple taxonomic groups and to combine species priorities when delineating ecological networks (Courtney Jones et al., 2025; Ma et al., 2025). Research on targeted urban retrofits further indicates that the location of an intervention can matter as much as the amount of area converted: strategically placed green infrastructure may address movement bottlenecks more efficiently than dispersed greening (Croeser et al., 2024a). Across these studies, the shared implication is that habitat patches should be planned as parts of a wider ecological network rather than as isolated amenities.

3. The need to distinguish design intentions and model outputs from observed biological responses. Connectivity models, scorecards, and design frameworks are valuable for comparing alternatives and making ecological considerations visible during planning. However, they do not by themselves demonstrate successful dispersal, reproduction, recruitment, or population persistence. The limited external validation reported for some urban invertebrate distribution models illustrates this distinction between model calibration and reliable prediction (Morpurgo et al., 2025). The original Fishermans Bend study likewise presented scenario-based connectivity gains while acknowledging that post-development ecological outcomes were not yet available (Kirk et al., 2021). The literature therefore supports a hierarchy of evidence in which proposed habitat, installed habitat, observed use, and long-term persistence are reported separately.

4. The ecological performance depends on implementation and long-term management, not simply on design quality at approval or construction. Vegetation maintenance, flowering-resource continuity, substrate condition, water quality, and management of threats influence whether habitat remains functional. Studies of residential development, pollinator gardens, and green-building assessment all point to the need for explicit objectives, maintenance arrangements, and monitoring rather than reliance on general sustainability claims (Dorian et al., 2025; Hernandez-Santin et al., 2025; Kiss et al., 2025). Governance research also shows that biodiversity ambitions can be weakened when they are not translated into procurement criteria, regulations, budgets, and assigned responsibilities (Mattijssen et al., 2023; Zhu et al., 2023). This convergence supports the proposed framework's emphasis on delivery commitments and post-occupancy accountability.

4.2 Points of disagreement and apparent contradictions

1. The first apparent disagreement concerns whether local vegetation provision or landscape-scale connectivity is the more important driver of urban biodiversity. In Munich, local vegetation cover was strongly associated with bird abundance and diversity, whereas distance to larger green spaces was not significant in the sampled residential blocks (Tobisch et al., 2026). By contrast, studies of ecological networks and targeted retrofits emphasize corridors, barriers, and landscape configuration as important determinants of movement opportunities (Croeser et al., 2024a; Ma et al., 2025). These findings should not be treated as mutually exclusive. They address different ecological processes, spatial scales, and taxa: local vegetation may determine resource availability within a residential block, while connectivity may determine whether organisms can reach, recolonize, or move between habitat patches. The apparent contradiction is therefore better understood as a scale- and taxon-dependence problem. The practical consequence is that planning should assess both local habitat quality and landscape permeability rather than selecting one as a universal substitute for the other.

2. A second apparent disagreement concerns the effectiveness of designed green elements. The Malmö study found no consistent difference in bumblebee and butterfly abundance or richness between newly designed biodiversity-oriented elements and conventional green elements; flowering-plant richness, floral cover, and element size were more informative correlates (Haaland, 2023). Other studies and design frameworks identify green infrastructure, vegetation complexity, and targeted retrofits as opportunities to improve biodiversity or connectivity (Croeser et al., 2024a; Visintin et al., 2026). The evidence does not establish that green infrastructure is ineffective. Rather, it challenges the assumption that an intervention's label or design intention guarantees an ecological response. A green roof, wall, verge, or pocket park may fail to provide suitable resources if plant composition, seasonal flowering, substrate, maintenance, or surrounding habitat are inadequate. Accordingly, the effectiveness of an intervention must be evaluated by its ecological function and the taxa it is intended to support.

3. A third tension concerns the relationship between biodiversity conservation and the delivery of ecosystem services or human benefits. Some studies seek surrogate species that may indicate both biodiversity and regulating services in particular urban settings (Liu et al., 2023), while broader ecosystem-service analyses emphasize the need to connect ecological structures and functions to human wellbeing (Uchiyama et al., 2025). However, the existence of a co-benefit pathway does not establish that all biodiversity objectives align with recreation, cooling, accessibility, or amenity. Intensive public use may disturb sensitive species; vegetation selected for visual or climatic performance may not provide suitable habitat; and water-management features may have ecological requirements that differ from recreational preferences. The literature therefore supports assessing social and ecological outcomes together, but not collapsing them into a single assumed win–win indicator.

4. A fourth tension concerns standardization versus ecological specificity. Composite indices and common benchmarks can make performance legible to planners and enable comparisons between sites (Croeser et al., 2026; Galeota Lanza et al., 2026; Visintin et al., 2026). At the same time, habitat requirements and movement thresholds differ among taxa and settings, making universal numerical thresholds difficult to justify (Courtney Jones et al., 2025). This is not simply a technical disagreement over indicator design. It

reflects a governance dilemma: authorities need comparable measures for regulation and reporting, whereas ecological validity requires locally appropriate reference conditions and species-specific measures. A defensible approach is to standardize reporting structure and minimum disclosure requirements while allowing ecological targets and thresholds to be locally calibrated.

4.2 Unresolved debates and research questions

1. The relationship between improved habitat condition and demographic recovery is not yet sufficiently established across the reviewed urban contexts. A site may provide more structurally complex vegetation or a more connected mapped network without evidence that target species reproduce, recruit, or persist. Longitudinal monitoring is therefore needed to test whether improvements in habitat resources and functional connectivity translate into population-level outcomes. Such studies should account for detectability, seasonal variation, regional source populations, and changes in the wider urban matrix. Until this evidence is available, claims of biodiversity gain should be limited to the level actually measured.

2. The appropriate balance between focal-species planning and broader community-level conservation remains contested. Target species make ecological requirements more tangible for designers and stakeholders, as demonstrated in the BSUD approach (Kirk et al., 2021). However, a small focal set may fail to represent less conspicuous taxa, soil organisms, invertebrates, or species with different movement and resource requirements. Multi-taxon assessment and expert elicitation can broaden the evidence base, but they introduce their own uncertainties and may rely on incomplete data (Courtney Jones et al., 2025; Morpurgo et al., 2025). Future applications should explain why particular taxa were selected, which ecological groups remain unrepresented, and how the selected indicators are expected to relate to wider community outcomes.

3. Third, the degree to which nature-positive claims can be standardized remains unresolved. Certification schemes and planning instruments can require biodiversity objectives, connectivity plans, monitoring, and audit trails, but a formal requirement does not guarantee additional ecological gain (Kiss et al., 2025). Conversely, highly context-specific ecological assessment may be difficult to compare or administer across jurisdictions. Further work is needed to establish how baselines, counterfactuals, additionality, off-site impacts, and time horizons should be documented. The proposed evidence-status labels—projected, installed, used, and persistent—offer a transparent reporting vocabulary, but they should be tested across different taxa and project types before being adopted as a formal standard.

4. The relationship between ecological improvement and environmental justice requires more direct evaluation. Access to green space, distribution of canopy, cultural recognition, and community participation are important dimensions of urban sustainability, but equitable access does not automatically indicate ecological quality, and ecological restoration does not automatically produce equitable social outcomes. Research on urban regeneration highlights participation, cultural sensitivity, and displacement risks, while spatial indices seek to expose inequalities in green provision (Galeota Lanza et al., 2026; Russo et al., 2026). The unresolved question is how planning institutions can protect habitat and nonhuman interests while ensuring that the costs, benefits, and decision-making authority are fairly distributed. This requires indicators for social distribution alongside, but analytically distinct from, ecological indicators.

5. The long-term responsibility for habitat performance remains insufficiently specified in many development settings. Biodiversity assets may cross public and private land, while design, construction, ownership, and maintenance are controlled by different actors. Existing studies identify institutional barriers, knowledge gaps, and weaknesses in the translation of biodiversity objectives into development practice (Mattijssen et al., 2023; Zhu et al., 2023). The unresolved debate is not only who should pay for ecological maintenance, but who is accountable when monitoring shows that promised habitat functions have not materialized. Comparative research on ecological covenants, maintenance funding, independent monitoring, and corrective obligations is needed to determine which governance arrangements are durable and enforceable.

CONCLUSIONS

Urban biodiversity-sensitive design is evolving from a framework for more sympathetic landscapes into a potential system for measurable ecological accountability. The original Fishermans Bend application showed how species-specific needs could be integrated into planning and how alternative urban forms could be compared through spatial modeling. Subsequent research has enriched that foundation through taxon-specific connectivity estimates, spatially targeted interventions, vegetation-complexity indicators, field evidence on wildlife responses and more explicit governance critiques. Collectively, these advances challenge the substitution of greenness, canopy coverage or design certification for demonstrated conservation outcomes.

A credible nature-positive development must state which organisms and processes it intends to benefit, identify mechanisms that connect interventions to those outcomes, protect existing irreplaceable ecological features, and evaluate whether target conditions materialize. Ecological performance must be monitored beyond installation, across seasons and life stages, and at scales that reflect organism movement and regional habitat networks. Social equity and meaningful participation should influence decisions without being misreported as biodiversity metrics. The proposed outcome-linked BSUD framework and evidence-status terminology offer a synthesis to be tested, not an already validated standard. The central policy implication is clear: greening is an intervention; biodiversity gain is a proposition that requires evidence.

REFERENCES

1. Ahmadian, E., & Perrotti, D. (2025). Mapping agency in urban metabolism research. A systematic characterisation of urban-level resource-use assessment models based on levels of engagement with agents. https://doi.org/10.1016/j.ecolmodel.2025.111140
2. Al Hazmi, A.F. (2026). Designing Ecocentric Urban Spaces for Human-Nature Connection: A Case Study of Orchard Hill Station Precinct. https://doi.org/10.1007/978-981-95-6864-2_11
3. Arshed, N., Anwar, A., Abbas, M., & Mughal, W. (2024). Natural habitat vs human in competition for breathing space: Need for restructuring clean energy infrastructure. https://doi.org/10.1016/j.ecolecon.2024.108177
4. Boros, J.Z., Shevchenko, V., Cay, D., & Gualtieri, G. (2024). A Framework for More-than-human Placemaking with Data Storytelling. https://doi.org/10.14627/537752023
5. Busari, R.S., & Adedeji, O.H. (2026). ASSESSMENT OF LANDSCAPE CONNECTIVITY OF URBAN GREEN INFRASTRUCTURE FOR BIODIVERSITY MANAGEMENT IN IBADAN. https://doi.org/10.2478/jlecol-2026-0011
6. Bush, J., Oke, C., Dickey, A., Humphrey, J., Harrison, L., Amati, M., Fornari, G., Soanes, K., Callow, D., & Van der Ree, R. (2023). A decade of nature: Evolving approaches to Melbourne's 'nature in the city'. https://doi.org/10.1016/j.landurbplan.2023.104754
7. Croeser, T., Bekessy, S.A., Garrard, G.E., & Kirk, H. (2024b). Nature-based solutions for urban biodiversity: Spatial targeting of retrofits can multiply ecological connectivity benefits. https://doi.org/10.1016/j.landurbplan.2024.105169
8. Croeser, T., Kirk, H., Weisser, W.W., Snow, S., Xiao, A.S.R., Visintin, C., & Bekessy, S.A. (2026). Towards an Everyday Nature Index for biodiversity in urban streets. https://doi.org/10.1016/j.ufug.2025.129195
9. Croeser, T., Sharma, R., Weisser, W.W., & Bekessy, S.A. (2024a). Acute canopy deficits in global cities exposed by the 3-30-300 benchmark for urban nature. https://doi.org/10.1038/s41467-024-53402-2
10. Kaszta, Ż., Cushman, S.A., Hearn, A., Sloan, S., Laurance, W.F., Haidir, I.A., & Macdonald, D.W. (2024). Projected development in Borneo and Sumatra will greatly reduce connectivity for an apex carnivore. https://doi.org/10.1016/j.scitotenv.2024.170256
11. Courtney Jones, S.K., O'Loughlin, L.S., Starrs, D., Humphrey, J.E., Pulsford, S.A., Allan, H., Beitzel, M., Birgen, K., Bond, S., Bounds, J., Bower, D., Brawata, R., Broadhurst, B., Carlson, E., Clulow, S., Cunningham, S., Dunn, L., Evans, L., Ferronato, B., … Snape, M.A. (2025). Quantifying taxon-specific habitat connectivity requirements of urban wildlife using structured expert judgement. Biological Conservation, 305, 110991. https://doi.org/10.1016/j.biocon.2025.110991

12. Davies, P.J., Keane, A., Perera, A.C.S., & Trinquart, L. (2026). Death of the front yards: How the house and car is replacing residential gardens. https://doi.org/10.1016/j.cities.2026.106929
13. de Oliveira Ferronato, B., Hoefer, A.M., Booksmythe, I., Ubrihien, R., & Georges, A. (2026). Nesting ecology of Chelodina longicollis in stormwater ponds, Australian Capital Territory, Australia. Australian Journal of Zoology, 74(5), ZO26017. https://doi.org/10.1071/ZO26017
14. Dein, J., & Tran, L. (2025). Scale dependence of bird diversity in London. https://doi.org/10.1007/s10980-024-02018-4
15. Dorian, N.N., Murphy, A.W., Iler, A.M., & CaraDonna, P.J. (2025). Setting goals for pollinator gardens. https://doi.org/10.1111/cobi.70009
16. Edejer, S.R., Haase, D., Dennis, M., & Larsen, A. (2024). Ten steps towards integrated decision making for ecological restoration in cities: Rewilding the European beaver (Castor fiber) in Berlin, Germany. https://doi.org/10.1016/j.mex.2024.102827
17. Fischer, L.K., Bender, E., Guenat, S., Jakstis, K., Krause, P., Wochner, M., & Müller, H. (2026). Urban biodiversity in green walls: Plant diversity and flower cover as drivers of pollinator abundance in vertical greening systems. Urban Forestry & Urban Greening, 122, 129510. https://doi.org/10.1016/j.ufug.2026.129510
18. Frantzeskaki, N., Oke, C., Barnett, G., Bekessy, S., Bush, J., Fitzsimons, J., Ignatieva, M., Kendal, D., Kingsley, J., Mumaw, L., & Ossola, A. (2022a). A transformative mission for prioritising nature in Australian cities. https://doi.org/10.1007/s13280-022-01725-z
19. Frantzeskaki, N., Ossola, A., & Bush, J. (2022b). Nature-based solutions for changing urban landscapes: Lessons from Australia. https://doi.org/10.1016/j.ufug.2022.127611
20. Friedman, A. (2024). Sustainable Lessons from People-Friendly Places. https://doi.org/10.4324/9781003384687
21. Galeota Lanza, G., Cipriano, P., Ciliberti, M., Pappalardo, S.E., & De Marchi, M. (2026). Beyond the 3-30-300 Rule: Construction of a Scalable Composite Index for the Evaluation of Urban Green—The Ferrara Case Study. https://doi.org/10.3390/ijgi15060256
22. Geropanta, V., Ampatzoglou, T., Parthenios, P., & Karagianni, A. (2023). Design for urban biodiversity: flourishing the vertical plane. https://doi.org/10.1051/e3sconf/202343612002
23. Grabowski, Z., Fairbairn, A.J., Teixeira, L.H., Micklewright, J., Fakirova, E., Adeleke, E., Meyer, S.T., Traidl-Hoffmann, C., Schloter, M., & Helmreich, B. (2023). Cosmopolitan conservation: the multi-scalar contributions of urban green infrastructure to biodiversity protection. https://doi.org/10.1007/s10531-023-02614-x
24. Grilli, J., & De Franco, A. (2025). Art-based heuristics for spatial inquiry and design: Insights from The Sensitive City project. Scopus record: https://www.scopus.com/pages/publications/105016325771?origin=resultslist
25. Guo, Y., Liu, S., Dong, Y., Wu, G., Liu, J., Wang, W., & Wang, J. (2025). Research progress and prospects of nature-based solutions in green infrastructure: A bibliometric analysis. https://doi.org/10.1016/j.ecofro.2024.11.007
26. Haaland, C. (2023). Bumblebees and butterflies in green structure elements in Malmö, Sweden. https://doi.org/10.1007/s11252-023-01400-5
27. Helmreich, B., Deeb, M., Eben, P., Egerer, M., Kollmann, J., Schulz, S., Pauleit, S., Weisser, W.W., & Schloter, M. (2024). Converting infiltration swales to sustainable urban drainage systems can improve water management and biodiversity. https://doi.org/10.3389/fenvs.2024.1524239
28. Hernandez-Santin, C., & Hes, D. (2025). Living Regeneratively: Housing Design That Enables Resident Agency in Ecological Restoration. https://doi.org/10.3390/land14071462
29. Hernandez-Santin, C., Amati, M., Bekessy, S., & Desha, C. (2022). A Review of Existing Ecological Design Frameworks Enabling Biodiversity Inclusive Design. https://doi.org/10.3390/urbansci6040095
30. Hernandez-Santin, L., EricRamirez-Bravo, O., & Hernandez-Santin, C. (2025). Vegetation regulations and upkeeping influence avifauna diversity within residential developments of Mexico City. https://doi.org/10.1007/s11252-025-01712-8
31. Iqbar, N. (2026). Biodiversity and stratification of dye plants in urban green spaces at Universitas Syiah Kuala, Banda Aceh, Indonesia. Biodiversitas, 27(1), d270115. https://doi.org/10.13057/biodiv/d270115

32. Kirk, H., Garrard, G. E., Croeser, T., Backstrom, A., Berthon, K., Furlong, C., Hurley, J., Thomas, F., Webb, A., & Bekessy, S. A. (2021). Building biodiversity into the urban fabric: A case study in applying biodiversity sensitive urban design (BSUD). Urban Forestry & Urban Greening, 62, 127176. https://doi.org/10.1016/j.ufug.2021.127176
33. Kirk, H., Wright, D., Garrard, G.E., Visintin, C., Selinske, M., & Bekessy, S.A. (2026). Rethinking environmental impact assessment for nature-positive development. Frontiers in Ecology and the Environment, 24(8), e70068. https://doi.org/10.1002/fee.70068
34. Kiss, B.M., Visintin, C., Garrard, G.E., & Bekessy, S.A. (2025). Evaluating Biodiversity Criteria in Green Building Rating Schemes: Toward 'Nature Positive' Development. https://doi.org/10.1002/sd.3369
35. Kopylova, T., Rumiankov, Y., Porokhniava, O., Muzyka, H., Vitenko, V., Bayura, O., Hrynyk, H., & Hrynyk, O. (2025). Phytosanitary condition of age-old trees of the V.V. Pashkevych arboretum of the National Dendrological Park "sofiyivka" of the National Academy of Sciences of Ukraine. https://doi.org/10.2478/ffp-2025-0007
36. Kurniawan, A., Hazmi, A.F.A., Nolasari, A.B., Wiranti, A., Abidzar, F., Toyyibah, W., Saragih, V.C., & Dahlan, M.Z. (2025). Harmonizing Urban Life with Natural Ecosystems in New Nusantara Capital City Through Biodiversity Sensitive Urban Design (BSUD). https://doi.org/10.1088/1755-1315/1447/1/012015
37. Lawler, J.J., Gross, J.E., Foden, W.B., & Midgley, G.F. (2025). Whole-Earth: A conservation-planning paradigm for a changing climate. Global Change Biology, 31(7), e70328. https://doi.org/10.1111/gcb.70328
38. Leino, H., & Nieminen, J. (2026). Endangered species in cities: The potential and practices of habitat patch creation in urban environments. Journal of Landscape Architecture, 21(1), 22–31. https://doi.org/10.1080/18626033.2026.2704436
39. Lemes de Oliveira, F. (2025). Nature in nature-based solutions in urban planning. https://doi.org/10.1016/j.landurbplan.2024.105282
40. Li, J., & Dounas, T. (2024). DIRECTIONS FOR RESEARCH ON INCENTIVISING AND GOVERNING THE INCREASE OF BIODIVERSITY IN CITIES WITH BLOCKCHAIN TECHNOLOGIES. https://doi.org/10.35490/EC3.2024.239
41. Liu, X., Zhao, Y., Zeng, D., Yang, Y., Li, W., Kang, Y., Wei, G., Yuan, X., Bo, S., & Si, X. (2023). Characterizing bird species for achieving the win-wins of conserving biodiversity and enhancing regulating ecosystem services in urban green spaces. https://doi.org/10.1016/j.ufug.2023.128064
42. Lund, L.N. (2022). Designing the regenerative city? A case study of urban actors working to integrate ideas of biodiversity in Copenhagen. https://doi.org/10.1088/1755-1315/1122/1/012008
43. Ma, Q., Yu, L., Xu, L., Yuan, J., & Yang, Y. (2025). Can ecological networks established through interactions of multi-species conservation priorities maintain biodiversity and contain urban development?. https://doi.org/10.1016/j.jnc.2025.126853
44. Mattijssen, T.J.M., Dijkshoorn-Dekker, M.W.C., Kortstee, H.J.M., Polman, N.B.P., & Snep, R. (2023). Nature-inclusive urban development: lessons learned in three real estate projects in Dutch cities. https://doi.org/10.1080/19463138.2023.2216654
45. Mensi, L., Grotto, G., & Buja, A. (2026). Effects of the urban environment and urban design on the well-being of older adults: an umbrella review. https://doi.org/10.1007/s10389-026-02699-y
46. Minixhofer, P., Scharf, B., Hafner, S., Weiss, O., Henöckl, C., Greiner, M., Room, T., & Stangl, R. (2022). Towards the Circular Soil Concept: Optimization of Engineered Soils for Green Infrastructure Application. https://doi.org/10.3390/su14020905
47. Mofrad, F., & Ignatieva, M. (2023). What Is the Future of the Bush Capital? A Socio-Ecological Approach to Enhancing Canberra's Green Infrastructure. https://doi.org/10.3390/land12010039
48. Morpurgo, J., Remme, R.P., Mudde, Q.D., Didaskalou, E.A., Serwatowska, K.J., Trimbos, K.B., Hu, M., & van Bodegom, P.M. (2025). Green and blue infrastructure but not anthropogenic drivers affect invertebrate communities in urban ecosystems. https://doi.org/10.1016/j.ecolind.2025.113650
49. Oliveira, A.P., Bajanca, A., & Paramés, A. (2025). Unveiling urban biodiversity: An interdisciplinary hands-on project that catalyzes awareness. https://doi.org/10.1016/j.indic.2024.100561
50. Parker, D., Soanes, K., & Roudavski, S. (2025). Learning with owls: Human–wildlife coexistence as a guide for urban design. https://doi.org/10.1002/pan3.70067

51. Parris, K.M. (2023). IMPACTS OF URBANIZATION ON AMPHIBIANS AND OPPORTUNITIES FOR THEIR CONSERVATION IN CITIES. https://doi.org/10.4324/9781003016120-22
52. Pobegaylov, O. (2023). Preservation of the natural landscape during construction. https://doi.org/10.1051/e3sconf/202337101062
53. Rahman, M.A., Hahs, A., Szota, C., Farrell, C., Williams, N., & Livesley, S.J. (2026). Multi-layered Urban Forests: can a City be dense and green?. https://doi.org/10.3389/frsc.2026.1842594
54. Roffe, M., & Trop, T. (2025). Willingness to purchase and to pay a price premium for apartments with exterior green walls. https://doi.org/10.1080/09613218.2025.2547729
55. Rogovskyi, S., Ishchuk, L., & Ishchuk, H. (2023). CHORNOBYL'S CURRENT DENDROFLORA: ANALYSIS OF NATURAL SUCCESSIONS IN THE ABANDONED URBAN PHYTOCOENOSES. https://doi.org/10.23902/trkjnat.1246847
56. Ruan, T., Paavola, J., Chan, F.K.S., Xu, Y., Baldacchini, C., & Calfapietra, C. (2024). A lack of focus on data sharing, stakeholders, and economic benefits in current global green infrastructure planning. https://doi.org/10.1016/j.jenvman.2023.119849
57. Russo, A., Baresi, U., & Cheshmehzangi, A. (2026). Nature-Based Solutions in Urban Regeneration: A Review of Methods, Governance, and Future Directions. https://doi.org/10.3390/urbansci10030130
58. Sekban, D.U.G., & Akyol, D. (2023). Contributions of Green Infrastructure-Oriented Planning and Designing in Residential Gardens to the City's Ecosystem: Case of Trabzon City, Turkey. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000898
59. Shafer, L.B., Klimas, C.A., Vogt, J., & Hasle, A.F. (2025). Community engagement in urban habitat creation for the Rusty Patched Bumble Bee (Bombus affinis) indicates the potential of conservation in private yards. https://doi.org/10.1016/j.ufug.2025.129129
60. Situmorang, L.K.N., Hermawan, R., & Zuhud, E.A.M. (2026). Analysis of Biophysical Potential and Urban Community Needs for Healing Forest in City Park 2 BSD, South Tangerang City. https://doi.org/10.29244/medkon.31.2.115
61. Sobhani, P. (2024). Urban development impacts on natural ecosystems in urban protected areas of Tehran province, Iran. https://doi.org/10.1016/j.heliyon.2024.e40572
62. Thomson, G., Newman, P., Hes, D., Bennett, J., Taylor, M., & Johnstone, R. (2022). Nature-Positive Design and Development: A Case Study on Regenerating Black Cockatoo Habitat in Urban Developments in Perth, Australia. https://doi.org/10.3390/urbansci6030047
63. Tobisch, C., Fuchs, E., & Moning, C. (2026). The importance of residential vegetation cover for urban birds – linking biodiversity thresholds to standards for human well-being. https://doi.org/10.1016/j.baae.2025.12.005
64. Uchiyama, Y., Sato, M., Ushimaru, A., & Minamoto, T. (2025). Analysis of integrated studies on ecosystem services, human well-being, and urban planning: regional trends and recommendations for future studies. https://doi.org/10.1007/s11252-025-01831-2
65. Ustaoglu, E., & Williams, B. (2024). The Inter-Relationships of Territorial Quality of Life with Residential Expansion and Densification: A Case Study of Regions in EU Member Countries. https://doi.org/10.3390/urbansci8010022
66. Visintin, C., Garrard, G.E., Weisser, W.W., Baracco, M., Hobbs, R.J., & Bekessy, S.A. (2025). Designing cities for everyday nature. https://doi.org/10.1111/cobi.14328
67. Visintin, C., Kirk, H., Garrard, G.E., Humphrey, J.E., & Bekessy, S.A. (2026). A novel vegetation assessment tool for comparing the biodiversity potential of different urban landscaping designs. https://doi.org/10.1038/s42949-026-00402-4
68. Wang, H., Wang, H., Chen, X., Han, B., Shu, C., Zhang, T., & Ding, S. (2023). Review on evaluation and enhancement of urban biodiversity. https://doi.org/10.5846/STXB202201280268
69. Wu, Y., Azmi, A., Ibrahim, R., Ghafar, A.A., & Salih, S.A. (2025). Creating a sustainable urban ecosystem: the Azheke village model. https://doi.org/10.1108/SASBE-10-2023-0292
70. Yang, Y., Ignatieva, M., Gaynor, A., & Hu, Y. (2024). Towards a conceptual design framework for bee botanic gardens: integrating perceptions on urban biodiversity into landscape design processes. https://doi.org/10.1007/s11252-024-01589-z
71. Zhang, X., Zhang, Y., Zhai, J., Wu, Y., & Mao, A. (2021). Waterscapes for promoting mental health in the general population. https://doi.org/10.3390/ijerph182211792

72. Zhu, D., Zhang, Y., Kendal, D., Fraser, L., & Flies, E.J. (2023). Nature-based solutions in Australia: A systematic quantitative literature review of terms, application and policy relevance. https://doi.org/10.1016/j.nbsj.2023.100092
73. Zibtseva, O., Troshkina, O., & Olkhovska, O. (2022). Dendroflora in Spatial Planning Composition of Children's Squares in Vyshhorod Town. https://doi.org/10.31548/forest.13(4).2022.30-40