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Developing a Biodiversity Assessment Tool to Enable the Integration of Biodiversity into Sustainable Building Practice: The New Zealand Biodiversity Factor—Building (NZBF-B)

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Abstract

Sustainable building practices can reduce environmental harm and support resilient urban development. To aid built-environment professionals such as architects, building scientists and planners in accomplishing regenerative design objectives, a variety of building rating and accreditation schemes have been developed, such as Greenstar or the Living Building Challenge. These schemes primarily focus on sustainability targets, such as energy and water use. Biodiversity considerations, despite their importance for ecosystem services and human health, are predominantly absent as core objectives in the building rating tools currently in use. To address this gap, we introduce the New Zealand Biodiversity Factor—Building (NZBF-B), a tool created to educate and incentivise the integration of biodiversity into buildings by assessing their biodiversity value, with a focus on prioritising native species. We outline the development of the NZBF-B, including its components, its scoring methodology, and an expert-informed weighting process used to determine the ecological relevance of each category. The tool captures key characteristics of building-associated biodiversity through measurable indicators that reflect both habitat provision and opportunities to strengthen human–nature connection. We advocate for the use of the NZBF-B alongside existing certification schemes to achieve more effective green building performance outcomes related to biodiversity.

Keywords: biodiversity assessment; building; sustainable building rating systems; urban vegetation; accreditation

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1. Introduction

Urban landscape expansion continues to result in ongoing biodiversity loss on a global scale [1–3]. As cities expand, grey non-permeable surfaces dominate, both horizontally through roads, parking lots and driveways, and vertically, through dense congregations of buildings [4]. These expansions and their associated modifications of natural landscapes place urban ecological communities under intense pressure, with native fauna often having to locate and compete for limited available resources [4–6]. The most concerning consequences of such transformations are habitat loss, degradation and fragmentation. These processes reduce the size of populations that can survive in an area and hinder the ability of species to disperse [7–9]. Ultimately, survival of native species and ecosystems in these landscapes becomes challenging or even impossible.

The dominance of grey impermeable landscaping not only limits species' ability to thrive, but it also leads to a growing disconnect from nature among human residents, since around 56% of the human population resides in urban spaces [10,11]. Spending time in greenspaces and having a connection to nature is linked to improved mental and physical wellbeing [12]. A recent study undertaken in Australia found that having a connection to nature was deemed as important as income in determining life satisfaction [13]. In Aotearoa New Zealand, those with greater nature-relatedness were more optimistic about future life satisfaction [14]. Biodiversity is fundamental for functioning ecosystems [15–17], which in turn provide services cities rely on, such as clean air, clean water, healthy soils, pollination and natural stormwater management [18].

In recognition of the detrimental ecological impacts caused by urbanisation and also the benefits people receive from biodiversity, urban professionals such as urban designers, developers, planners and architects are increasingly incorporating ways to reduce environmental harm [19–23]. Green building rating systems have been introduced to promote sustainability during the design and construction processes of buildings. Examples include: the "Building Research Establishment Environmental Assessment Method" (BREEAM) released in 1990 in the UK [24], the "Leadership in Energy and Environmental Design" (LEED) released in 1998 in the US [25], the Melbourne Green Factor released in 2020 [26], and Greenstar released in 2003 in Australia [27] and released in 2007 in New Zealand [28]. While these rating systems have a strong focus on sustainability considerations, such as energy consumption and materials used [21,29], considering or integrating biodiversity into building design is often treated as a "nice to have" rather than a necessity [30]. This is a missed opportunity, and arguably, truly "sustainable" and "green" labelling and marketing should include biodiversity as a fundamental component [31].

As cities become denser, relying solely on extensive, horizontal greenspaces at ground level (for example, home gardens and public greenspace) for the creation of habitat may not be possible to meet the goal of enhancing biodiversity and ecosystem functioning [32], as well as human wellbeing. Instead, buildings themselves should be designed in ways that incorporate new habitat for species, facilitate dispersal of some flora and fauna, and, at the same time, strengthen the human–nature connection [32–35]. This can be achieved through the installation of building-integrated vegetation on building walls and roofs [36–38], which if designed strategically, could support ecological connectivity across the urban landscape, facilitating movement and dispersal opportunities for flora and faunal species, and enhancing human–nature connection [39]. A prominent example is the "Greenest of the Green" building in Finland, where residents can relax in specifically designed gardens, grow their own food and witness the change of seasons through the planting of deciduous plant species [40]. Green roofs can contribute to a 'green' dispersal network across urban matrices that are typically dominated by grey impermeable surfaces [41]. The diversity of fauna attracted to green roofs is variable and depends on many factors, including building height [42], proximity to on-ground greenspace [42,43], the chosen substrate depth [41], and the plant species and plant composition chosen for the green roof [44].

In this study we aimed to develop an assessment tool that supports the integration of biodiversity into buildings, is founded in ecological theory, and meets a current and pressing gap in the information available to built-environment professionals. This work is timely as demand for buildings is growing in New Zealand; building consents for educational institutions alone rose by 30% while building consents for commercial and transport buildings were up by 1.9% in 2025 compared to 2024 [45]. Our objective was to develop an accessible, easy-to-use tool for people with limited ecological knowledge or resources. The assessment tool, the New Zealand Biodiversity Factor—Building (NZBF-B), is designed to assess the biodiversity value of buildings by assessing characteristics that are known to support and benefit ecological processes, with the goal that it can be used during the design development stage of the architectural building process, as well as on completion. Rather than assessing ecological processes (such as dispersal opportunities) directly, the NZBF-B measures proxies that are known to support these principles. The NZBF-B values native species more highly than non-native ones. In New Zealand, many native fauna have co-evolved with native vegetation [46], which therefore plays an important role in providing habitat and attracting native species back into urban spaces. For human residents, experiences of and interactions with native species in particular [47,48] are tightly linked to the creation of a sense of place—that is, a place rooted in belonging and identity [49]. In Australasia non-native species are more abundant than native ones across the rural-to-urban gradient [50]. We do acknowledge that non-native species are beneficial in creating habitat, especially if multiple vegetation heights are present in any given place, increasing structural diversity and habitat niches [51–53]. Mature non-native trees planted within the development boundary can offer dispersal opportunities and food resources for native avifauna [54], while both non-native and native flowering plants attract invertebrates into urban spaces [55].

The primary aim of our study is to describe the creation process of the NZBF-B, its components and the ecological reasoning for their inclusion. We describe the process of using expert feedback in weighting the different components of the tool to provide a numerical rating. Finally, we provide an example of how even very recent biodiversity-focused updates to a building rating system for buildings can fail to incorporate potentially important biodiversity considerations.

2. Materials and Methods

2.1. NZBF-B: Process of Creation

The NZBF-B's layout and scoring system were based on the NZBF-R [56] and Garden-Star NZ [57], which assess the biodiversity value of residential developments and private gardens respectively. The creation process of the NZBF-B occurred over seven stages, using the five biodiversity-sensitive urban design (BSUD) principles as the guiding framework [58]. These five principles are: (1) maintain and introduce habitat (protect existing and introduce new habitat in the form of heterogeneous native vegetation); (2) facilitate dispersal; (3) minimise threats and anthropogenic disturbances; (4) facilitate natural ecological processes; and (5) improve potential for positive human–nature connections. For the purpose of the NZBF-B, habitat is defined as novel habitat in the form of vegetation physically attached to, or part of, the building envelope, hereafter referred to as "building-integrated vegetation".

The process of creation is outlined in Figure 1.

Stage 1: Existing green factor tool review. To examine the extent of biodiversity provision within existing building rating schemes, components of both the New Zealand Green Building Council (NZGBC) "Green Star Design & As Built New Zealand v 1.1.1" and the NZGBC "Green Star NZ Buildings v.1" assessment tool [59], as well as the Melbourne Green Factor tool [26], were drawn on. Due to local relevance, we specifically focused on the "Green Star NZ Buildings v.1" assessment tool, which is set to replace the "Green Star Design & As Built v1.1.1" tool within the Green Star NZ framework. The "Green Star Buildings NZ" tool is described as a holistic tool that "act[s] on the areas of sustainability that matter most, future proofing a building for the long-term" [60], and consists of eight high-level categories ("Responsible", "Healthy", "Resilient", "Positive", "Places", "People", "Nature", "Leadership"). Both of the NZGBC Green Star tools' characteristics were reviewed for biodiversity-related content using NZGBC publicly available submission templates [59,61].

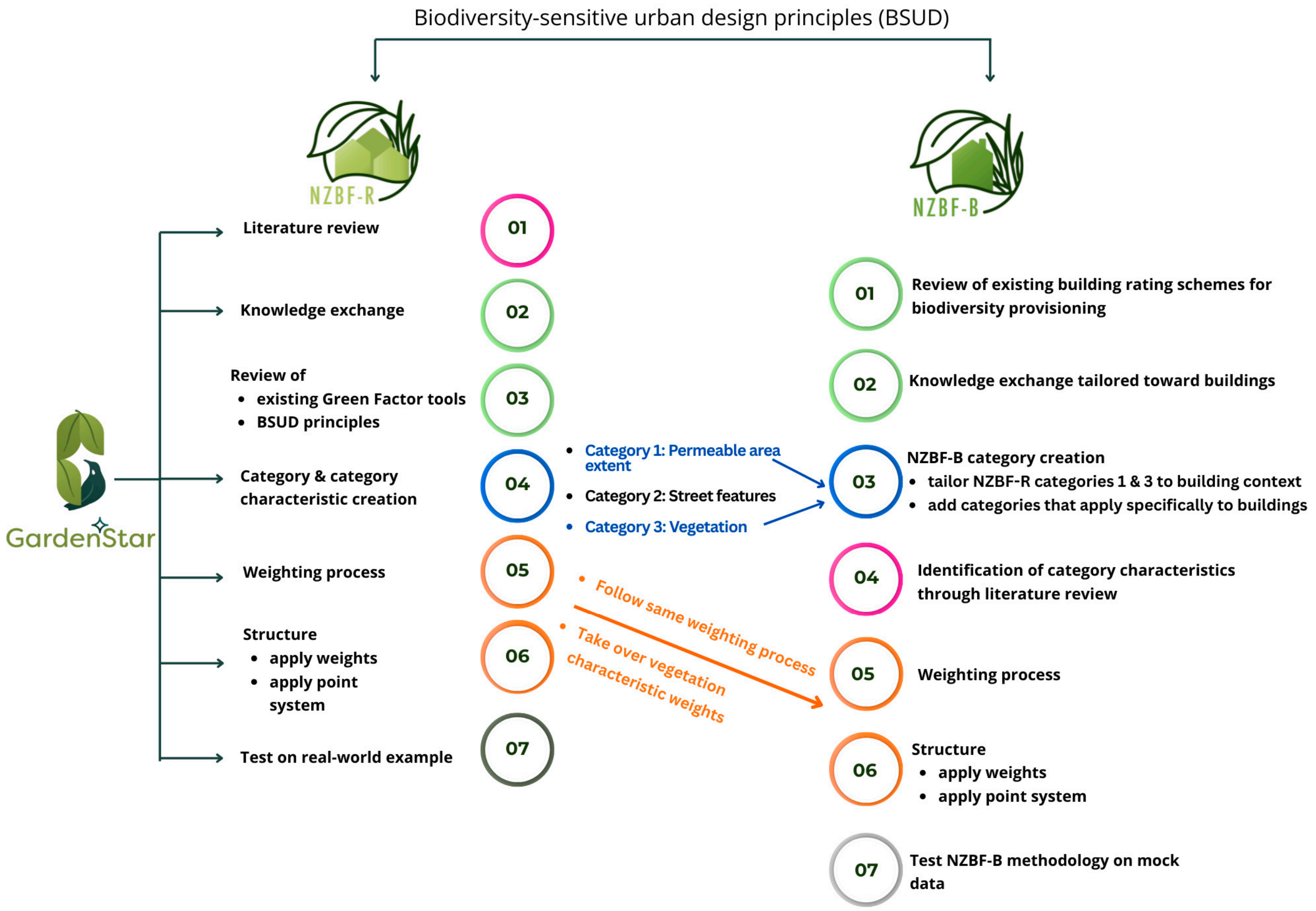

Figure 1. NZBF-B's process of creation. The antecedent tool, GardenStar NZ [57] informed the process of creation steps in the NZBF-R (numbered circles 1, 2, 5, 6, and 7). The NZBF-R process of creation steps highlighted in the same colour as those of the NZBF-B served as the foundation to the NZBF-B development process. The BSUD principles [58] underpin both the NZBF-R and NZBF-B categories and their contents.

Stage 2: Knowledge exchange. A knowledge exchange with New Zealand-based experts took place to explore options and practical considerations for the incorporation of building-integrated vegetation. Details of the experts and areas of expertise are outlined in Table 1.

Table 1. Details of experts who took part in knowledge exchange.

Expert	Area of Expertise	Affiliation
Expert 1	Installation of various types of green walls.	Hanging Gardens, Auckland, New Zealand
Expert 2	Regenerative design, sustainable architecture	Auckland University of Technology, Auckland, New Zealand
Expert 3	Building-integrated vegetation, sustainable architecture	Victoria University of Wellington, Wellington, New Zealand
Expert 4	Architecture (commercial, industrial, residential)	AHHA, Dunedin, New Zealand
Expert 5	Landscape architecture, green infrastructure	Knox City Council, Melbourne, Australia

Stage 3: Creation of the tool's categories. Stages 1 and 2 led to the creation of five categories: (1) Building-integrated vegetation extent (the area of building-integrated vegetation as a proportion of the total area of the building that could realistically support vegetation). (2) Minimising human impact (design strategies that can have positive and can mitigate negative impacts on biodiversity conservation or regeneration). (3) Building-integrated vegetation system (the ways in which building-integrated vegetation can be integrated, i.e., green roof, green wall, balconies). (4) Management and education (building-integrated maintenance and educational content of biodiversity-friendly features for inhabitants of the respective building). (5) Building-integrated vegetation quality (building-integrated vegetation characteristics reflecting habitat quality).

Stage 4: Identification of characteristics in each of the five NZBF-B categories. The 'Building-integrated vegetation quality' characteristics were derived from the NZBF-R, which was based on a systematic literature search and weighting process [56]. The characteristics for the remaining four high-level categories were based on a further literature search and review focused on buildings. To identify the relevant literature, combinations of search terms were entered into the search engines and included either 'building', 'green', 'living', 'vegetation' and/or 'biodivers*' with additional search terms relating to building structures, urban dwellers or wildlife. For example, terms such as, 'balcony', 'bird', 'building', 'certification', 'collision', 'ecosystem services', 'façade', 'green', 'invertebrate', 'New Zealand', 'pollination', 'roof', 'rooftop', 'sustainability', 'vegetation', 'wall', 'window', 'window view', 'wildlife' or a combination thereof were used.

Stage 5: Creation of weightings. The point system that is key to making the NZBF suite a quantitative tool required the creation of weightings for each of the five high-level categories. To do so, a weighting exercise drawing upon the expertise of twenty-one experts in the fields of plant ecology, vertebrate ecology, restoration ecology, entomology, geography, landscape architecture, landscape ecology, climate change and vegetation, and sustainable architecture took place (for details on experts, refer to Appendix A, Table A1). Experts were purposely recruited from multiple ecological regions (sub-tropical to temperate), disciplines, organisations (universities, consultancies, NGOs, national and local government research organisations), and across New Zealand and Australia, to ensure representation and mitigate potential biases. Those experts directly working with and/or researching building-scale systems have a variety of expertise across multiple building types. Experts were asked to rate the importance of each high-level NZBF-B category to biodiversity on a scale from 0 (least effect) to 10 (most effective), while taking into account each category's contribution to the five biodiversity-sensitive urban design principles [58].

To determine the final weightings, all expert scores were summed per category and divided by the sum of the overall scores received for all five categories [56]. We applied the weights attained through the NZBF-R weighting process to the building-integrated vegetation characteristics [56]; these were also arrived at using experts in the fields of botany, plant and animal ecology, entomology, and geography. Experts also had the opportunity to supply feedback about the tool's categories. The feedback was then used to refine and finalise the NZBF-B.

Stage 6: Structure of the NZBF-B. The NZBF-B tool was created in Microsoft Excel (version 2025) and closely mirrors the NZBF-R [56] in its structure, although the content of each section differs and is tailored to the building context. The 'Result' sheet shows a summary of (a) scores achieved per category, (b) overall score achieved for all categories combined (called the 'Biodiversity Factor'), and (c) tailored recommendations for biodiversity improvement based on the data entered in the 'Worksheet'. It incorporates speedometer charts to visualise the scores achieved and show where room for improvement exists (Figure 2).

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Figure 2. Example of how speedometer charts are incorporated into the 'Results' sheet, visualising scores achieved from least (dark grey) to best (dark green) possible score distribution for the relevant area, with the black lines pointing towards scores achieved. The top speedometer chart labelled 'Biodiversity Factor' reflects the overall biodiversity score achieved, with the speedometer charts below showing scores achieved per category: (1) Building-integrated vegetation extent, (2) minimising human impact, (3) building-integrated vegetation system, (4) management and education, (5) building-integrated vegetation quality.

Stage 7: Test NZBF-B application methodology on mock example. To ensure that the NZBF-B's underlying calculations and process of data entry work as intended, mock data were entered into the 'Worksheet'.

2.2. Building Rating Scheme Case Study

The lead author compared the characteristics within the NZGBC "Green Star NZ Buildings v.1" assessment to those in the NZBF-B tool and classified these as (a) reflected, (b) partially reflected, and (c) not reflected (NZBF-B characteristic is absent).

A characteristic was classified as "reflected" if the respective NZBF-B characteristic is fully mirrored in the "Green Star NZ Buildings v.1" assessment, and "partially reflected" if the respective NZBF-B characteristic theme is mirrored in the "Green Star NZ Buildings v.1" assessment, but specificity is lacking in terms of specific ecological recommendations that would enhance biodiversity. A characteristic was classified as "not reflected" if the respective NZBF-B characteristic is not present in the "Green Star NZ Buildings v.1" assessment.

3. Results

While the NZBF-B creation process mirrors that of GardenStar [57] and the NZBF-R [56], its overall components, scale of application, spatial application, targeted end-users and expert composition during the weighting process differed (Table 2).

The Results section first outlines the final tool components and respective category weights (Sections 3.1 and 3.2), then describes how the finalised tool works in practice (Section 3.3) and finally describes the results of the comparison with the building rating scheme Green Star NZ Buildings v.1 (Section 3.4). The components of the finalised tool are visualised in Figure 3.

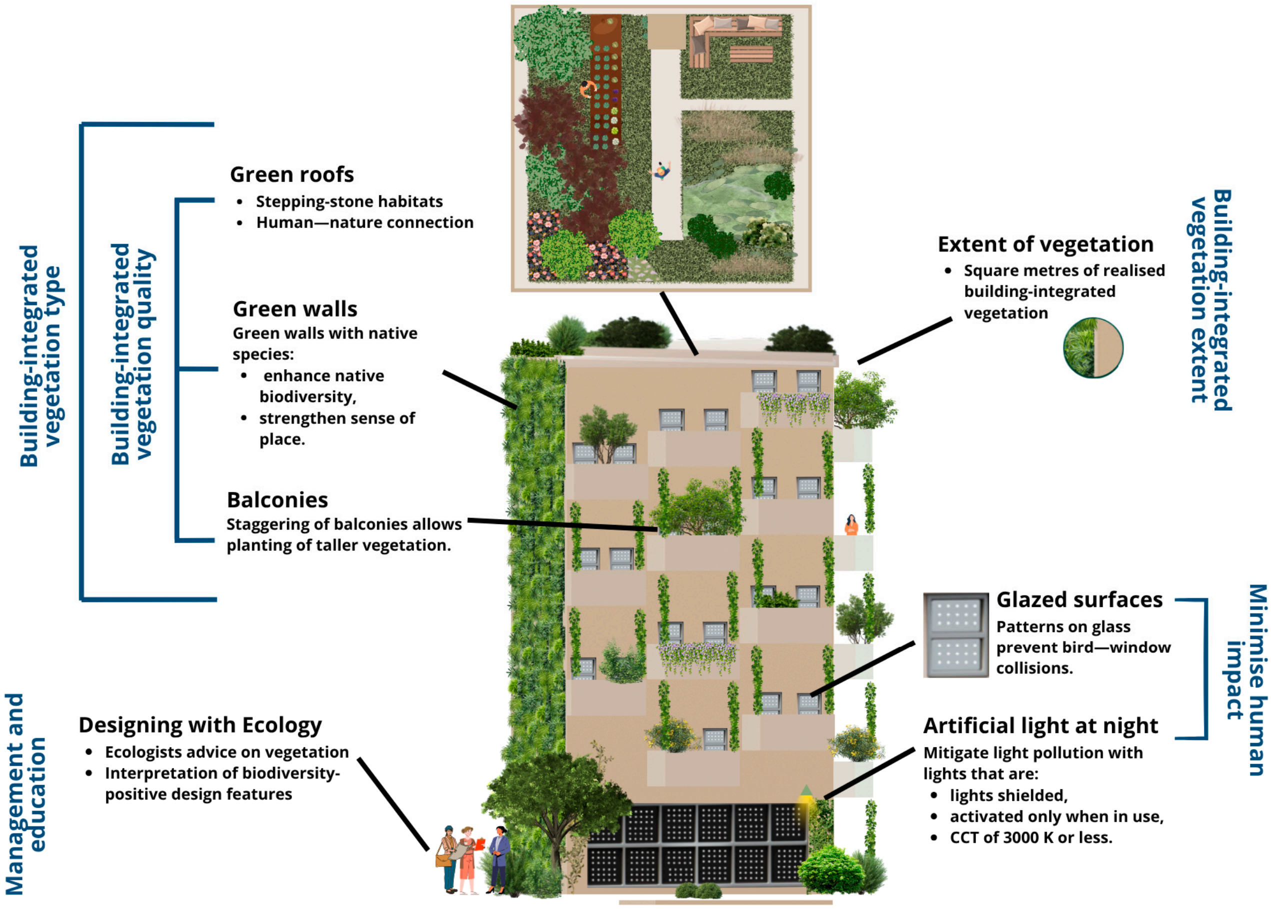

Figure 3. Components of the NZBF-B that enhance biodiversity, with category names (dark blue) and their components where applicable (black text).

Table 2. Broad differences between GardenStar, NZBF-R and NZBF-B that warranted the creation of a new framework.

	GardenStar [57]	NZBF-R [56]	NZBF-B
Categories	(1) Habitat extent (2) Habitat quality (3) Habitat management (4) Habitat context	(1) Permeable area extent (2) Street features (3) Vegetation	(1) Building-integrated vegetation extent (2) Minimising human impact (3) Building-integrated vegetation system (4) Management and Education (5) Building-integrated vegetation quality
Scale of application	Individual residential property scale	Landscape/urban residential development scale	Building scale
	Private gardens	Private gardens, kerb-side planting, public parks, restoration, open spaces	Building-integrated vegetation (building-integrated podium, green façades, green roof, green walls, rooftop garden)

Table 2. *Cont.*

	GardenStar [57]	NZBF-R [56]	NZBF-B
Spatial application	Horizontal	Horizontal	Vertical and building-integrated
Target users/end-users	Homeowners	Urban developers, planners, architects, landscape architects, councils, urban designers	Architects, developers, designers, building professionals
Expert composition	Plant & animal ecology, landscape architect	Plant & vertebrate ecology, entomology, geography, urban ecology, zoology	Architecture, plant & vertebrate ecology, entomology, geography, landscape planning, urban design, urban ecology

3.1. NZBF-B Characteristics for Each of the Five Main Categories

The initial stages resulted in the NZBF-B's focus on three main ways in which building envelopes can contribute to urban biodiversity (the inclusion of green walls, green façades and green roofs), and the inclusion of 53 characteristics across the five high-level NZBF-B categories (Table 3). In total, 127 journal articles were consulted.

Table 3. NZBF-B characteristics in each of the five categories, the reason for characteristic inclusion, and its relation to the five biodiversity-sensitive urban design principles, where 1 = maintain and introduce habitat, 2 = facilitate dispersal, 3 = minimise threats and anthropogenic disturbance, 4 = facilitate natural ecological processes and 5 = improve potential for positive human–nature connections.

NZBF-B Characteristic	NZBF-B Category	Reason for Inclusion	BSUD Principle
Total m^2 of surfaces that, in theory, can be greened	Building-integrated vegetation extent	Designing a building that has physical structures onto which green installations can be incorporated is important for habitat provision.	1, 2
Lighting: Shielding provision	Minimising human impact	When lighting is installed using shielding, the light is directed into the ground where it is most needed, lowering light pollution. Lowering light pollution, especially at night, is imperative for invertebrate conservation [62–64].	3
Lighting: Colour	Minimising human impact	The lower the Correlated Colour Temperature (CCT), the less disruptive the light is to fauna, particularly to their circadian rhythms [63].	3
Lighting: Duration	Minimising human impact	Lighting installed with motion detectors or timers reduces light pollution to the times when it is needed.	3
Windows: Avoiding through-vision	Minimising human impact	Placing windows or glass features opposite each other (i.e., windows in walls directly opposite) leads to through-vision, allowing birds to see through both panes. Through-vision increases the risk of bird–window collisions [65].	3
Windows: Avoiding reflective glass	Minimising human impact	Birds do not understand glass as a barrier to their dispersal [66]. Reflective glass, especially when reflecting nearby habitat like trees, is a risk for bird–window collisions [67]. It is therefore advised to avoid reflective glass on buildings.	3
Windows: Application of bird–window collision deterrents	Minimising human impact	The following deterrents have been found successful in preventing bird–window collisions: applying dots or other markers spaced no more than 5 cm apart, sticker-based vertical or horizontal lines, or securely fixed hanging cords [66,68,69].	3
Transport: Building encourages sustainable transport options, such as bike storage or electric vehicle charging stations	Minimising human impact	Sustainable transport options reduce environmental impacts, such as noise and air pollution. Providing facilities such as secure bike storage, for instance, may increase the likelihood that residents/employees choose cycling over driving their cars. Biking activity can also increase the human–nature connection.	3

Table 3. *Cont.*

NZBF-B Characteristic	NZBF-B Category	Reason for Inclusion	BSUD Principle
Wildlife enhancement: Native nectar-producing plants	Minimising human impact	The provision of native nectar-producing plants will be beneficial to (native) species as a food resource [70,71].	3, 4
Wildlife enhancement: Wētā motels	Minimising human impact	Wētā motels can attract wētā and other insects and offer refuge [72,73]. Depending on placement and types of surrounding vegetation, different wētā species and other invertebrates may be attracted [72].	1, 3, 5
Wildlife enhancement: Rock piles	Minimising human impact	Rock piles are a common practice to create habitat for some species of lizard [74,75].	1, 3
Wildlife enhancement: Dead wood/log features	Minimising human impact	Dead wood or log features are important habitat to many ground-dwelling invertebrate species and lizards [74,76,77].	1, 3
Wildlife enhancement: Gabion structures	Minimising human impact	If some type of retainment wall is needed, the use of gabion structures, where applicable, is advised as these can act as a refuge for herpetofauna [78].	1, 3
Wildlife enhancement: Predator control	Minimising human impact	Eliminating key invasive predators in New Zealand, specifically targeting mustelids (ferrets [*Mustela furo*], stoats [*Mustela erminea*], weasels [*Mustela nivalis*]), rats [*Rattus* spp.] and possums [*Trichosurus vulpecula*]) as well as stray and feral cats (*Felis catus*) is crucial to protect NZ native species [79,80].	3
Balconies: Presence/absence	Building-integrated vegetation system	Balconies can be used for urban greening and thus introduce not only faunal habitat, but also strengthen the human–nature connection [81–83].	1, 2, 3
Balconies: Installed in staggered fashion	Building-integrated vegetation system	Designing buildings with staggered balconies (balconies are offset rather than directly above/beyond each other) is beneficial as plants can grow to taller height due to less obstruction vertically [84].	1, 2, 5
Exterior green wall: Presence/absence	Building-integrated vegetation system	Green walls, also referred to as living walls [85,86], are building-integrated wall vegetation that can support a vast array of low-growing plant species. The presence of green walls is linked to the attraction of faunal species, possibility of pollinator habitat creation, improved aesthetic value, improved air quality and reduced noise [87–90].	1, 3, 5
Exterior green wall: Type (continuous, modular)	Building-integrated vegetation system	Modular green walls are perceived as more valuable to boost biodiversity as the amount of soil or other growing medium present in modular systems allows for greater root expansion [37]. Continuous green walls consist of absorbent screens with pockets, such as felt, and do not require soil expansion [37].	1, 3
Exterior green façade: Presence/absence	Building-integrated vegetation system	Exterior green facades are vertical greening systems of upward climbing plants on a building's exterior wall [37]. They are rooted either directly in the ground or in planter boxes installed at different height levels. Adding vegetation in the form of green façades can contribute to biodiversity.	1
Exterior green façade: Type (direct/indirect)	Building-integrated vegetation system	Green façades are installed either directly on the wall surface or indirectly supported by structures such as trellises or cables. Indirect green facades allow air to circulate between the wall and the plants, which is beneficial to both the plant health and the building wall itself [37].	1, 2
Exterior green walls and exterior green façade: Installed below or at eye level	Building-integrated vegetation system	To strengthen the human–nature connection and enhance wellbeing benefits, it is recommended that the green wall and/or green façade, or at least part of it, begins at eye level so that people can easily notice and appreciate the plants [91]. The presence of vertical building-integrated vegetation has the potential to further aid the increase in beneficial aerobiomes [91,92].	5

Table 3. *Cont.*

NZBF-B Characteristic	NZBF-B Category	Reason for Inclusion	BSUD Principle
Interior green walls and/or green façades: Presence/absence	Building-integrated vegetation system	Visible vegetation can strengthen human–nature connections and increases self-perceived wellbeing [93,94].	5
Interior vegetation: Dominated by native species	Building-integrated vegetation system	Native species are linked to the creation of a sense of place, strengthening the human–nature connection [47].	5
Green roof: Presence/absence	Building-integrated vegetation system	Green roofs are a good stormwater and climate mitigation strategy and can provide valuable habitats for fauna [75]. If located near green infrastructure or natural habitats, green roofs can act as stepping stones [95,96].	1, 2, 3, 4
Green roof: Type (extensive, semi-intensive, hybrid, intensive)	Building-integrated vegetation system	The deeper the soil depth on a green roof, the greater the opportunities to install various vegetation height layers [75].	1, 2, 3, 4
Rooftop garden and/or building-integrated podium: Presence/absence	Building-integrated vegetation system	Rooftop gardens designed for growing food crops and/or relaxations can encourage spending time outdoors.	5
Vegetation visibility to public and inhabitants	Building-integrated vegetation system	Viewing vegetation while walking and viewing out the window is linked to positive mental and physical wellbeing impacts [93,97,98].	5
Design, selection and installation of vegetation conducted by, or through help with, trained plant ecologists	Management and education	Plant ecologists are trained professionals with extensive understanding and knowledge about local environment–plant–animal interactions. Engaging plant ecologists to guide the installation of building-integrated vegetation will ensure the right plants are chosen for desired biodiversity outcomes.	1, 2, 3, 4
Eco-sourcing of vegetation	Management and education	Genetic diversity across cultivars for common native plant species tends to be low [99]. Eco-sourcing, especially in combination with knowledge of genetic variation within source populations, can mitigate low genetic diversity outcomes [99].	4
Vegetation: Showcasing seasonal changes to help people observe natural cycles	Management and education	Observing seasonal plant and wildlife changes, such as the emergence of invertebrates like butterflies or bumble bees can aid in strengthening the human–nature connection [100].	4, 5
Education: Building features information on building-integrated vegetation features, chosen plant species and their ecological function	Management and education	Noticing nature and education about environmental concepts ARE linked to an increased human–nature connection [101].	5
Native vegetation	Building-integrated vegetation quality	The planting of native vegetation is linked to increased microbiomes in the soil [102]. Native vegetation is linked to the attraction of native fauna [70,103,104]. The presence of native species aids in the creation of a 'sense of place' and increased human–nature connection [47].	1, 2, 4, 5
Non-native vegetation	Building-integrated vegetation quality	Non-native vegetation can support natural ecological processes, such as pollination [105–107], dispersal opportunities as well as habitat [54,108,109]. It is important to note that in some instances non-native species can become invasive; ecologists can assist in navigating this. It is further suggested to manually manage pest weed species.	1, 2, 4
Flowers	Building-integrated vegetation quality	Flowering plant species attract a variety of pollinators, with native flowering plants being preferred by native pollinators [70].	2, 4
Ground vegetation	Building-integrated vegetation quality	The planting of ground vegetation increases habitat niches for ground-dwelling invertebrates [110,111].	
Diverse vegetation height layers in one space	Building-integrated vegetation quality	Vegetation of varying height layers in any given space increases habitat provision, food resources and nesting sites [51,52,112].	1, 2, 3, 4

3.2. NZBF-B Weightings

The weighting exercise (Stage 5) resulted in the following high-level category weightings: "Building-integrated vegetation quality" category (weight = 23.6, mean = 8.96, SD = 1.21), "Management and Education" category (weight = 20.7, mean = 7.86, SD = 1.70), "Building-integrated vegetation extent" (weight = 20.5, mean = 7.76, SD = 2.20), "Building-integrated vegetation system" (weight = 18.3, mean = 6.96, SD = 1.53), and "Minimising human impact" (weight = 16.9, mean = 6.43, SD = 2.40).

3.3. NZBF-B Application Methodology

The interface to use the tool includes a series of questions covering five categories as outlined below. For a complete list of characteristics of all categories see Appendix B. The detailed scoring methodology is outlined in Appendix C.

"Building-integrated vegetation extent" This is calculated from measurements of the total exterior wall surface area (m^2), excluding windows, transparent walls, external doors, as well as the total surface area (m^2) of the building's roof. The tool then subtracts 15% of the combined sum (wall surface area + roof) for potential fixtures to gain the maximum possible coverage (m^2) for building-integrated vegetation extent. The assessor then estimates the total area that is covered by vegetation to identify the percentage of the maximum possible building-integrated vegetation extent score achieved.

"Minimising human impact" is divided into four sub-categories, lights, windows, transport and wildlife enhancements, covering characteristics that can mitigate negative impacts on wildlife, such as exterior light specifications, window specifications to mitigate bird–window collisions, and wildlife enhancement strategies that can be incorporated into the building envelope to increase habitat availability and reduce impacts of invasive species. The assessor is asked to answer questions with simple "yes" or "no" answers. The total points achieved are expressed as a percentage of the maximum possible score of 18 points.

"Building-integrated vegetation system" is divided into seven sub-categories: balconies, exterior green walls, exterior green façades, interior green walls and interior green façades, green roof, rooftop gardens, and vegetation visibility. These are scored as above, with a maximum possible score of 22 points.

"Management and Education" consists of eight questions, three of which relate to educational content displayed around the building interior, and five of which relate to the planting and ongoing maintenance of installed vegetation. The employment of qualified plant ecologists to ensure genetic diversity and the selection of plants suitable to the respective ecosystem is also suggested. These are scored as above, with a maximum possible score of eight points.

"Building-integrated vegetation quality" captures the quality of the novel building-integrated vegetation habitat and is divided into two sub-categories: (1) building-integrated external wall vegetation and (2) building-integrated external roof vegetation. Vegetation characteristics include three vegetation height layers, adapted from [113]: ground covers (including native vs. exotic vegetation below 30 cm height), shrub layer 30 cm–2 m height (native vs. exotic origin), shrub/tree layer of above 2 m height (native vs. exotic origin). To determine the m^2 taken up per plant species once mature, the maximum plant species width is taken from planting plans and entered into the NZBF-B calculation aid, which is incorporated into the tool. It applies the following formula:

$$\text{Plant species area} = \pi * (\frac{\text{plant width}}{2})^2$$

The total points achieved for the "Building-integrated vegetation quality" are expressed as a percentage of the maximum possible score of 95 points, which was arrived at by considering an empty intensive green roof plot, which was then filled with those vegetation features that had the highest weightings in the NZBF-R [56] and were deemed important to biodiversity in the literature review phase. A detailed explanation is outlined in Appendix C.

3.4. NZBF-B Expert Feedback and Tool Refinement

Key concerns in the feedback received from experts involved in the weighting exercise (Appendix A, Table A4) included the potential lack of future stewardship, the importance of landscape context, landscape connectivity, and the need for qualified ecological professionals, while recognising that many landscape architects are skilled at planting planning in relation to built environmental constraints. One additional characteristic was incorporated: 'Will trained plant ecologists be responsible for the design, selection and installation of the planting? Alternatively, will trained plant ecologists be partnered with qualified horticultural practitioners?' For details about expert comments, their implications for NZBF-B and our responses, refer to Appendix D, Table A3.

3.5. Building Rating Scheme Case Study

The comparison of the characteristics of the NZBF-B to the "Green Star NZ Buildings v.1" rating tool indicated that in total, 15 out of 34 NZBF-B characteristics were not reflected in the Green Star tool, 10 out of 34 were partially reflected, and nine out of 34 NZBF-B characteristics were reflected (Appendix E, Table A4). This comparison shows that even when progress is being made, key features are still not represented and the use of the NZBF-B in parallel to Greenstar NZ Buildings v.1 is warranted.

4. Discussion

Here we have outlined the creation of the NZBF-B, a tool designed to assess the potential biodiversity value of individual buildings, and to provide a practical and accessible way for built-environment professionals to explore how a building can be improved for biodiversity. The NZBF-B fills an important gap in the focus of currently available evaluation tools, which generally aim at holistic sustainability achievements and consider biodiversity only at a very broad-scale, overlooking opportunities for ecologically meaningful biodiversity enhancements. Given that buildings sit within a wider landscape context, and the biodiversity benefits at the scale of a building will be related to features of the surrounding neighbourhood, we recommend that the NZBF-B be applied in combination with a tool that evaluates biodiversity in the built environment at the neighbourhood scale, such as the New Zealand Biodiversity Factor—Residential [56]. Our comparison of the NZBF-B with a building rating tool in use in Australia and Aotearoa New Zealand identified a number of biodiversity characteristics that are not considered by the existing certification process. We therefore recommend that for individual building construction projects, the NZBF-B should be applied in parallel to existing sustainable building rating schemes, like Greenstar NZ, to ensure that buildings certified as '6 star', 'sustainable' or 'living' genuinely deliver positive biodiversity outcomes as well as those relating to sustainable or regenerative design.

4.1. Comparison of Biodiversity Provision in Green Star NZ Versus NZBF-B

Our comparison of "Green Star NZ Buildings v.1" and the NZBF-B revealed differences in how biodiversity potential is addressed. "Green Star NZ Buildings v.1" assesses the greenery that is or will be installed, without rating it against a maximum potential scenario. While the NZGBC lists a total of eight high-level categories to which projects should aspire to, the lack of a maximum potential scenario may limit the rating scheme's ability to motivate end-users to fit buildings with building-integrated vegetation. Without actively designing and encouraging building envelopes to make room for building-integrated vegetation systems, the BSUD principles cannot be accomplished. In contrast, the NZBF-B computes the maximum amount of greenery that potentially could be realised on the building (based on surfaces available for vegetation) and treats it as the maximum possible score against which performance is assessed. This is in line with existing green factor tool principles, which base their calculations on the proportion of green, i.e., surfaces that allow vegetative growth, versus grey impermeable surfaces [26,56,57,114,115].

The stated goal of "Green Star NZ Buildings v.1" is to aspire to "World Leadership", which corresponds to a six-star rating. Historically, buildings have been able to receive such a rating without incorporating vertical or horizontal building-integrated vegetation. This is because the creation of habitat for flora and fauna is not treated as a core component of world-leading performance [116]. While the "Green Star NZ Buildings v.1" is set to replace the former "Green Star Design & As Built v 1.1.1" version and places a greater focus on biodiversity provision, habitat creation under current changes to the framework can still be achieved without vegetation integrated on buildings themselves.

Although "Green Star NZ Buildings v.1" does encourage vertical greenery in landscape design choice, the newly introduced minimum landscaping requirements in the updated version can be achieved through horizontal ground-level landscaping on the development site [61], provided the development site is large enough. Only when the site is too small are green installations required on the building itself. The incorporation of vertical building-integrated vegetation systems is important beyond the creation of habitat and has the potential to also positively influence human wellbeing. A view of green walls, for instance, is linked to enhanced academic performance [117,118], and green window views lead to shorter hospital stays [97] as well as greater wellbeing among office employees [93]. Installing interior and exterior green walls and green façades where both inhabitants and passersby can view vegetation is beneficial beyond the creation of viable habitat.

In "Green Star NZ Buildings v.1" as well as the NZBF-B, native vegetation is weighted as more important than non-native vegetation. Green Star also requires pre- and post-development assessment of ecological value. Vegetation, water and surface characteristics present are weighted and must be entered in square metres (m^2), similar to the NZBF-B. However, structural diversity of vegetation is not considered, whereas the NZBF-B includes the assessment of vegetative height categories, which has long been known to increase habitat niches for flora and fauna [51,52,112].

Unlike the NZBF-B, "Green Star NZ Buildings v.1" does include a category on species and habitat connectivity. To meet the requirements of the NZGBC connectivity components, the development must either include certain infrastructure specifications or include a landscaped area of at least 182 m^2. However, no guidance is provided in Green Star on which kind of green roofs (i.e., intensive or extensive) or green façades (i.e., direct or indirect) may be more beneficial to biodiversity. The absence of such guidance limits the tool's ability to guide end-users in supporting ecological outcomes. Many of the suggested infrastructure specifications made in that category to boost connectivity are already incorporated in the NZBF-B through characteristics such as the installation of green roofs. Intensive green roofs, for instance, are especially beneficial to biodiversity as they allow the greatest substrate depth, when compared to semi-intensive and extensive green roofs, thus offering the opportunity for the planting of shrubs and trees [75]. A recent study in Córdoba, Argentina, showed that deeper soil depth on green roofs was positively correlated with arthropod richness [44], while in Paris, France, it plays an important role in pollinator attraction [119]. The choice of flowering plant species to attract pollinators to green roofs is equally important, with plant species of native origin showing greater attraction of pollinators such as those belonging to the Hymenoptera (i.e., bees, wasps) or Diptera (flies) [120].

The new "Green Star NZ Buildings v.1" version has improved the inclusion of habitat provisioning: for instance, a new requirement is the provision of one nesting site or one type of habitat per 250 m^2 of landscaped area (Exceptional Performance) or per 500 m^2 (Credit Achievement). In line with the NZBF-B, "Green Star NZ Buildings v.1" requires the employment of trained ecologists for managing and assessing planned landscaping, which will have positive impacts on biodiversity provision. It has long been understood that ecologists offer in-depth scientific understanding of ecosystem functioning [121]. Yet the employment of ecologists in urban spaces is a reasonably recent process [122,123]. Incorporating professional ecological knowledge into building envelopes is now more important than ever to ensure that knowledge gaps are effectively covered [124]. This is particularly critical when the goal is to represent native ecosystems in meaningful and ecologically appropriate ways, in the oftentimes harsh and altered landscapes associated with human-made structures such as buildings.

Mitigation strategies for bird–window collisions are not considered in Green Star NZ Buildings v.1 and extensive glazing is not discouraged. While certain types of glazing solutions are deemed a low-impact solution on carbon emissions and thus are labelled "sustainable", these not only offer no opportunity to incorporate building-integrated vegetation systems, but they also are the leading cause of bird–window collisions in highly built-up cities [65,68,125]. The "Building-integrated vegetation extent" category in the NZBF-B penalises end-users for building designs that offer little opportunity to incorporate greenery by calculating the maximum possible square metres of building-integrated vegetation available. Should the building be designed to consist of predominantly glazed surfaces, the possibility of bird–window collisions can still be minimised. In the United States alone, it is estimated that between 365 and 988 million birds die every year through the impact of bird–window collisions [126]. The application of dots or markers across the full window surface at regular intervals has proven successful in mitigating bird–window collisions [66,67]. Bird–window collisions can also be prevented by not placing glazed surfaces directly opposite to each other, as that breaks "through vision". If glass is chosen for the design, it should be non-reflective, especially when the building is surrounded by natural landscapes, such as trees, as birds may mistake the reflection for real habitat [127].

4.2. Expert Weighting and Feedback

Agreement by experts that the "Building-integrated vegetation quality" category was most important to urban biodiversity was relatively strong. This is unsurprising given the important role that good-quality vegetation of differing heights and species plays in supporting habitat and food resource provisioning for fauna [51,103,128], in line with BSUD principle (1), which is to maintain and introduce habitat, and (2), which is to facilitate dispersal.

The moderate agreement in weighting strength for "Management and Education" and "Building-integrated vegetation system" may reflect the differences in respective sector backgrounds and expertise of chosen experts. For instance, those predominantly focused on nature-based solutions and architecture rated the "Building-integrated vegetation system" slightly higher than those experts not directly involved in architecture. Differences in the opinions of built-environment professionals and environmental scientists and researchers with regard to carbon sequestration and habitat provisioning through building design are known to exist, emphasising the value of engaging biologists and experts along with architects and landscape designers during the pre-design phase to more effectively implement the provision of ecosystem services into architecture [129]. The "Building-integrated vegetation extent" and "Minimising human impact" categories had the highest degree of disagreement. Unlike the antecedent tools, the extent to which space is available for vegetation was not deemed to be one of the most important contributors to urban biodiversity. This finding may reflect differing perspectives around the value of viable vertical habitats when compared to ground-level interventions. Notably, there were no clear patterns with respect to expert disciplines and scores for “Building-integrated vegetation extent” or “Minimising human impact”. The “Minimising human impact” category is directly linked to BSUD principle (3), which is to minimise threat and human disturbance.

These findings highlight the importance of multi-disciplinary collaboration at the pre-design phase of a building project. The absence of clear patterns in the extent to which categories were valued by experts with differing knowledge indicates that experts’ disciplinary backgrounds do not explain these variations alone. They could be understood better in the context of the experts’ individual backgrounds, expertise, values and priorities with respect to biodiversity enhancement in urban spaces. Ecologists and environmental scientists will also develop a better appreciation of the relative efficacy of various building-integrated greening strategies as more studies on ecological outcomes are published.

4.3. Implications and Recommendations for Industry

The implementation of recommendations from green building rating schemes, while not mandatory, can have long-lasting, positive impacts on urban ecosystem health and biodiversity outcomes, especially if applied widely. If connectivity across urban landscapes for flora and fauna is the goal, the consistent use of tools that primarily focus on biodiversity such as the NZBF-B, in parallel to tools that have a more encompassing approach, such as the Living Building Challenge or Green Star NZ, can aid in achieving a holistic approach to urban ecosystem health and resilience. The use of the NZBF-B can assist urban building professionals to incorporate meaningful habitat into vertical and above-ground spaces, thus complementing ground-level greenspace operations and transforming vertical structures into viable stepping-stone habitats that facilitate dispersal across the anthropogenic landscape. Buildings are key components of the urban landscape and can be designed to positively contribute to urban ecological networks. Past studies have shown that buildings, when designed with ecologically meaningful goals in mind, not only contribute to city-wide biodiversity, but also host species assemblages that differ to those on the ground. In a recent study undertaken in Zürich across 52 extensive green roofs, each of which was paired with a nearby and ground-level habitat, Perrelet and colleagues [130] found that merely 10% of invertebrate species were shared between the habitat types, showing that buildings, if designed right, increase biodiversity and are an important component of the urban ecological network.

Current practice often overlooks the importance of building-integrated habitat as a core principle to enhance and accommodate biodiversity across the urban matrix, and focuses on the provision of habitat in general on the scale of the development site [30,61]. This approach limits habitat creation and connectivity opportunities; industry professionals should consider integrating habitat on buildings themselves, to create viable stepping-stone habitats. For example, a recent spatial analysis undertaken in the city centre of Wellington, New Zealand, found that habitat connectivity for some native avifauna could be achieved if only 9% of buildings were fitted with green roofs [34]. Focusing on the establishment of habitat on buildings will help address current criticism on branding buildings as ‘green’ when they are using building materials that may be classed as sustainable, but the building design does not integrate biodiversity, and may even include problematic features such as highly glazed façades [31]. The NZBF-B can support an approach that treats biodiversity as a fundamental requirement.

In a recent survey analysing NZ contractor limitations, 40% of respondents indicated that current Green Star NZ tools are not adequately tailored to the New Zealand context [22].

While the NZBF-B is tailored to the New Zealand context specifically, it can be adjusted to more closely align with region-specific situations. For example, the integration of artificial refuges into building envelopes, such as specifically designed bird boxes in Poland [131] and Germany [132], are strategies not recommended in Aotearoa New Zealand where the most likely occupants of nest boxes would be common introduced species, and even if native cavity-nesting birds were to use them, they are likely to fall prey to introduced predators [133]. However, for other regions such as Europe or the United States, the addition of strategies such as bird boxes and the removal of others such as wētā motels could be effected to ensure ecological relevance. While the weightings applied to vegetation categories are based on the international literature, in situations where native species are not valued over introduced species, new weighting exercises would have to be carried out. Regional differences in climate are also likely to influence the type and amount of vegetation a building could feasibly support; for this reason it is not appropriate to directly compare such scores; however, within-region scores are still comparable and the principles of the tool still apply across all regions.

4.4. Limitations and Future Research Directions

There are limitations to this study which inform future research directions. First, the NZBF-B has yet to be validated using empirical data. The primary aim of this paper is the description of the multi-stage creation process and the principles underlying each included characteristic; however, confidence in the NZBF-B is contingent on its successful application to real-world building projects. The next step is to apply the NZBF-B across a range of building types in different cities and follow this up with long-term ecological monitoring of a range of ecological processes and taxa, in order to determine whether the ecological objectives of the building projects had been achieved.

Second, the literature on the biodiversity outcomes of the various greening strategies in the NZBF-B is still relatively sparse across the range of taxa, for the range of greening strategies, and more long-term ecological surveys are necessary to provide evidence that supports the inclusion of the characteristics in the NZBF-B.

Third, the NZBF-B does not include a section that measures ecological landscape connectivity; however, it does directly measure features that serve as indicators to landscape connectivity, based on the literature that links them to the facilitation of species dispersal and movement [58]. The NZBF-B does not predict ecological success of dispersal, but measures and assesses features that are known to do so. Future ecological studies focused on species movement and dispersal across urban landscapes in relation to specific greening strategies on buildings, and long-term ecological surveys on buildings rated with the NZBF-B would provide stronger support for their contribution to this ecological process.

Fourth, the expert weighting exercise is based on expert judgement which is inherently linked to subjective scoring. To mitigate this, the weighting exercise drew on a pool of experts with experience spanning multiple ecological and built-environment contexts across Aotearoa New Zealand and Australia. To reduce the influence of any single disciplinary perspective, the process incorporated participants from multiple fields related to ecology, architecture, planning, urban biodiversity, and implementation practice. Participants included researchers and practitioners with expertise in regenerative design, biodiversity-integrated architecture, building-integrated vegetation, urban ecology, environmental planning, sustainable architecture, bird–window collision mitigation, and people–environment relations. Collectively, these experts had experience across a range of building typologies and urban conditions, including residential, institutional, commercial, and public realm projects. While the study did not explicitly recruit participants according to socioeconomic upbringing, within Aotearoa New Zealand, architecture and built-environment education is delivered only through publicly funded universities, with relatively limited institutional stratification compared with contexts characterised by strong distinctions between elite private and public institutions, such as in the USA. Consequently, socioeconomic background was not considered a primary differentiating factor for expertise relative to this study in biodiversity factors in the built environment. Nevertheless, we acknowledge that expert-based weighting processes inevitably reflect the disciplinary perspectives, regional experiences, and professional priorities of participants. The resulting weightings should therefore be understood as informed and context-dependent assessments rather than universally fixed or 'quantifiably true' values. Future iterations of the tool may further strengthen inclusivity and transferability by incorporating a wider range of regional, cultural, and practice-based perspectives, but we have strong confidence that this would not change the weightings of criteria to a large degree.

4.5. Challenges to the Implementation of Building-Integrated Vegetation

There are many barriers to the uptake of greening strategies on buildings, including (a) structural and load-bearing concerns, especially when buildings are retrofitted with building-integrated vegetation such as green roofs [134–136]; (b) high initial and ongoing costs involved in implementing and maintaining building-integrated vegetation and structures [22]; (c) long-term vegetation maintenance which requires complex irrigation systems, specialised knowledge and labour [22,135,136]; (d) a lack of requirements in local and national policy and planning regulations [129]; (e) a lack of financial incentives for developers; (f) a lack of precedent buildings to follow [129] and a lack of coordination and communication between different stakeholders and different design and construction-related disciplines [129]; (g) a lack of plants available, and/or excessive focus on a few high-profile species [136]; and (h) limited awareness and/or knowledge [136]. After examining examples of successes and failures, Terblanche [136] identified the following key determinants of the success of green infrastructure: thorough structural assessments to ensure load-bearing capacity appropriate for the climate of the region; proper drainage systems to avoid structural collapse, erosion and plant mortality; and specialised maintenance to ensure long-term longevity and functionality, as well as selection of appropriate plants and substrate design for the climate [137]. However, information on plant suitability is often lacking [138,139].

While these factors ultimately determine the uptake of greening strategies, the NZBF-B serves as a supportive biodiversity assessment tool that, once the decision has been made to incorporate greening strategies, can guide positive biodiversity outcomes rather than serving as an implementation feasibility or cost-modelling tool. Future research should explore potential strategies to solve these barriers and explore the extent to which tools like the NZBF-B may motivate end-users and interact with existing incentives to facilitate the adoption of greening strategies.

5. Conclusions

While some sustainability targets are integrated into current building design and construction projects, particularly in those that engage with sustainable building rating tools, gaps remain regarding biodiversity considerations [30]. In their review, Kiss et al. [30] identified that most sustainable building rating tools do not include biodiversity objectives and solely allocate a small proportion of maximum achievable points to biodiversity. The New Zealand Biodiversity Factor—Building (NZBF-B) was created to address this gap. Designed to be used in parallel to existing green building rating schemes, the NZBF-B assesses the biodiversity value of building designs specifically and in detail. With urban densification increasing across commercial and residential sectors, resulting in developments designed to support vertical, high-density working and living, it has never been more important to incorporate biodiversity into buildings. Doing so will support habitat provision for wildlife, mitigate the fragmentation of urban landscapes, and create opportunities to strengthen human–nature relationships through architectural design.

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Abbreviations

The following abbreviations are used in this manuscript:

BREEAM	Building Research Establishment Environmental Assessment Method
BSUD	Biodiversity Sensitive Urban Design
LEED	Leadership in Energy and Environmental Design
NZ	New Zealand
NZBF-B	New Zealand Biodiversity Factor—Building
NZBF-R	New Zealand Biodiversity Factor—Residential
NZGBC	New Zealand Green Building Council

Appendix A. Expert Details

The weighting exercise for the NZBF-B categories. Twenty-one experts took part in the weighting exercise.

Table A1. Details of experts that took part in the weighting exercise.

Expert	Area of Expertise	Affiliation	Building Type	Professional Sector	Ecological Region
Expert 1	Plant evolutionary ecology, plant niches and diversification	Department of Botany, University of Otago, Dunedin, New Zealand	N/A	Academia	Southern NZ temperate ecosystems; plant diversification across climatic gradients globally.
Expert 2	Urban restoration ecology	Tonkin & Taylor Australia/New Zealand.	N/A	Environmental & Engineering Consultancy	Wellington urban temperate forests (lower North Island coastal urban environment).
Expert 3	Native bee ecology, social invertebrate behaviour	Department of Zoology, University of Otago, Dunedin, New Zealand	N/A	Academia	Cross-regional. NZ temperate ecosystems. Urban—agricultural—natural environments.
Expert 4	Entomology, biocontrol, pest management	Bioeconomy Science Institute, Invermay, Dunedin, New Zealand	N/A	Public Research Organisation	NZ pastoral grassland and agro-ecosystems; temperate grassland ecosystem.

Table A1. *Cont.*

Expert	Area of Expertise	Affiliation	Building Type	Professional Sector	Ecological Region
Expert 5	Urban ecology, entomology	Ecology Programme, Department of Zoology, University of Otago, Dunedin, New Zealand	N/A	Academia	Southern NZ urban to temperate ecosystems.
Expert 6	Conservation biology, species restoration, reintroduction biology	Department of Zoology, University of Otago, Dunedin, New Zealand	N/A	Academia, Applied conservation	NZ national scale terrestrial ecosystems
Expert 7	Biodiversity-incorporated architecture, human factors and ergonomics	Auckland University of Technology, Auckland, New Zealand	All building typologies.	Academia	NZ wide urban ecosystems; nature based solutions
Expert 8	People-environment relations, planning for biodiversity	Faculty of Architecture and Urban Design Innovation, Victoria University of Wellington, New Zealand	N/A	Academia	NZ wide urban ecosystems; nature-based solutions
Expert 9	Urban ecology, predators on urban wildlife, human-wildlife interactions	Department of Zoology, University of Otago, Dunedin, New Zealand	N/A	Academia, Applied conservation	NZ wide urban ecosystems; NZ coastal temperate ecosystems.
Expert 10	Biodiversity, conservation, ecological restoration	University of Auckland, Auckland, New Zealand	N/A	Academia, Applied conservation	NZ wide urban ecosystems.
Expert 11	Bird window strikes	Save the Kiwi charity, Takapuna, Auckland, New Zealand	High-rise building typologies, urban residential, urban commercial.	Conservation NGO	Urban ecosystems (NZ temperate and Southeast Asian tropical).
Expert 12	Climate change and vegetation, ecological variation in space and time	Department of Geography, University of Otago, Dunedin, New Zealand	N/A	Academia	NZ temperate terrestrial ecosystem (climatic and elevational gradients).
Expert 13	Biodiversity, conservation, urban ecology	Bioeconomy Science Institute, Christchurch, New Zealand	N/A	Public Research Organisation	Restoration of NZ lowland and urban temperate forests.
Expert 14	Restoration ecology, biodiversity, plant-soil interactions, landscape architecture.	Adelaide Hills Council, Adelaide, Australia	N/A	Government	Temperate urban restorations ecosystems
Expert 15	Building-integrated vegetation, sustainable architecture	Victoria University of Wellington, Wellington, New Zealand	Urban residential, commercial, institutional. Focus on green façades, green walls, green roofs.	Academia	NZ urban-temperate build environment ecosystems
Expert 16	Native New Zealand plant ecology, vegetation changes over time	University of Auckland, Auckland, New Zealand	N/A	Academia	NZ temperate terrestrial ecosystem
Expert 17	Urban ecology, green infrastructure, landscape architecture	Design School, Discipline of Landscape Architecture, University of Western Australia, Perth, Australia	Urban residential, commercial, institutional buildings. Focus on biophilic design and green architecture.	Academia	Urban temperate ecosystems (AUS and NZ). Nature-based solutions.
Expert 18	Urban ecosystem services, green infrastructure, landscape architecture	School of Architecture and Built Environment, Queensland University of Technology, Brisbane, Australia	All building typologies. Focus on green infrastructure and nature-based solutions.	Academia	Urban temperate ecosystems (nature-based solutions).
Expert 19	Restoration ecology, human-nature interactions	Zealandia Te Māra a Tāne, Wellington, New Zealand	N/A	Conservation NGO, Academia, Applied conservation	NZ urban ecological restoration systems.

Table A1. *Cont.*

Expert	Area of Expertise	Affiliation	Building Type	Professional Sector	Ecological Region
Expert 20	Landscape ecology, urban planning and design, urban ecology	Bioeconomy Science Institute, Christchurch, New Zealand	N/A	Academia, Government	NZ temperate landscape (nature-based solutions)
Expert 21	Regenerative design, sustainable architecture	Auckland University of Technology, Auckland, New Zealand	All building typologies. Focus on green infrastructure and nature-based solutions.	Academia	Northern NZ temperate urban ecosystems

Appendix B. NZBF-B Categories and Characteristics

Category 1: Building-integrated vegetation extent

- Total area (m^2) of building's exterior walls (not including windows, externa transparent walls, external doors)
- Total area (m^2) of the building's roof.

Category 2: Minimising human impact

- Lights:
    - installed on the exterior walls of, or directly adjacent to, the building? (yes/no)
    - fitted with shielding to direct light onto the ground? (yes/no)
    - are motion detectors or timers installed, or are lights dimmed at night? (yes/no)
    - set to a correlated colour temperature (CCT) of 3,000 K or lower? (yes/no)
- Windows:
    - are windows positioned in such a way that the sky on the other side of the building can't be seen (through-vision)? (yes/no)
    - is reflective glass used? (yes/no)
    - are window wells of basement units covered? (yes/no)
- Windows: are any of the below bird-window collision deterrents applied to windows? (yes/no)
    - Dots or other markers spaced no more than 5 cm apart horizontally and vertically ('2 × 2 rule')
    - Vertical or horizontal lines (sticker-based), spaced no more than 5 cm apart
    - Hanging cords, with cords ≥0.3 cm thick, ≤10 cm apart, securely fixed, dark coloured?
- Transport: does the building encourage sustainable transport options, such as bicycle storage or electric vehicle charging stations? (yes/no)
- Wildlife enhancement:
    - Native nectar-producing plants present? (yes/no)
    - Wētā motels present? (yes/no)
    - Rock piles present? (yes/no)
    - Dead wood/log features present? (yes/no)
    - Gabion structures present? (yes/no)
    - Predator control? (yes/no)

Category 3: Building-integrated vegetation system

- Balconies:
    - Presence, and potential to incorporate greenery? (yes/no)
    - Placed in staggered fashion so plants can grow taller? (yes/no)
- Exterior green walls:

    - Presence? (yes/no)
    - Installed to start below, or at eye level? (yes/no)
    - Type: continuous or modular
- Exterior green façades:
    - Presence? (yes/no)
    - Installed to start below, or at eye level? (yes/no)
    - Type: direct or indirect?
    - Planted in ground, or planting box?
- Interior green walls and interior green façades:
    - Presence? (yes/no)
    - Is interior vegetation dominated by native vegetation? (yes/no)
    - Designed to start at, or below, the eye level? (yes/no)
- Green roof
    - Presence? (yes/no)
    - Type: extensive, semi-intensive, hybrid, intensive?
- Rooftop/communal terrace to grow own produce? (yes/no)
    - Presence? (yes/no)
- Vegetation visibility
    - Exterior building-integrated wall vegetation visible to public? (yes/no)
    - Exterior building-integrated wall vegetation visible to inhabitants of building from within their home/office? (yes/no)

Category 4: Management and Education

- Trained plant ecologists responsible for design, selection and installation of the planting? Alternatively, will trained plant ecologists be partnered with qualified horticultural practitioners? (yes/no)
- Will the planting be checked regularly by qualified horticultural practitioners informed/partnered with trained plant ecologists? (yes/no)
- Will the planting be maintained seasonally by qualified horticultural practitioners informed/partnered with trained plant ecologists? (yes/no)
- Vegetation: eco-sourced? (yes/no)
- Does the planting showcase seasonal changes (e.g., flowering, fruiting, leaf colour) to help people observe natural cycles? (yes/no)
- Does the design include information (e.g., QR codes or signage) to help residents or occupants learn about the building-integrated vegetation features (e.g., green walls, green roof) and their ecological benefits? (yes/no)
- Does the design include information (e.g., QR codes or signage) to help residents or occupants learn about the chosen plant species and their value to native biodiversity? (yes/no)
- Does the design include information (e.g., QR codes or signage) explaining the ecological function of the vegetation (i.e., cooling, habitat provision)? (yes/no)

Category 5: Building-integrated vegetation quality

- Wall vegetation—Area (m^2) covered by:
    - Vegetation < 30 cm: native
    - Vegetation < 30 cm: exotic
- Rooftop and terrace vegetation—Area (m^2) covered by:
    - Lawn $\leq$ 10 cm height
    - Lawn > 10 cm height

- Ground cover: loose stone
- Ground cover: bark or leaf litter
- Ground cover: bare soil
- Vegetable garden
- Flower bed
- Wood piles/rotting wood/wood logs
- Vegetation < 30 cm: native
- Vegetation < 30 cm: exotic
- Vegetation, 30 cm–2 m: native
- Vegetation, 30 cm–2 m: exotic
- Vegetation >2 m: native
- Vegetation >2 m: exotic

Appendix C. NZBF-B Biodiversity Factor Score Calculation

Appendix C.1. NZBF-B Category Maximum Possible Scores

Appendix C.1.1. Category 1

The maximum score possible that can be achieved for Category 1 “Building-integrated vegetation extent” is 100%.

Appendix C.1.2. Category 2—Category 4

Category 2 (“Minimising human impact”), Category 3 (“Building-integrated vegetation system”) and Category 4 (“Management and Education”) are based on a point system. Category 2 can achieve a maximum possible score of 18 points, Category 3 can achieve a maximum possible score of 22 points, and Category 4 can achieve a maximum possible score of 8 points (Table A2).

Table A2. Point scoring system for NZBF-B Category 2 (“Minimising human impact”), Category 3 (“Building-integrated vegetation system”) and Category 4 (“Management and Education”).

Category 2: “Minimising Human Impact”	
Condition	**Points**
No lights installed	6
Lights installed with shielding	2
Lights installed with motion detectors, timers or lights are dimmed at night	2
Lights have a correlated colour temperature (CCT) of 3,000 K or lower	2
Windows positioned in such a way that the sky on the other side of the building can’t be seen (through-vision)	1
Window wells of basement units are covered	1
Reflective glass is used for windows	If yes, then -1 If no, then 1
Any of the below bird-window collision deterrents are applied to windows: - Dots or other markers spaced no more than 5 cm apart horizontally and vertically (‘2 × 2 rule’) - Vertical or horizontal lines (sticker-based), spaced no more than 5 cm apart - Hanging cords, with cords ≥0.3 cm thick, ≤10 cm apart, securely fixed, dark coloured?	If yes, then 2 If no, then 0
The building encourages sustainable transport options, such as bicycle storage or electric vehicle charging stations	1
Native nectar-producing plants will be present	1
Wētā motels will be present	1

Table A2. *Cont.*

Rock piles will be present	1
Dead wood/log features will be present	1
Gabion structures will be present	1
Predator control will be conducted	1
Category 3: "Building-integrated vegetation system"	
Condition	**Points**
Balconies are installed and have the potential to incorporate greenery	1
Balconies are placed in a staggered fashion	1
Exterior green walls are installed	1
Exterior green walls start below, or at eye level	1
Exterior green wall type: continuous	1
Exterior green wall type: modular	2
Exterior green façades are installed	1
Exterior green façades start below, or at eye level	1
Exterior green façades type: direct	1
Exterior green façades type: indirect	2
Exterior green façades planted in ground	2
Exterior green façades planted in a planting box	1
Interior green walls and/or interior green façades are present	1
Interior green walls and/or interior green façades are dominated by native species	1
Interior green walls and/or interior green façades start at, or below, the eye level	1
Green roof is installed	1
Green roof type: extensive	1
Green roof type: semi-intensive	2
Green roof type: hybrid	2.5
Green roof type: intensive	3
Rooftop garden/communal terrace present to grow own produce	1
Exterior building-integrated wall vegetation is visible to public	1
Exterior building-integrated wall vegetation visible to inhabitants of building from within their home/office	1
Category 4: "Management and Education"	
Condition	**Points**
Trained plant ecologists are responsible for design, selection and installation of the planting. Alternatively, trained plant ecologists are partnered with qualified horticultural practitioners.	1
Planting will be checked regularly by qualified horticultural practitioners informed/partnered with trained plant ecologists.	1
Planting will be maintained seasonally by qualified horticultural practitioners informed/partnered with trained plant ecologists.	1
Vegetation is eco-sourced to ensure genetic diversity.	1
The planting showcases seasonal changes to help people observe natural cycles.	1
The design includes information (e.g., QR codes or signage) to help residents or occupants learn about the building-integrated vegetation features (e.g., green walls, green roof) and their ecological benefits.	1

Table A2. *Cont.*

The design includes information (e.g., QR codes or signage) to help residents or occupants learn about the chosen plant species and their value to native biodiversity.	1
The design includes information (e.g., QR codes or signage) explaining the ecological function of the vegetation (i.e., cooling, habitat provision)	1

Appendix C.1.3. Category 5

The maximum score possible that can be achieved for Category 5 "Building-integrated vegetation quality" is 95 points. Green walls were imagined to be filled with native vegetation below 30 cm height. An imagined empty intensive green roof plot was imagined and filled with the following vegetation: 10% flowers, 25% native ground vegetation below 30 cm height, 32.5% native vegetation of 30 cm–2 m height, 32.5% native vegetation above 2 m height. To gain the final score of 95 points, the potential percentage of the vegetation area occupied by each vegetation characteristic was multiplied by its corresponding weight (Table A3), with weights adapted from the NZBF-R [56] by removing vegetation above 5 m height.

Table A3. Vegetation characteristic weights.

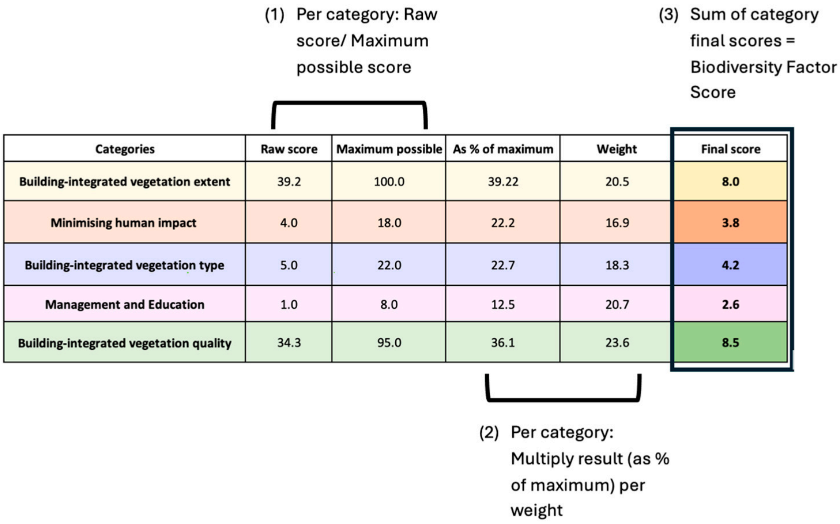
Vegetation Characteristic	Weight
Lawn $\leq$ 10 cm height	0.09386282
Lawn > 10 cm height	0.16967509
Ground cover: loose stones	0.13357401
Ground cover: bark or leaf litter	0.28519856
Ground cover: bare soil	0.15523466
Vegetable garden	0.18050542
Flower bed	0.22021661
Wood piles; rotting wood	0.33935018
Ground vegetation < 30 cm: native	0.37184116
Ground vegtation < 30 cm: exotic	0.22382671
Vegetation, 30 cm–2 m: native	0.42599278
Vegetation, 30 cm–2 m: exotic	0.28519856
Vegetation $\geq$ 2 m: native	1
Vegetation $\geq$ 2 m: exotic	0.74368231

Vegetation above 5 m height was excluded for the purposes of the NZBF-B as it is unlikely that trees will grow, or be installed, to grow to that height on buildings.

Appendix C.2. NZBF-B Biodiversity Factor Final Score Calculation

To gain the final score, the NZBF-B is pre-programmed with five automated steps, and follows those outlined in the NZBF-R (Theis et al., 2025 [56]):

1. The summaries of the raw scores for each category are transferred onto the 'Results' sheet, into the 'Summary' (Figure A1) section.
2. The proportion of each category's maximum possible score is calculated.
3. The weights of each category (as achieved through the weighting exercise) are multiplied by the proportions achieved in the above step.
4. The result of step 3 are the final scores per category. They represent the category's contribution to the overall Biodiversity Factor score.
5. The final scores per category are summed to gain the final NZBF-B Biodiversity Factor score as a proportion of 100%. Six speedometer charts are automatically computed to visualise the points achieved per category, and the overall points achieved of all categories combined.



Categories	Raw score	Maximum possible	As % of maximum	Weight	Final score
Building-integrated vegetation extent	39.2	100.0	39.22	20.5	8.0
Minimising human impact	4.0	18.0	22.2	16.9	3.8
Building-integrated vegetation type	5.0	22.0	22.7	18.3	4.2
Management and Education	1.0	8.0	12.5	20.7	2.6
Building-integrated vegetation quality	34.3	95.0	36.1	23.6	8.5

Figure A1. Step by step explanation of how the final Biodiversity Factor score is calculated: (1) raw scores are first divided by the maximum possible score, (2) the results are then multiplied with the category weight, and (3) the category final scores are summarised to gain the final Biodiversity Factor score.

Appendix D. Expert Feedback

Table A4. Experts' feedback and its implementation into the NZBF-B.

Theme	Expert Comment	Implication for NZBF-B	Response
Weighting	New buildings being assessed at the design stage would receive a different weighting than those that "have been up long enough for the facility management style and vegetation planted to have reached a reasonably established state (say 3–5 years minimum)."	Risk of overestimating biodiversity	Risk acknowledged. To mainstream the assessment process across all tools within the NZBF suite, the NZBF-B is intended to be used at the design stage and calculates the Biodiversity Factor score based on future maximum growth, as done in Theis et al. (2025) [56].
Execution of landscape design	"Landscaping/biodiversity is often the first area to be cut when projects run over-budget. Therefore, designed intent is rarely executed fully. [. . .]"	Risk of overestimating biodiversity	Same response as above. Whether or not the end-user fulfils their design plans is beyond our scope. However, we strongly encourage that the NZBF-B should be applied to projects again if the designed intent was not fully realised, and to receive an up-to-date Biodiversity Factor score.
Landscape context	"For a free-standing, isolated building surrounded mostly by natural features/vegetation, I would think 'human impact' should receive a high weighting. In contrast, for a building in the middle of a CBD where there is hardly any natural features left anyway, I would think that 'human impact' should receive a lower weighting."	Weightings will not always reflect local context.	While that is correct, we maintained fixed weightings for two reasons: (1) Maintaining fixed weights to ensure comparability across different projects that utilise the NZBF-B (2) The designer/developer/architect has little control over the context/landscape outside the development boundary that the building is situated in.
Experts' background will influence weighting scores	"I thought that the answers would be very much correlated with the person's professional background, and also the familiarity with the local context."	Final weights in NZBF-B are subject to experts that took part in weighting exercise.	Twenty-one experts took part in the weighting exercise, each of which had a different area of expertise. The weightings, therefore, are informed through a balanced range of perspectives.
Incorporation of professional ecological knowledge	"Qualified horticulturalists and landscape architects generally do not have the requisite knowledge of ecosystem dynamics or detailed enrichment species opportunities—so they must always be informed or partnered with trained/experienced plant ecologists."	Building-integrated vegetation may not be incorporated in ecologically meaningful ways.	The suggestion of employing trained/experienced plant ecologists was consequently included in the NZBF-B and receives a point towards the maximum score of 8 points of the NZBF-B category 4 ("Management and Education").

Table A4. *Cont.*

Theme	Expert Comment	Implication for NZBF-B	Response
Landscape connectivity	"I would also like to suggest that the NZBF-B indicator could be further strengthened by incorporating something like 'safe ecological connectivity' that could be merged with 'Minimising human impacts'."	Landscape connectivity not adequately addressed	We want to ensure that all projects have the same opportunity to gain full scores, without rewarding those that are situated in a context where where landscape connectiviy may be easier to achieve. As connectivity depends on the external, surrounding landscape of the development, the NZBF-B focuses on including building-integrated vegetation regardless of context. The more buildings adopt connectivity-enhancing features like green roofs, the greater and safer ecological connectivity will be across urban landscapes.
Maintenance	"Ensure that qualified professionals maintain and check plantings seasonally."	Risk of making long-term maintenance not clear	This has been added to the Management and education category. Endusers receive a point for long-term and seasonal maintenance in place.
Human-nature connection	"Encourage occupant interaction with the planting/ecology".	Human interaction not adequately considered	The human-nature interaction has been incorporated throughout the NZBF-B categories. The feedback from this expert helped in making it a theme throughout the existing NZBF-B categories. Examples include building-integrated vegetation systems that (1) actively encourage occupant interaction with plantings (i.e, rooftop gards, terrace), (2) serve to strengthen the human-nature connection through education (i.e., information on building-integrated vegetation features, chosen plant species and their ecological function), (3) the planting of plants to experience seasonal changes, (4) visibility and installation of interior vegetation to strengthen human wellbeing.
Habitat features beyond plants	"Recognise habitat features beyond plants: Include features such as nesting boxes, insect hotels, or piles of decaying wood that support native fauna, not just flora."	Native faunal species not adequately considered	This comment is very useful, though features other than plants alone to create habitat had already been considered and incorporated into the tool. Examples include rock piles (invertebrates, herpetofauna), dead wood/log features (invertebrates), wėtā motels (invertebrates), gabion structures (herpetofauna). The use of bird boxes is not advised in the urban New Zealand context as the most common inhabitats of these bird boxes would be common introduced species. Even if native birds were to use them, they would likely fall prey to introduced predators. We have therefore awarded points specifically for the installation of nectar-producing native plants as that is the optimal strategy to provide resources for native birds.
Vertical layering	"Account for vertical layering and structural diversity: Consider scoring or rewarding buildings that provide multiple vegetation layers (ground cover, shrubs, small trees, large trees) to mimic natural habitats and increase biodiversity."	Habitat complexity not adequately considered	This suggestion had already been incorporated into the tool prior to knowledge exchange with this expert. The NZBF-B encompasses the scoring of vegetation of multiple height categories, from ground cover to vegetation between 2–5 m in height.

Appendix E. "Green Star Buildings v.1" Comparison with NZBF-B Components

Table A5. Classification of NZBF-B characteristics within "Green Star NZ Buildings v.1" rated as (a) reflected (NZBF-B characteristic is reflected within Green Star NZ Buildings v.1), (b) partially reflected (NZBF-B characteristic is addressed, but does not fully align), and (c) not reflected (NZBF-B characteristic is absent).

NZBF-B Characteristic	Classification of NZBF-B Characteristic Within Green Star NZ Buildings v.1	Explanation for Classification
Total m^2 of surfaces that, in theory, can be greened	Not reflected	Green Star NZ measures what is/will be there, not what could be designed to be there. While there is a minimum requirement for landscaping (15%), these activities do not need to be realised on the building itself and may occur anywhere on the development site.
Lighting: shielding provision	Reflected	Unnecessary spill of ALAN (artificial light at night) must be minimised according to 'AS/NZS 4282:2023', the current official NZ and AU standard for obtrusive effects of outdoor lighting.
Lighting: colour	Reflected	Colour temperature specifications are set out in AS/NZS 4282:2023.
Lighting: duration	Partially reflected	Excessive lighting is discouraged.
Windows: avoiding through-vision	Not reflected	While glazing requirements are in place, these reflect the desire to protect the design from future deterioration. Glazing is an encouraged design choice to make the building attractive to urban dwellers.
Windows: avoiding reflective glass	Not reflected	
Windows: application of bird-window collision deterrents	Not reflected	
Transport: Building encourages sustainable transport options, such as bike storage or electric vehicle charging stations	Reflected	It is encouraged to design buildings with available bike storage/parking.
Wildlife enhancement: native nectar-producing plants	Partially reflected	The planting of native plants is encouraged. However, nectar- producing plants are not specifically suggested.
Wildlife enhancement: wētā motels	Partially reflected	It is recommended to provide one nesting site or one habitat provision for native species per 500 m^2 of landscaped area. Specific wildlife enhancements are not laid out.
Wildlife enhancement: rock piles	Partially reflected	
Wildlife enhancement: dead wood/log features	Partially reflected	
Wildlife enhancement: gabion structures	Partially reflected	
Wildlife enhancement: predator control	Partially reflected	Predator control is suggested as a possible offsite conservation measure.
Balconies: presence/absence	Not reflected	It is not outlined how balconies can have the potential to contribute to biodiversity provision.
Balconies: installed in staggered fashion	Not reflected	
Exterior green wall: presence/absence	Partially reflected	Vertical landscaping is suggested as viable biodiversity enhancement strategy. External green walls are not specifically listed as option.
Exterior green wall: type (continuous, modular)	Not reflected	No points or recommendations given regarding the biodiversity value of green wall types.
Exterior green façade: presence/absence	Partially reflected	Vertical landscaping is suggested as viable biodiversity enhancement strategy. External green façades are not specifically listed as option.
Exterior green walls and exterior green façade: installed below or at eye level	Not reflected	No requirement to install vertical greening at certain heights.

Table A5. *Cont.*

NZBF-B Characteristic	Classification of NZBF-B Characteristic Within Green Star NZ Buildings v.1	Explanation for Classification
Exterior green façade: type (direct/indirect)	Not reflected	No recommendation given on how to incorporate vertical greening.
Interior green walls and/or green façades: presence/absence	Reflected	Interior greenery is encouraged and may be installed vertically.
Interior vegetation: dominated by native species	Not reflected	No recommendation given as to which origin of indoor plants should dominate.
Green roof: presence/absence	Reflected	Green roofs are included as viable landscaping strategy.
Green roof: type (extensive, semi-intensive, hybrid, intensive)	Not reflected	No recommendation as to which green roof type may be more beneficial to biodiversity enhancement.
Vegetation visibility to public	Partially reflected	It is encouraged to design visually pleasing buildings for pedestrians. However, exterior vegetation is not specifically listed as an attractive option.
Vegetation visibility to inhabitants	Reflected	It is encouraged incorporate green views in the building.
Design, selection and installation of vegetation conducted by, or through help with, trained plant ecologists	Reflected	It is a recommendation to employ trained ecologist(s) to manage, review and assess the landscaped area. Pre-development assessments must be conducted by a trained ecologist.
Eco-sourcing of vegetation	Not reflected	Genetic diversity of vegetation in the form of eco-sourcing is not considered.
Vegetation: showcasing seasonal changes to help people observe natural cycles	Not reflected	The planting of plants to reflect seasonal changes is not considered.
Education: building features information on building-integrated vegetation features, chosen plant species and their ecological function	Not reflected	Educational content within buildings is not considered.
Native vegetation	Reflected	It is a requirement to plant predominantly native vegetation. Native vegetation is weighted greater than non-native vegetation.
Non-native vegetation	Reflected	Non-native vegetation may be planted. Non-native vegetation is weighted lower than native vegetation and must make up less proportion than native vegetation.
Diverse vegetation height layers in one space	Not reflected	Structural diversity is not considered. Instead, planting should follow the 10/20/30 rule.

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