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The New Zealand Biodiversity Factor—Residential (NZBF-R): A Tool to Rapidly Score the Relative Biodiversity Value of Urban Residential Developments

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Abstract: The loss of biodiversity in urban residential areas that are densifying in response to increasing housing demand has serious implications for urban ecosystem functioning and human wellbeing. There is an urgent need for integrating biodiversity-sensitive design into urban planning and development. While several existing "Green Factor" tools guide greening strategies in cities, none have biodiversity as their primary focus. We describe here a tool that specifically evaluates biodiversity in residential developments, with a particular emphasis on supporting native biodiversity. The NZBF-R (New Zealand Biodiversity Factor—Residential) also educates users through embedded explanations on how various design features positively impact biodiversity and it provides tailored recommendations for effective biodiversity enhancement, enabling urban professionals to make informed landscape design decisions. Developed through literature review, analyses of existing Green Factor tools, and a robust weighting process, the NZBF-R identifies and ranks characteristics that support urban biodiversity, based on evidence from the scientific literature. We demonstrate the application of the NZBF-R on one case study. The NZBF-R can be applied across the planning, design, and retrofitting stages of urban residential projects, making it a valuable resource for urban planners and designers.

Keywords: biodiversity assessment; green area factor; residential development; urban development; urban vegetation

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1. Introduction

Urbanisation results in loss of biodiversity through the modification, fragmentation and destruction of habitats, with existing urban ecological communities suffering ongoing losses due to threats such as increasing landscape fragmentation, weed invasion, and light, noise and air pollution [1]. Despite this, there is global recognition of the importance of the ecosystem services that natural environments in urban areas provide for humanity [2–4], including the regulation of water, temperature, and air quality [3,5], and the physical, mental and social wellbeing of city residents [6]. Since biodiversity underpins ecosystem services, loss of biodiversity is associated with substantially diminished services due to altered ecosystem functioning and stability [4,7,8]. Halting biodiversity loss was included in 2015 as one of the United Nations Sustainable Development Goals [9].

Cognisant of the importance of biodiversity in urban environments, city planners, urban designers and architects are increasingly looking for ways to support biodiversity through urban design, acknowledging the pressing need for locally relevant guidance that ensures biodiversity is promoted effectively [10–14]. Encouraging the introduction of more vegetation (greening) and other strategies that enhance biodiversity in residential suburbs, where the majority of urban dwellers live [15], can contribute to mitigating the increasing human disconnect with nature [16], and the loss of essential ecosystem services. To guide the establishment of sustainable strategies that enhance ecosystem services and support climate change mitigation in cities, several 'Green Factor' tools have been developed that measure the quality and density of vegetation on and around infrastructure, among other things. These include the Biotope Area Factor released 1990 [17]; the Seattle Green Factor released 2009 [18]; the Helsinki Green Factor released 2014 [19,20]; the Stockholm Green Area Factor released 2015 [21]; and the Melbourne Green Factor released 2020 [22,23]. These tools calculate a Green Factor score based on the ratio of permeable to non-permeable areas and can be applied to commercial or residential developments. While the Seattle, Helsinki, and the Melbourne Green Factors are focused on sustainability, the Biotope Area Factor and the Stockholm Green Factor have a strong focus on ecosystem services. However, none of these tools have biodiversity as their primary focus, despite the body of evidence linking biodiversity with human wellbeing benefits and ecosystem functioning [7,24,25]. We advocate for the mandatory application of such tools in the planning application and design process for urban residential developments. An exemplar is the UK's Biodiversity Net Gain UK legislation that requires most developments to account for lost habitat by measuring biodiversity prior and post development to ensure at least a 10% net gain in biodiversity [26].

In New Zealand, Home Star NZ and Green Star NZ are used to rate aspects of the sustainability of private homes and commercial developments, respectively [27]; yet, as with the Green Factor tools, biodiversity is not the primary focus [28]. In recognition of the substantial potential that private gardens in residential areas have for supporting city-wide biodiversity [14,29], GardenStar was developed as a biodiversity evaluation tool. This tool also educates and incentivises householders to improve the biodiversity value of their private gardens [30]. However, the biodiversity of people's living environments also relies on neighbourhood-scale factors, such as habitat availability, connectivity and landscape-scale planning and design across both private and public spaces [31–33]. A biodiversity evaluation tool designed to be applied to residential areas needs to consider both private and public spaces at the scale of the neighbourhood.

Here we describe the development of the New Zealand Biodiversity Factor—Residential (NZBF-R), an evaluation tool that can be applied at the scale of the residential neighbourhood and which considers both private and public green spaces, greening features, and design features that can support biodiversity. While lower-density residential neighbourhoods have contributed significantly to city-wide biodiversity [29], the current ongoing shift from low to medium-density housing in New Zealand and globally, driven by a pressing demand for housing supply, poses complex challenges to biodiversity conservation in urban areas [34–36]. The spatial configuration of built environments, including car-related infrastructure, the extent of private versus public greenspace, the integration of stormwater mitigation features, and building-integrated vegetation can all have significant impacts on the amount of biodiversity in a residential area [34]. The NZBF-R has been designed to show urban professionals how to incorporate biodiverse features into new developments in ecologically meaningful ways. The NZBF-R values native New Zealand species more highly than non-native species and provides a score and a set of recommendations on strategies to enhance biodiversity at the planning stage of a residential development. We outline the creation and demonstrate the application of the NZBF-R through a case study, illustrating its potential to guide the enhancement and conservation of native biodiversity across urban landscapes.

2. Materials and Methods

2.1. NZBF-R: Process of Creation

The NZBF-R does not require specialist ecological, design or planning skills and is intended to be applied at the design or planning stage of a residential development. By entering measured features of the development from a plan, an urban designer and/or planning professional can compare biodiversity scores for the area proposed for development before and after the development takes place and use the recommendations in the tool's output to improve the biodiversity score by making adjustments to the design of the development. The NZBF-R's layout and scoring system were based on those of the Helsinki Green Factor Tool [19] and GardenStar NZ [30]. The NZBF-R creation took place over four stages, and is guided by the five biodiversity-sensitive urban design principles (BSUD) [37]: (1) maintain and introduce habitat (maintain existing habitats, protect biodiversity, create and enhance habitats to meet species' needs, such as the introduction of complex 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. 'Habitat' is considered to be any area that supports biodiversity, either natural (e.g., wetlands) or constructed (e.g., gardens, green walls): habitats will vary depending on the developers' goals (e.g., lizard protection, wetland restoration etc).

Stage 1: Creation of high-level categories. We used satellite imagery of New Zealand urban areas (Auckland, Wellington, Dunedin), review of the relevant literature, knowledge exchange with experts from architectural and ecological fields, and evaluation of existing assessment tools to identify salient factors influencing residential biodiversity, which led to the creation of three broad categories that reflected the urban design elements that impact biodiversity. These categories were as follows: (1) "Permeable area extent" (proportion of development area covered by permeable surfaces, defined as any surface area that allows water to seep through and is able to support any form of vegetative growth); (2) "Street features" (street characteristics that have impacts on biodiversity maintenance and conservation); and (3) "Vegetation" (vegetation characteristics reflecting habitat quality).

Stage 2. Identification of features within high-level categories. To create the NZBF-R, a systematic literature search process (Appendix A) was applied, and relevant literature was reviewed to identify features of street characteristics and permeable spaces that can support biodiversity. To identify relevant literature, each combination of search terms entered into the search engines included "urban" and/or "biodivers*" with additional search terms relating to urban landscape scale habitats and their inhabitants, in detail "assessment", "biodiversity", "bird", "car", "corridor", "development", "factor", "fragmentation", "green", "habitat", "human", "housing", "invertebrate", "native", "patch", "permeable", "measurement", "microbiome", "New Zealand", "residential", "road*", "sense of place", "stepping stones", "stormwater", "street*", "street width", "tool", "traffic", "traffic calming", "vegetation", "wildlife", or a combination thereof.

To find policy papers and council reports, Google was used as a search engine by entering the above-mentioned literature search terms in addition to place-based terms, notably New Zealand territorial authorities (e.g., "Canterbury", "Otago"). Once read, literature was deemed relevant if the relationships of various taxa, in particular floral and/or faunal and/or human, and their immediate environment were explored. Literature was also deemed relevant if impacts of urbanisation on biodiversity were focused on, or if the article explored any of the five BSUD principles. If the content of the journal article focused on conservation land only, or landscapes typically inaccessible to humans, these articles were excluded.

Stage 3. Application of weightings. We used expert elicitation (see Appendix B, Table A1 for expert details) to calculate weightings for both the three main high-level categories ("Permeable area extent", "Street features", "Vegetation") and each habitat feature within the "Vegetation" category. Seventeen experts in the fields of botany, plant and animal ecology, entomology and geography, all with ecological expertise in urban environments, were independently asked to rate the importance of each of the three categories on a scale from 0 (no positive effect on biodiversity) to 10 (greatly benefits biodiversity) while taking into consideration the biodiversity-sensitive urban design principles. The panel of experts then applied the same rating system to the 28 habitat characteristics in the "Vegetation" category. To calculate the weight for each high-level category, we summed all expert scores per category and divided this sum by the overall scores received for all three categories. Within the "Vegetation" category only, we summed the scores for each vegetation characteristic and divided these by the sum of all vegetation scores. We normalised the result for each vegetation characteristic to place all vegetation characteristic scores on the same relative scale, ranging from zero to one, using the following formula:

$$x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{1}$$

where x is the result for the vegetation characteristic being normalised, x_{min} is the lowest score of all vegetation characteristics, x_{max} is the highest score of all vegetation characteristics and x_{new} is the derived normalised value between zero and one [30].

Stage 4. Structure of the NZBF-R. The NZBF-R tool was created using Microsoft Excel (version 2024) and consists of five linked worksheets that provide the information necessary to apply the tool, a form for data entry, and a self-generating results page. The sheets are as follows:

(1) 'Start here': The purpose of the NZBF-R is outlined along with instructions for users.
(2) 'Worksheet': This sheet serves as the data entry sheet, providing assessment instructions to guide the user through the NZBF-R process. Embedded information icons link the 'Worksheet' with the 'Information' sheet.
(3) 'Information': This sheet provides detailed descriptions of characteristics and their relevance to biodiversity.
(4) 'Results': Each scorable metric within the three main categories ("Permeable Area Extent", "Street Features", and "Vegetation"; Appendixs C and D) is linked to a set of conditional recommendations (Appendix E), which are provided to the end-user alongside the NZBF-R biodiversity score (Appendix F), which is generated based on the data entered once all required fields in the NZBF-R are completed. The 'Results' sheet presents a summary of the scores, showing the overall score as well as individual high-level category scores in the form of four speedometer charts. These charts offer a clear visual representation of performance, highlighting how well each category contributes to the Biodiversity Factor and identifies areas with potential for improvement.
(5) 'BAT': A locked sheet where all calculations occur, using Excel functions.

2.2. NZBF-R Application Methodology

Permeable area extent can be calculated using the information from the development plan by overlaying a site drawing of the masterplan onto a satellite imagery program, such as Google Earth Pro or ArcGIS, and using the polygon function for square metre measurements. "Private" (e.g., private gardens) and "communal" (e.g., street vegetation;) permeable areas are calculated separately and entered into the tool in square metres. The tool then calculates the percentage of private and communal permeable areas, automatically determining the total permeable area achieved relative to the theoretically best possible score, which is 100% permeability.

The "**Street Features"** category requires the user to enter details about streetlight specifications (streetlight duration, intensity and direction), walking path characteristics (i.e., connection to public greenspace), and traffic calming strategies (i.e., speed limits, roundabouts; Appendix C). The points for the "Street Features" category are calculated as a percentage of the maximum possible score, based on the best-case development scenario with no streets present.

The "**Vegetation"** category captures habitat quality within the development and is divided into five sub-categories: street vegetation, communal vegetation, private gardens, stormwater solutions, and significant restoration (Appendix C). Vegetation features were based on four vertically stacked layers following Hurst & Allen (2007) [38]: ground cover (12 types and totalling the area of permeable cover); shrub layer (30 cm–2 m; predominantly non-native/native); shrub/tree layer (2–5 m; predominantly non-native/native); and tree layer (>5 m; predominantly non-native/native). Further habitat features within the "Vegetation" category were stormwater solutions and an evaluation of whether restored habitat areas, if present, could be considered significant, following established criteria. The area (in m^2) of each of the vegetation features (e.g., ground cover <30 cm height, predominantly native) can be retrieved and calculated using landscape plans. The planned vegetation is grouped by origin (native versus non-native) and their maximum height and width. To determine the vegetation area per plant species (in m^2), the maximum plant width (in metres) is extracted from the landscape plans and entered into the tool's built-in calculation aid which applies the following formula:

$$Area = \pi * \left(\frac{plant\ width}{2}\right)^2 \quad (2)$$

Based on the landscape plans, vegetation is categorised into street vegetation (i.e., associated with streets and walking paths), communal greenery (vegetation present in communal carparks, parks, reserves, playgrounds), stormwater solutions (raingardens, bioswales, green roofs, natural and artificial water features; Appendix C), and private gardens, which are evaluated using a modified version of GardenStar NZ [30]; Appendix D.

Additional to the above vegetation features, restored habitats within the development area (i.e., a purposeful rehabilitation of an area to recreate a functioning ecosystem, for example, a wetland) can contribute to the NZBF-R score. To qualify as a restored habitat, the habitat must be assessed as potentially meeting at least one of the criteria for Significant Natural Areas as defined in the National Policy Statement for Indigenous Biodiversity (NPSIB [39]). A qualified ecologist must be used to evaluate the restoration and determine whether it meets any of the restoration criteria (representativeness, diversity and pattern, rarity and pattern and ecological context), under the assumption that all vegetation and other necessary features within the restoration area survive and grow. Finally, none of the Significant Natural Area exclusion criteria should apply [39]. If deemed significant, the area of the restoration and the vegetation within it is re-entered into the significant restoration sub-category. A multiplier is applied to the restoration area's vegetation weightings to reflect its value (0.125) and this is doubled to 0.25 if the area is contiguous with another significant natural area outside the development boundary to reward design that promotes connectivity.

The conversion of the final vegetation score to a percentage of the theoretically best possible score was based on imagining an empty plot, "filled" to 100% with the vegetation features that had the highest weightings without the inclusion of a restored habitat. A detailed explanation of the NZBF-R point scoring system is provided in Appendix F.

2.3. NZBF-R User Feedback, Tool Refinement and Case Study

The development of the NZBF-R involved consultation with end-users, including representatives from a large development company, urban planners, landscape architects, and consultant ecologists, to ensure the tool's appropriateness and useability. Over a one-and-a-half-year period, more than 30 meetings were held to gather feedback on its applicability, with demonstrations, Q&A sessions, and testing on hypothetical and real masterplans. We also sought advice on how best to incorporate principles of mātauranga Māori (Māori knowledge) to ensure the inclusion of indigenous knowledge and perspectives. Here, we present one case study, a 62,836 sqm medium-density housing development, developed on a greenfield site (Figure 1).

(**a**) (**b**) (**c**)

Figure 1. Images of the case study site showing (**a**) the pre-development greenfield site (aerial image); (**b**) the extent of the permeable area resulting from the proposed development. Red lines indicate the development boundary, dark blue and green polygons represent the wetland and communal greenery, respectively, and turquoise polygons represent private permeable space; and (**c**) finished development.

3. Results

3.1. Identification of Characteristics That Positively and Negatively Affect Urban Biodiversity

The literature search resulted in the consultation of 119 journal articles, 17 online resources and 38 governmental and council publications. These sources identified 30 characteristics across the three NZBF-R categories ("Permeable area extent", "Street Features", "Vegetation"), some of which are presented in relation to the five BSUD principles in Table 1). Characteristics included as components of the tool that have the potential to positively affect and mitigate negative effects on urban biodiversity are listed in Table 1.

Table 1. NZBF-R characteristics categorised under the three NZBF-R categories ("Permeable area extent", "Street features", and "Vegetation") as derived from the literature (column 1). Justification for the characteristics' inclusion into the NZBF-R (column 2) and their alignment with the five BSUD principles (column 3), where 1 = Maintain and introduce habitat; 2 = Facilitate dispersal; 3 = Minimise threats and anthropogenic disturbances; 4 = Facilitate natural ecological processes; and 5 = Improve potential for positive human-nature connections, are provided.

NZBF-R Characteristic and Category	Reason for NZBF-R Inclusion	BSUD Principle
Permeable area (_/100%) (Permeable area extent)	Permeable surfaces are essential for below-ground biodiversity, supporting organisms such as invertebrates, fungi, and microorganisms [40]. Permeable surfaces enable ecosystem processes such as nutrient cycling, water infiltration, and organic matter decomposition [41]. Healthy soils support healthy plants and provide food resources for fauna. Soil microbiomes contribute to human physical and mental wellbeing [42]. Non-permeable surfaces are linked to, for instance, lower bee visitation rates [43], urban heat island effect (UHI), and increased flooding risks [44].	1, 4
Streets (Street Features)	The presence, surface area and layout of streets is indicative of landscape fragmentation [45]. Streets create barriers to movement of species, inhibit gene flow, and separate wildlife from resources [45,46]. Streets cause wildlife mortality through vehicle collisions [47,48], as well as the alteration of surrounding habitats through vegetation removal, non-native plantings, and chemical use [49]. Traffic noise disrupts wildlife [50].	3
Traffic calming strategies (Street Features)	Traffic calming strategies lower vehicle speed [51], reducing wildlife–vehicle collisions [52] and improve pollen dispersal by narrowing streets [46]. Traffic calming features such as chicanes and roundabouts provide planting opportunities.	3
Pathways (Street Features)	Walking paths connect homes to each other, streets and car parking lots, with their layout and surface area indicating the level of fragmentation. Fragmented surfaces hinder species movement [45,46]. Shared pathways support species movement better than individual ones and reduce fragmentation. By connecting to local greenspaces, pathways enhance human–nature connections, which have flow-on effects on biodiversity conservation [53].	3, 5
Streetlight: direction (Street Features)	Streetlight shields reduce light pollution by directing light onto the path and/ or street, benefitting biodiversity by minimising the impact of artificial light, such as, but not limited to, global invertebrate declines [54], changes in invertebrate reproductive activity [54], invertebrate community composition [55] and changes in circadian rhythm [56].	3

Table 1. *Cont.*

NZBF-R Characteristic and Category	Reason for NZBF-R Inclusion	BSUD Principle
Streetlight: colour (Street Features)	Streetlights that have a CCT of 3000 K or lower mitigate the negative impacts of light pollution on wildlife [57]. Lower CCT is less disruptive to circadian cycles [56] and aids in reducing the glare that high CCT streetlights produce.	3
Streetlight duration (Street Features)	Streetlights with motion detectors or timers reduce light pollution by being activated only when needed for urban dwellers.	3
Vegetation complexity and structure (Vegetation)	Heterogeneous vegetation, with diverse species and diverse vegetation heights in one space, enhances biodiversity by creating habitats, food, and nesting sites [30,32,58]. In the NZBF-R, vegetation is expressed in height categories (<30 cm, 30 cm = 2 m, 2–5 m, >5 m) and grouped by origin (NZ native versus non-native). Heterogeneous vegetation decreases in complexity along the rural–urban gradient [32]. Rich vegetation understory is important for species diversity and abundance [59]. Increased vegetation diversity above ground leads to more diverse below-ground soil bacteria, leading to increased plant health and functioning through nitrogen fixation [60].	1, 2, 4
Native vegetation—general (Vegetation)	Native vegetation has been linked positively to increased soil microbial diversity [61]. Native fauna prefer inhabiting, and making use of, native vegetation across the rural-urban gradient [62]. The enhancement and conservation of endemic native species is linked to the creation of a 'sense of place' [63]. Native vegetation is associated with specific native fauna, as a result of linked co-evolutionary histories [64].	1, 2, 4, 5
Non-native vegetation—general (Vegetation)	Non-native species contribute to the maintenance of natural ecological processes, such as pollination [65]. Exotic vegetation can also support biodiversity through the provision of habitat resources and the facilitation of dispersal [66].	1, 2, 4
Lawn < 10 cm height, Lawn > 10 cm height (Vegetation)	Lawns are frequently used as an urban greening strategy [65]. On traditional lawns, strategies such as mowing lawns less frequently or setting aside no-mow areas, can be beneficial to biodiversity by increasing vegetation height [67].	1, 3
Flowers/meadow (Vegetation)	Lawns have the potential to contribute more to biodiversity if a transition from traditional lawns to 'tapestry lawns' or 'spontaneous vegetation' takes place; these include flowering plants that create habitat for pollinators through diverse groundcovers [11,65].	1, 4
Wood piles/rotting wood (Vegetation)	Wood piles and rotting wood provide habitat and food resources for a wide range of invertebrates [68,69].	1, 4
Leaf litter, mulch/bark (Vegetation)	Leaf litter, bark and mulch provide important habitat niches for invertebrates and thus food resources for other fauna, such as birds [70,71].	1, 4

Table 1. *Cont.*

NZBF-R Characteristic and Category	Reason for NZBF-R Inclusion	BSUD Principle
Isolated trees planted on non-permeable ground (Vegetation)	Isolated trees, which stand alone with their canopies not touching one another, can act as stepping stones for urban wildlife by facilitating dispersal and serving as hotspot habitats for fauna like arthropods [72].	1, 2
Isolated trees planted on non-permeable ground, installed through a vault system (Vegetation)	Vault systems for street tree installation are honeycomb-like, open grid structures underground that support tree growth by creating soil vaults beneath non-permeable surfaces. Vault systems allow roots to grow laterally, while preventing root damage to non-permeable surfaces such as pathways and roads [73].	1, 4
Communal greenery—general (Vegetation)	Communal greenery, for the purposes of the NZBF-R, is defined as vegetated areas within a development that can be used by all inhabitants, such as communal gardens, parks, and streetside vegetation. All vegetation present as communal greenery is evaluated and entered into the NZBF-R.	1, 2, 5
Private gardens—general (Vegetation)	Private gardens have the potential to be valuable habitat patches within the urban matrix [30,37,74,75].	1, 2, 4, 5
Garden clustering (Vegetation)	Clustering refers to the degree of grouping of vegetative elements, and the proportion of the private garden area taken up by these groups. The more clustered a garden is, the more heterogeneous the vegetation structure (multiple layers and types) becomes, which increases the availability of different habitat niches (see "Vegetation complexity and structure").	1, 2, 4, 5
Wildlife enhancements (Vegetation)	Wildlife enhancements aimed at benefiting native species involve a range of strategies, including providing sugar water, establishing lizard habitats, installing bat boxes, creating insect hotels, and planting native plants that produce nectar [30]. These initiatives contribute to the conservation and well-being of local wildlife by offering essential resources and habitats and can be added to private gardens to attract wildlife, thus strengthening the human-nature connection [30].	3, 5
Compost bin (Vegetation)	Composting offers the benefit of minimising waste and transforming organic matter into valuable nourishment for the soil [76].	4, 5
PF 2050 neighbourhood (Vegetation)	The Predator Free 2050 strategy seeks to eliminate key invasive predators in New Zealand, specifically targeting mustelids (*Mustela putorius furo*, *Mustelia erminea*, *Mustela nivalis*), rats (*Rattus norvegicus*, *Rattus rattus*) and possums, which will allow New Zealand's native species to thrive in urban areas (if cats are kept inside [77]).	3, 5
Natural water feature (Vegetation)	Natural water features, such as lakes, rivers, streams or wetlands, are important habitat for fauna and flora and thus increase biodiversity if preserved or enhanced [78].	1, 2, 4

Table 1. *Cont.*

NZBF-R Characteristic and Category	Reason for NZBF-R Inclusion	BSUD Principle
Bioswales (Vegetation)	Bioswales are a common stormwater solution in urban areas, designed to direct stormwater runoff away from urban installations [79]. The vegetation planted in bioswales aids in stormwater purification (e.g., debris removal) and offers habitat for an array of species, thus boosting biodiversity [79].	1, 3, 4
Raingardens (Vegetation)	Raingardens are a common stormwater solution in urban areas. Raingardens have densely packed vegetation, thus benefitting biodiversity [79].	1, 3, 4
Green roofs (Vegetation)	Green roofs are a good stormwater and climate mitigation strategy that can provide valuable habitats for fauna [80]. Green roofs can act as stepping stones, facilitating dispersal for some organisms [81].	1, 2
Artificial water feature (Vegetation)	Depending on the size of the artificial water feature, these can aid in stormwater mitigation strategy and, further, fulfil important ecosystem services, such as phytopurification [82].	1, 3

3.2. Weighting Process

The "Vegetation" category had the highest weighting (weight = 0.428), followed by "Permeable area extent" (weight = 0.359), and "Street Features" (weight = 0.213). The normalised weights of the different vegetation characteristics that contributed towards the "Vegetation" ranged from 0.188 (lawn less than 10 cm height) and 0.268 (ground cover: loose stones) to 0.906 (vegetation 2–5 m, native) and 1 (vegetation > 5 m, native; Appendix F, Table A4). Ground vegetation characteristics that were given relatively high weightings were 'bark or leaf litter' (0.572), 'wood piles/rotting wood' (0.681) and 'ground vegetation < 30 cm, native' (0.746).

3.3. NZBF-R User Feedback and Tool Refinement

The NZBF-R was well received by urban planners, developers and landscape architects. The main comments were that the breakdown of categories provides a clearer understanding of how these elements interact to enhance biodiversity in ecologically meaningful ways. Several developers reported that the NZBF-R has the potential to aid in educating individuals and could be used by individuals with no to little ecological training and little knowledge of the actors that contribute to biodiversity, such as the choice of vegetation, and what it means to create valuable habitats. We were advised to highlight how the NZBF-R reflects and contributes to Māori objectives, rather than incorporating mātauranga Māori as a specific characteristic or category within the NZBF-R. The NZBF-R aligns with the Te Aranga principles, which have been established through dialogue with mana whenua ("people of the land") to guide urban design processes [83]. These principles reflect mātauranga Māori (Māori knowledge) and address the interconnectedness of people, land and biodiversity. The development-specific recommendations provided by the NZBF-R align with the third (Taiao = natural environment is protected, restored and enhanced), and fourth Te Aranga principles (Mauri Tū = environmental health is protected, maintained and enhanced [83]).

Based on the feedback received, the tool was refined through revisions which simplified data entry, improved output visualisation (i.e., inclusion of speedometer charts), adjusted category features (i.e., streetlight specifications), and acknowledged the value provided by habitat restorations and connectivity to natural areas outside the development (i.e., inclusion of the option to assess a restored area as significant when a professionally-employed ecologist is hired).

3.4. NZBF-R Case Study

A key feature of the case study residential development is the restoration of a wetland that is situated along the northern development boundary. Adjacent to the communal vegetation lies the residential area. Streets are incorporated in a grid-like layout. Each private property within the development includes a private garden, while the streets include planted verges. Pre- and post-development biodiversity scores were obtained using the NZBF-R. The case study's pre-development greenfield achieved a Biodiversity Factor score of 63.2 out of 100 (Table 2; Figure 2; see Appendix F, Figure A3 for an explanation). Both the "Permeable Area Extent" and "Street Features" categories achieved full scores, contributing 35.9 and 21.3 points to the Biodiversity Factor, respectively. The site was entirely permeable, and the absence of streets meant there was no landscape fragmentation. The "Vegetation" category achieved a raw score of 34.1 points out of 242.1, resulting in 14.1% of the maximum possible score, due to the presence of predominantly low, non-native grassland that lacked diversity and structural complexity: this resulted in six points being added to reach the final score.

Table 2. Summary of the case study's pre-development results, with the sum of final scores equalling the Biodiversity Factor.

NZBF-R Category	Raw Score	Maximum Possible	As % of Maximum	Weight	Final Score
Permeable area extent	100.0	100.0	100.0	35.9	35.9
Street features	10.0	10.0	100.0	21.3	21.3
Vegetation	34.1	242.1	14.1	42.8	6.0
Biodiversity Factor					63.2

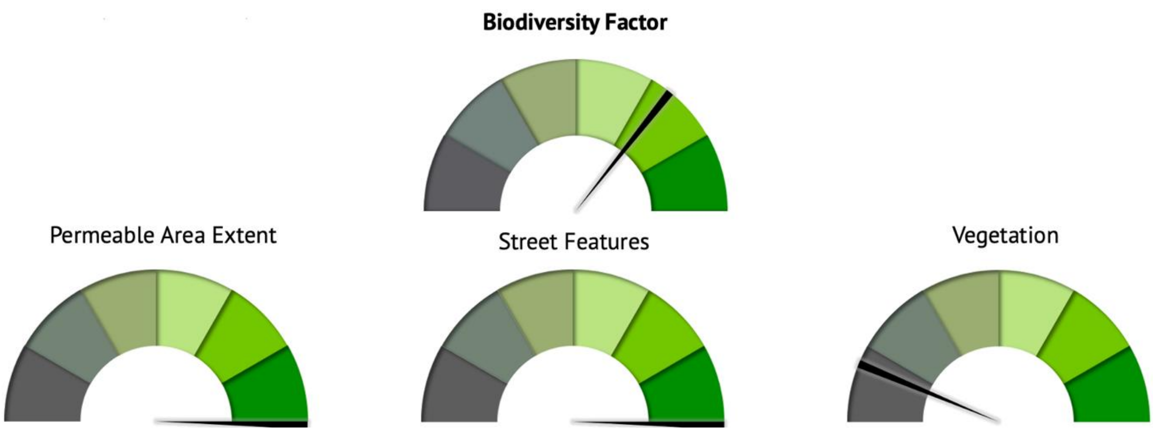

Figure 2. Speedometer charts reflecting the pre-development site performance. Dark grey represents the least and dark green the best possible score. The top speedometer chart reflects the overall Biodiversity Factor, while the bottom three speedometer charts (from left to right) reflect the performance of the three categories: "Permeable area extent", "Street Features" and "Vegetation".

Post-development, the Biodiversity Factor was 42.2 out of 100, a decrease of 33% when compared to the pre-development condition (Table 3; Figure 3). About one third of the development is permeable (33.8%), contributing 21.1 points to the Biodiversity Factor and resulting in a habitat loss of 66.2%. The 'Street features' category achieved 30% of the best possible score for the category, contributing 6.4 out of a possible 21.3 points toward the

Biodiversity Factor. The streets within the development have traffic calming strategies incorporated, and the communal walking pathways were shared between homes and connect to urban public greenspaces. However, the installation of streetlight shielding, streetlight timers and streetlights with lightbulbs of a CCT of 3000 K or less alone would have increased the Biodiversity Factor by 12.8 points.

Table 3. Summary of the case study's post-development results, with the sum of final scores equalling the Biodiversity Factor.

NZBF-R Category	Raw Score	Maximum Possible	As % of Maximum	Weight	Final Score
Permeable area extent	33.8	100.0	33.8	35.9	12.1
Street features	3.0	10.0	30.0	21.3	6.4
Vegetation	134.2	242.1	55.4	42.8	23.7
Biodiversity Factor					42.2

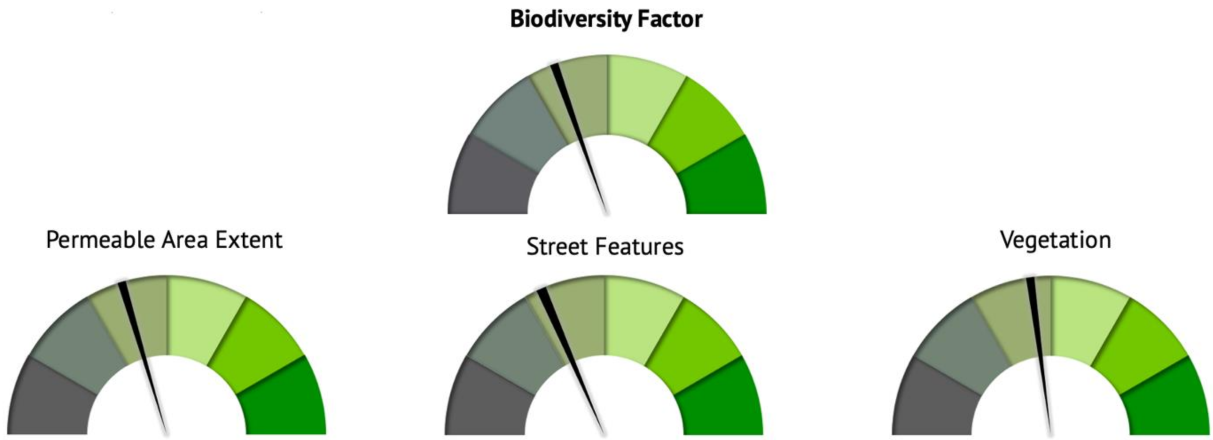

Figure 3. Speedometer charts reflecting the post-development site performance. Dark grey represents the least and dark green the best possible score distribution. The top speedometer chart reflects the overall Biodiversity Factor, while the bottom three speedometer charts (from left to right) reflect the performance of the three categories: "Permeable area extent", "Street Features" and "Vegetation".

In contrast, the "Vegetation" category score, when compared to the pre-development condition, has improved by 41.3%, achieving a raw score of 134.1 out of 242.1, resulting in the greatest contribution to the Biodiversity Factor at 23.7 points. The improved "Vegetation" score reflects greater vegetation species complexity and diversity. For instance, the pre-development site predominantly consisted of rank non-native grass, while the post-development site, specifically around the wetland area, features a more diverse range of native vegetation. The chosen vegetation includes native species with future maximum heights ranging from 30 cm to over 5 m, representing a total of 47 plant species. To increase the vegetation score, lawns kept at below 10 cm in height should be replaced with more complex, native vegetation of varying heights in both private gardens and streetside vegetation (i.e., berms/verges).

4. Discussion

Here we have outlined the development and application of the New Zealand Biodiversity Factor-Residential (NZBF-R), a tool created to facilitate high-level desktop assessments of biodiversity-supporting characteristics of planned residential developments. A key objective was to ensure the NZBF-R encouraged aspirational and effective planning and implementation of development features that promote biodiversity.

By following a thorough tool creation process, the NZBF-R identifies characteristics that positively and negatively affect biodiversity within residential developments. The weighting process of the high-level categories produced similar weight scores for the NZBF tool among the experts and resulted in the "Vegetation" category being deemed as most important for urban biodiversity (42.8%), followed by the "Permeable area extent" (35.9%) and "Street features" (21.3%).

4.1. NZBF-R Categories

The "**Vegetation**" category focuses on the habitat quality of the communal and private permeable areas within the residential development, scoring native vegetation higher than non-native. Native vegetation is often positively associated with native fauna when there is a history of co-evolution, a phenomenon not only observed in Australasia but globally [62,64]. The prevalence of non-native over native plant species has been linked to declines in reproductive output in birds feeding on invertebrates, such as the Carolina chickadee (*Poecile carolinensis*) [62]. In a recent study in Southern California, USA, urban residential gardens landscaped with native vegetation resembling the region's natural habitats, attracted a higher abundance of birds naturally associated with the local terrestrial ecosystem [84]. In Hungary, urban breeding great tits (*Parus major*) were found to actively avoid non-native plant species when out foraging and finding food for their young [85]. Native heterogeneous vegetation has been shown to increase ecosystem services, such as a higher microbiome diversity both below and above ground, which contributes to a healthy gut microbiome and immunoregulatory pathways in humans [61]. Promoting native species is considered vital in New Zealand, where non-native species in urban landscapes outnumber native species: Australasia is the only continent where non-native flora and fauna are more abundant in cityscapes than native ones [86]. A systematic literature review of studies from over 100 cities and 34 countries found strong evidence that native plants support higher faunal abundance and diversity than non-native plants in urban landscapes, particularly specialist species among the arthropods, as well as higher levels and diversity of ecosystem services [87]. In New Zealand, the enhancement and conservation of endemic native species is also linked to the creation of a 'sense of place', as they comprise essential components of local ecosystems and in the context of New Zealand are of importance to Māori identity in urban settings [63,88].

Nevertheless, interactions between the plants commonly used in landscaping and native and non-native fauna can be complex. Non-native vegetation can support native invertebrates and vertebrates through the provision of habitat resources and the facilitation of dispersal [66,89]. Non-native vegetation and increasing structural complexity of vegetation provided habitat and supported wildlife communities in the US [90] and the UK [91]. More than half of pollinators across a range of land use types in the UK were found in gardens with a mix of native and non-native flowering plants [91]. In New Zealand gardens where 83% of all woody species were non-native, two-thirds of beetle species were native. In these gardens, woody plant diversity, density and vegetation structural complexity influenced beetle community composition rather than the provenance of the plants [92]. Food resources provided by non-native plants can support native animals during periods of low food availability in urban areas [93]. Schlaepfer et al. (2011) [94] argue that non-native species might contribute to achieving conservation goals in the future because they may be more likely than native species to persist and provide ecosystem services in areas where climate and land use are changing rapidly, such as urban areas. Schlaepfer (2018) [95] suggests that the contributions of these species to biodiversity and ecosystem services are overlooked, and that biodiversity and sustainability indices should include all species. In New Zealand, Rastandeh et al. (2018) [96] argue that indigenous purity is not likely to be achievable in the real world in urban settings and instead attention should be drawn to the potential ecological benefits of some non-native species (e.g., stepping stone habitat to facilitate dispersal and mitigation of edge effects in patches of natural vegetation) that are already present in urbanised landscapes.

It is also important to bear in mind that landscaping in residential areas using non-native species can impart significant negative impacts by driving the introduction and spread of non-native species, including invasive species, into nearby natural habitats [97–99]. In New Zealand, two common and widespread non-native urban bird species (blackbirds *Turdus merula*, and starlings *Sturnus vulgaris*) are probably the most important dispersers of more than 20 weed species; starlings pose additional risks because they disperse seeds long distances to roost sites [100]. The relative merits of native or non-native plants in supporting other native biodiversity are fraught with conflicting positions based on values, perceptions and aesthetics (e.g., [101]) and sometimes equivocal results confounded by differences in patch size, the presence of other species in the patch, variable structure between patches, and the nature of the surrounding matrix [102]. Shackleton argues that when framed as a conservation debate, the question is not whether non-native plants can sustain native biodiversity, but rather whether they sustain higher species richness or abundance, and whether if the non-native species were removed, it would result in a loss of certain native biodiversity that was dependent upon them.

Taking these factors into account, including the evidence indicating the value of native vegetation in supporting native biodiversity, the risks posed by some non-native species to native biodiversity, but also the role non-native species play in supporting native fauna, the NZBF-R acknowledges the contribution of non-invasive non-native species to urban residential biodiversity in the evaluation process, but applies a higher weighting to native species than non-native species in the same height category. The unequivocal evidence from the review of Tartaglia and Aronson (2024) [87] indicates that this weighting can be applied in regions other than New Zealand.

To account for the importance of vegetation heterogeneity (i.e., vegetation that varies in structure, height, and species assemblages), both non-native and native vegetation were divided up into four different vegetation layers within the NZBF-R: ground cover below 30 cm, shrubs of 30 cm–2 m, shrubs/trees of 2–5 m, and trees over 5 m [38]. Heterogeneous vegetation offers more habitat niches and a greater range of resources when compared to homogeneous vegetation and is important in enhancing biodiversity and ecosystem services in the urban landscape [61,79,92,103]. A rich vegetation understory is important for species diversity and abundance [104].

The ground cover that is predominantly present in urban landscapes is lawn, commonly maintained below 10 cm height, which lacks heterogeneity in terms of height and species' assemblages [65]. Lawns do have the potential to contribute more to biodiversity if a transition from traditional lawns to 'tapestry lawns' takes place: these include flowering plants that create habitat for pollinators through diverse groundcovers [65]. Even on traditional lawns, different management strategies can be implemented to enhance biodiversity, such as minimising management practices, i.e., leaving leaf litter to decompose naturally and mowing lawns less frequently [67].

Vegetation can also be introduced in the form of stormwater management strategies, such as raingardens and bioswales, which provide the additional service of mitigating excessive rainfall events resulting from climate change [10,80]. If installed in an ecologically meaningful way, stormwater solutions can also act as stepping-stone habitats [79,80].

The "**Permeable area extent**" category serves as the foundation to the biodiversity assessment, in line with other 'Green Factor' tools [19,20,22,23]. Without permeable areas, none of the BSUD principles can be supported; thus, the greater the permeable area extent, the greater the likelihood of enhanced urban biodiversity [37,80,105]. However, concerns over environmental impacts of urban sprawl, housing shortages and affordability, and car dependency have led to planning for more compact cities and higher density living [106], posing significant constraints on permeable space within developments.

In New Zealand, in 2020, the government's National Policy Statement on Urban Development (NPS-UD) was introduced, directing city councils to support higher density development in five of its largest cities. In a study of four residential developments in NZ, moving from low-density to medium-density development resulted in a loss of between 61% and 67% of permeable area, even though housing unit density ranged from 25–80 per hectare [107], suggesting scope for better design for biodiversity in some developments. While introducing ecologically meaningful green spaces can be challenging, there are an array of options that increase permeable area, such as, but not limited to, the installation of green roofs [79] and the reduction of private carparks in lieu of permeable space. Reallocation of many small private greenspaces into fewer communal greenspaces to gain larger vegetation patches, as has been done in Cohousing developments [108], creates the opportunity to have more diverse and complex vegetation clusters within the same total area [109]. Policy supporting the protection and enhancement of biodiversity in residential spaces is generally lacking in New Zealand [28]; stronger policy is needed to protect vegetation and mandate minimum thresholds of permeable areas. Current policy gaps reflect a lack of understanding of the important role that built environments can have in supporting biodiversity, which limits opportunities for ecologically meaningful biodiversity outcomes [28].

The "**Street features**" category was weighted as the least important of the three NZBF-R categories and includes characteristics that can be implemented to mitigate adverse impacts on biodiversity linked to street activity: these include traffic-calming strategies, pathway characteristics and streetlight specifications. Traffic calming strategies, that is, vertical (i.e., road humps and road cushions), horizontal (i.e., roundabouts and chicanes) and street narrowing strategies, can lower traffic speed and traffic volumes, which have been linked to noise pollution, wildlife vehicle collisions and road avoidance behaviour [48,110]. Roundabouts and chicanes provide opportunities for plantings. Light pollution through artificial street lighting has been linked to changes in invertebrate community composition and global invertebrate declines due to increased predation and changes in reproductive activity [54] with the magnitude of detrimental effects dependent on light intensity [55]. Thus, the streetlight colour, duration and direction play an important role in mitigating the detrimental impacts of artificial light at night [54].

4.2. NZBF-R Case Study

The case study application of the NZBF-R provides an example of how a high NZBF-R score requires attention to detail throughout the development. The case study development included a well-executed communal green area comprised of solely native plantings surrounding a wetland. Despite this feature and an improved "Vegetation" raw score when compared to the pre-development condition, there remained areas for improvement. The plantings in other permeable areas in the development, such as the streetside vegetation and private gardens, contributed to a less diverse habitat and a lower biodiversity outcome due to the predominance and maintenance of lawns kept at below 10 cm in height.

The reduction in permeable area by 66.2% compared to the pre-development condition greatly reduced the score for that category. Tools like the NZBF-R need to accurately reflect the loss of permeable space, as the availability of permeable space is a key factor affecting the provision of habitat. Loss of permeable space can be minimised through alternative housing typologies [108,109], the removal of car-related infrastructure [10], and the use of alternative paving surfaces [11].

Additionally, application of the NZBF-R to the case study development highlighted the deficiency in light pollution mitigations, such as streetlight direction (i.e., streetlight shielding), streetlight duration (i.e., streetlight timers) and streetlight colour (i.e., CCT of 3000 K or less). These measures would aid in reducing the impact of artificial light at night on invertebrate populations [55]. Implementation of these measures would have increased the overall score by 12.8 points. Together, these strategies emphasise the importance of holistic planning to achieve greater biodiversity outcomes.

4.3. Limitations

While the NZBF-R can be deployed without the necessity for advanced ecological knowledge (except for the optional assessment of the significance of a habitat restoration) or the use of specific software skills, it is important to acknowledge some limitations. First, we have not undertaken detailed ecological surveys against which to validate the NZBF-R scores. Such surveys, which could include seasonal assessments of species richness and diversity of invertebrates and vertebrates in relation to the features of the NZBF-R, is where future research should be directed. However, the composition, extent and structure of the vegetation as well as habitat features are often assumed to be surrogates for biodiversity [59,111–113]. For example, faunal diversity, in particular invertebrate herbivore diversity, is related to vegetation cover and volume, particularly for co-evolved species [64,87,114,115]. Ecologists performing surveys commonly assume that invertebrate diversity is reflected in plant diversity, particularly in the case of native species [58,62,116,117].

Secondly, the application of the NZBF-R to masterplans is based on landscape plans that specify the maximum width and maximum height that the vegetation that is planted should grow to. Therefore, when applied to masterplans, the NZBF-R score reflects a future "best-case" scenario rather than conditions when the vegetation is first planted. This could be addressed by dividing the maximum values by a value such as a half or a quarter, to approximate a less-than-mature state. Furthermore, the NZBF-R's estimation of vegetation canopies is based on a simplified formula that assumes a uniform canopy shape, and it assumes that all planted vegetation will survive and reach its maximum potential.

5. Conclusions

With increasing demand for housing leading to more and denser developments, it is critical that new developments consider their impacts upon urban biodiversity. Doing so will ensure social, physical and psychological wellbeing benefits for residents and resilient ecosystem services. Biodiversity evaluation tools have the potential to both educate and incentivise urban professionals on how to create more biodiverse living environments. The NZBF-R differs from other Green Factor tools in its sole focus on biodiversity, with weights that explicitly value the contribution of a range of features to biodiversity, prioritising native biodiversity. The NZBF-R offers a robust framework that can guide planning and design for biodiversity and contribute to mitigating the ongoing loss of habitats. While developed for use in New Zealand, the principles behind the NZBF-R are drawn from the international literature on floral, faunal and human relationships with urban and peri-urban environments. Hence, the NZBF-R has the potential to be applied internationally, supporting developers, urban designers and planners, architects and development professionals, to create better living environments and positive conservation outcomes.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

PF 2050	Predator Free 2050
NZBF-R	New Zealand Biodiversity Factor—Residential
NPS-UD	National Policy Statement on Urban Development
NPSIB	National Policy Statement for Indigenous Biodiversity
BSUD	Biodiversity Sensitive Urban Design

Appendix A. Literature Search Process

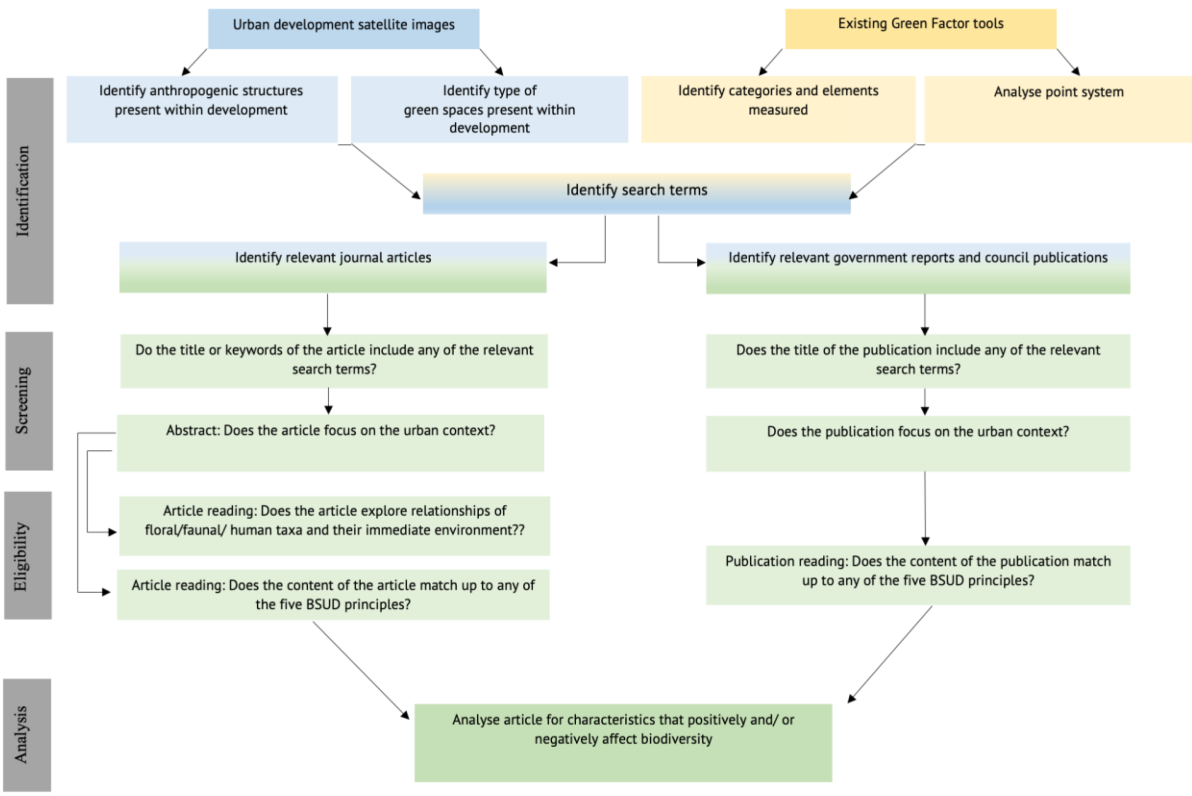

Figure A1. Systematic literature search process.

Appendix B. Expert Details

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

Expert	Area of Expertise	Affiliation
Expert 1	Entomology, biocontrol, pest management	AgResearch, Mosgiel, New Zealand.
Expert 2	Biodiversity, conservation, ecological restoration	University of Auckland, Auckland, New Zealand.
Expert 3	Restoration ecology, ecosystem health, genomics	Department of Biology, Flinders University, Adelaide, Australia.
Expert 4	Pollination science	The New Zealand Institute for Plant & Food Research Ltd., Brisbane, Australia.
Expert 5	Ecology, indigenous flora, indigenous ecosystems	Department of Conservation, New Zealand.
Expert 6	Behavioural ecology, social insects	Department of Zoology, University of Otago, Dunedin, New Zealand.
Expert 7	Biodiversity, conservation, urban ecology	Landcare Research, Lincoln, New Zealand.
Expert 8	Climate change and vegetation, ecological variation in space and time	Department of Geography, University of Otago, Dunedin, New Zealand.
Expert 9	Restoration ecology, human-nature interactions	Zealandia Te Māra a Tāne, Wellington, New Zealand.
Expert 10	Conservation biology, species restoration, reintroduction biology	Department of Zoology, University of Otago, New Zealand
Expert 11	Ecology, soils, landscape policy	Landcare Research, Lincoln, New Zealand.
Expert 12	Biodiversity, biosecurity, invasive species, urban ecology	School of Biological Sciences, University of Auckland, Auckland, New Zealand.
Expert 13	Urban ecology, entomology	Department of Zoology, University of Otago, Dunedin, New Zealand.
Expert 14	Ecosystem protection, rare species management, site evaluation, long-term restoration planning	Whirika Consulting, Dunedin, New Zealand
Expert 15	Urban ecology, predators on urban wildlife, human-wildlife interactions	Department of Zoology, University of Otago, Dunedin, New Zealand.
Expert 16	Urban native ecosystem restoration	The University of Waikato, Environmental Research institute, Hamilton, New Zealand.
Expert 17	Herpetology, urban ecology, human-wildlife interactions	Zealandia Te Māra a Tāne, Wellington, New Zealand.

Appendix C. List of NZBF-R Categories and Characteristics

Category 1: Permeable area extent

- Total development area
- Total permeable area, divided up into communal and private permeable area (as % of permeable total)
- Total non-permeable area

Category 2: Street Features

- If no streets present: Do communal driveways extend throughout the development? (yes/no)
- Number of traffic calming strategies (Qty)

- Streetlights: CCT of 3000 K or lower? (0 = no, 1 = yes)
- Streetlights: Equipped with shielding? (0 = no, 1 = yes)
- Streetlights: Timers installed, motion detectors installed, lights dimmed at night? (0 = no, 1 = yes)
- Pathways: Are pathways shared between homes? (0 = no, 1 = yes)
- Pathways: Do pathways connect to urban greenspace? (0 = no, 1 = yes)

Category 3: Vegetation
Area (square metre) covered by:

- Lawn <= 10 cm height
- Lawn > 10 cm height
- Ground cover:
    - Loose stones
    - Bark or leaf litter
    - Bare soil
- Vegetable garden
- Flower bed
- Wood piles; rotting wood
- Vegetation
    - <30 cm: native
    - <30 cm: non-native
    - 2–5 m: native
    - 2–5 m: non-native
    - >5 m: native
    - >5 m: non-native
    - Isolated tree, up to 2 m, native on non-permeable ground
    - Isolated tree, up to 2 m, non-native on non-permeable ground
    - Isolated tree, over 5 m, native on non-permeable ground
    - Isolated tree, over 5 m, non-native on non-permeable ground
- Stormwater solutions
- Bioswales
- Raingardens
- Natural water feature (e.g., lake, river, stream, wetland)
- Artificial water feature (e.g., pond)
- Proportion of isolated trees on non-permeable ground installed via soil vault system

Appendix D. Private Garden Assessment

Category 1: Habitat extent

- Total sum of private lot area
- Total sum of private impervious area

Category 2: Vegetation
Area (square metre) covered by:

- Lawn
- Ground cover:
    - Leaf litter
    - Bare ground
    - Damp soil/mud/sand
    - Rank grass
    - Rock piles

- Vegetable garden
- Flower bed
- Wood piles; rotting wood
- Vegetation
    - <30 cm: native
    - <30 cm: non-native
    - 2–5 m: native
    - 2–5 m: non-native
    - >5 m: native
    - >5 m: non-native
- Water feature (pond, wetland, stream)

Category 3: Habitat management

- Wildlife enhancement (presence/absence):
    - None
    - Native nectar producing plant
    - Bat box
    - Lizard habitat
    - Sugar water station
    - Insect hotel/insect log
- Compost bin
    - Presence/absence
    - If present: Open? Covered? Pest proof?

Category 4: Context

- Climbers: presence/absence
- Vines: presence/absence
- Predator Free 2050 neighbourhood: yes/no
- 'No cat policy' in development: yes/no
- Garden cluster score (Figure A3)

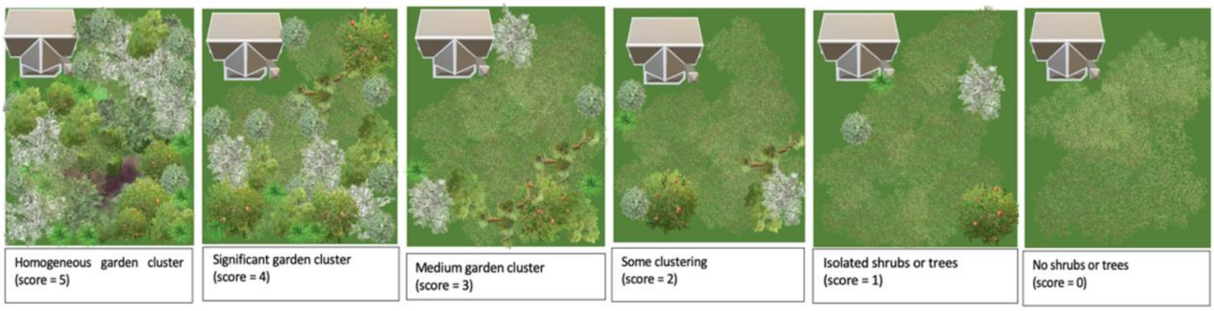

Figure A2. Private garden vegetation cluster scores.

Appendix E. NZBF-R Recommendation Output

Table A2. NZBF-R recommendation outputs.

[Neighbourhood Title]—Strategies to Improve Biodiversity Rating	
Permeable Area Extent	
"The permeable area at [neighbourhood title] takes up [permeable area] % of the overall development area. The only way to increase habitat extent within [neighbourhood title] is by reducing the amount of non-permeable area and increasing the extent of permeable areas in ecologically meaningful ways. One way that could be achieved is through converting non-permeable driveways or carparks to permeable ones, made from gravel, permeable pavers or pavers with enough space between them to allow vegetation to grow through, For other ways to increase permeable areas in ecological meaningful ways, please see below for more information."	
Vegetation	
"The vegetation characteristics of the [permeable area] at [neighbourhood title] are indicative of the habitat quality; they contribute [vegetation final score] points towards the biodiversity score of [biodiversity score]."	
Streetside and communal vegetation	
Condition	**Recommendation output**
More native than non-native vegetation is present	"There is more native vegetation than non-native vegetation present. The best way to maintain that balance and continue to increase the habitat quality is by ensuring that any newly planted vegetation is of native origin."
Equal amounts of native and non-native vegetation present	"There is an equal amount of native and non-native vegetation present. The best way to increase the habitat quality is by ensuring that any newly planted vegetation is of native origin."
More non-native vegetation than native vegetation present	"There is more non-native vegetation than native vegetation present. The habitat quality, and thus the biodiversity score, can be increased by planting more native vegetation."
Of the native vegetation present: there is more native vegetation below 2 m height than above 2 m height	"The native vegetation planted is predominantly made up of vegetation below 2 m in height. While many natives may still be growing, do make sure to plant natives of varying height categories. Planting vegetation of varying height increases the availability of habitat niches. Further, vegetation higher than 2 m and 5 m, facilitates dispersal across the urban matrix. That applies to native as well as non-native vegetation."
Of the native vegetation present: equal amount of native vegetation above and below 2 m height	"There is an equal amount of native vegetation below and above 2 m in height. Planting vegetation of different height categories is a great way to increase habitat niches and ensures dispersal facilitation in the urban matrix. That applies to native as well as non-native vegetation."
Of the native vegetation present: more native vegetation above 2 m height than below 2 m height	"There is more native vegetation above 2 m in height than native vegetation below 2 m in height. Tall vegetation is beneficial for facilitating dispersal in the urban matrix."; "Do make sure to plant the understorey with suitable native plants that are lower in height or cover the ground, to increase habitat niches. That applies to native as well as exotic vegetation."

Table A2. *Cont.*

[Neighbourhood Title]—Strategies to Improve Biodiversity Rating	
Streetside and communal vegetation	
Condition	**Recommendation output**
Greater amount of lawns kept below 10 cm height	"Lawns are kept below 10 cm. Try to minimise disturbance by mowing lawns less frequently. Invertebrates will thank you for it. :-)"
Greater amount of lawns kept above 10 cm	"Lawns are maintained above 10 cm. Invertebrates will thank you for it. :-)"
Equal amounts of lawns below and above 10 cm height	"Lawns are kept at varying heights. Try to minimise disturbance by mowing the lawns less frequently. Invertebrates will thank you for it. :-)"
More lawns present than ground vegetation below 30 cm	"There is more lawn than other ground vegetation below 30 cm. Consider planting mat-forming native plants in lieu of lawn whenever possible."
More ground vegetation below 30 cm than lawns present	"There is more vegetative ground cover below 30 cm than lawn present. This is beneficial to biodiversity as vegetative ground cover provides more habitats than lawns due to their more complex structure."
Equal amount of ground cover below 30 cm and lawns	"There is an equal amount of lawns and ground vegetation <30 cm present. Going forward, make sure that any vegetative ground cover installed at [neighbourhood title] are mat-forming plants of native origin."
Combined amount of ground cover of bare soil and loose stones outweighs that of bark and leaf litter	"There is more combined ground cover of loose stones and/or bare soil than bark and leaf litter. To increase biodiversity, and if mat-forming native ground cover is not considered, bark or leaf litter should be made the dominant ground cover to increase the availability of habitat niches."
Combined amount of ground cover of bare soil and loose stones is lower than that of bark and leaf litter	There is more bark and leaf litter than loose stones and bare soil as ground cover. Continue to use bark and leaf litter as ground cover, if not using mat-forming native ground vegetation, as they provide more habitat niches and thus greater biodiversity benefits when compared to loose stones and bare soil."
Combined amount of ground cover of bare soil and loose stones equals that of bark and leaf litter	"There is an equal amount of loose stones/bare soil and bark/leaf litter as ground cover present. In future, make sure that any ground cover at [neighbourhood title] consists of leaf litter and bark if mat-forming native ground cover is not considered."
Private gardens	
If no private gardens are present	"There are no private gardens present within the development."
If private gardens are present	"There are [number] private gardens present in the development."
If private gardens are present	"The biodiversity score for the private permeable space is [score] out of a possible score of 100."

Table A2. *Cont.*

[Neighbourhood Title]—Strategies to Improve Biodiversity Rating	
Private gardens	
If there is more non-native vegetation than native vegetation	"There is more non-native vegetation than native vegetation present. The habitat quality, and thus the biodiversity score, can be increased by planting more native vegetation."
If there is more native vegetation than non-native vegetation	"There is more native vegetation than non-native vegetation present. The best way to maintain that balance and continue to increase the habitat quality is by ensuring that any newly planted vegetation is of native origin."
If there is an equal amount of native and non-native vegetation	"There is an equal amount of native and non-native vegetation present. The best way to increase the habitat quality is by ensuring that any newly planted vegetation is of native origin."
If there is no vegetation present	"There is not enough vegetation present to provide habitats and resources for native wildlife. Consider planting native plants of different height categories to increase your biodiversity score."
If there is more lawn than other ground vegetation	"There is more lawn than other ground vegetation present. Consider planting mat-forming native plants in lieu of lawn whenever possible."
If there is more vegetative ground cover than lawn	"There is more vegetative ground cover than lawn present. This is beneficial to biodiversity as vegetative ground cover provides more habitats than lawns due to their more complex structure."
If there is an equal amount of lawns and ground vegetation	"There is an equal amount of lawns and ground vegetation present. Going forward, make sure that any vegetative ground cover installed at [Development Name] are mat-forming plants of native origin."
If there is no ground vegetation below 30 cm present	"There is no ground vegetation below 30 cm present. Consider planting native ground vegetation below shrubs and trees to increase the availability of habitat niches."
If there is no lawn or vegetative ground cover present	"There is no lawn and no vegetative ground cover present."
If there are private gardens and the average garden cluster score is less than 5	"The average garden cluster score is [X.X] points out of a possible garden cluster score of 5 points. To increase native biodiversity, urban dwellers residing at [Development Name] should be encouraged and educated about planting patches of different species of native vegetation that grow to different heights."
If there are no private gardens	"There are no private gardens present at [Development Name]. Therefore, no clustering score is obtained."
If there are private gardens and the average garden cluster score is 5	"The average garden cluster score is 5.0 points. [Development Name] has therefore achieved the highest points possible for the garden cluster section."

Table A2. *Cont.*

[Neighbourhood Title]—Strategies to Improve Biodiversity Rating	
Private gardens	
If the development is not within a Predator Free 2050 neighbourhood	"The development does not lie within a Predator Free 2050 neighbuorhood. Nevertheless, you can still do a lot to preserve and protect our precious native wildlife. Encourage urban dwellers residing at [Development Name] to put predator traps out and service them regularly. Visit https://predatorfreenz.org/toolkits/ (accessed on 1 February 2024) for more information on how to trap predators efficiently."
If the development is within a Predator Free 2050 neighbourhood	"The development lies within a Predator Free 2050 neighbourhood. That is great! Encourage urban dwellers residing at [Development Name] to aid the PF2050 vision by putting predator traps out and servicing them regularly. Visit https://predatorfreenz.org/toolkits/ (accessed on 1 February 2024) for more information on how to trap predators efficiently."
If there are no private gardens or other specified conditions	Blank.
If the development allows urban dwellers to own cats	"The development lies within an area that allows urban dwellers to own cats. Educate urban dwellers residing at [Development Name] about ways to mitigate the risks that cats pose to our native wildlife. Information can be found at https://predatorfreenz.org/stories/up-your-game-responsible-cat-owner/ (accessed on 1 February 2024)."
If the development does not allow urban dwellers to own cats	"The development lies within an area that does not allow urban dwellers to own cats. That is very beneficial to our native wildlife as cats are known to successfully hunt and kill our native wildlife."
If there are no private gardens or other specified conditions	Blank.
If wildlife enhancements are in place	"The wildlife enhancements in place are as follows: [list of relevant enhancements from native plants, bat boxes, lizard habitats, sugar water feeders, insect hotels]."
If no wildlife enhancements are in place	"Make sure to incorporate wildlife enhancements such as nectar-producing native plants. Refer to the 'Information' tab for ideas on how to incorporate these."
If no private gardens are present or no relevant data	Blank.
Street features	
Condition	**Recommendation**
No streets are present and if a driveway is present, the driveway does not extend through the development	"There are no streets and no extensive driveways present within the development boundaries of [neighbourhood title]. When there are no streets present as part of the development boundaries, there is also less likelihood of fragmentation and anthropogenic disturbance. Therefore, the absence of streets and extensive driveways scores 8 points toward the Street Features section."

Table A2. *Cont.*

[Neighbourhood Title]—Strategies to Improve Biodiversity Rating	
Street features	
Condition	**Recommendation**
No streets are present and if a driveway is present, the driveway does extend through the development	"There are no streets present within the development boundaries of [neighbourhood title]. When there are no streets present as part of the development boundaries, there is also less likelihood of fragmentation. However, the driveway extends throughout the development, thus scoring 6 points, and not possible 8 points, toward the Street Features section."
There are a higher quantity of traffic calming strategies in place than there are streets present	"Maintain the traffic calming strategies that are in place as they are beneficial to biodiversity, such as through the reduction of wildlife-vehicle collisions and noise pollution."
As many as 1/3 of streets on average have traffic calming strategies in place	"Maintain the traffic calming strategies that are in place and, if possible, consider introducing more traffic calming strategies since reduced vehicle speed is beneficial to biodiversity, such as through the reduction of wildlife–vehicle collisions."
If, on average less than 1/3 of streets have traffic calming strategies present	"Consider introducing more traffic calming strategies as reduced vehicle speed is beneficial to biodiversity, such as through the reduction of wildlife-vehicle collisions and noise pollution."
If no streetlights are installed with shielding	"The streetlights are not fitted with shielding. Investigate the possibility of retrofitting streetlights with shielding to prevent unnecessary light spread."
If some streetlights are fitted with shielding	"Not all streetlights are fitted with shielding. Investigate the possibility of retrofitting shielding on unshielded streetlights to minimise light spill."
If all streetlights are fitted with shielding	"The streetlights installed are fitted with shielding. This is beneficial to biodiversity as it mitigates light pollution and directs light to where it is most needed."
If some streetlights meet the CCT of 3000 K or less	"Not all streetlights have a CCT of 3000 K or less. A CCT of 3000 K or lower aids in mitigating the negative impacts of light pollution on (native) wildlife, such as invertebrates. Investigate the possibility of ensuring that all streetlights consistently meet the CCT of 3000 K or lower."
If no streetlights meet the CCT of 3000 K or less	"The streetlights do not have a CCT of 3000 K or less. A CCT of 3000 K or lower helps mitigate the negative impacts of light pollution on (native) wildlife, such as invertebrates. Investigate the possibility of changing the CCT to consistently be lower than 3000 K."

Appendix F. NZBF-R Biodiversity Score Calculation

Appendix F.1. NZBF-R Maximum Category Score Calculations

NZBF-R Category 1: Permeable area extent

The maximum possible score that can be achieved for "Permeable area extent" is 100, if all walkways, roads and greenspaces were permeable, and all homes had green roofs.

NZBF-R Category 2: Street Features

The "Street Features" category is based on a point system and can score a maximum of ten points (Table A3).

Table A3. Point scoring system for the NZBF-R "Street Features" category.

Condition	Points
There is a higher quantity of traffic calming strategies in place than there are streets present	2
As many as 1/3 of streets on average have traffic calming strategies in place	1
If, on average less than 1/3 of streets have traffic calming strategies present	0
Streetlights are fitted with a colour temperature of 3000 K or lower	2
Streetlights are fitted with shielding	2
Streetlights are programmed to operate on a timer or motion detector or lights are dimmed at night	2
Pathways connect to public greenspace	1
Pathways are shared between homes	1

NZBF-R category 3: Vegetation

The maximum possible score for "Vegetation" resulted in a score of 242.1. An empty plot was imagined, which was "filled" to 100% with the highest scored "Vegetation" characteristics in a realistic configuration: in detail: 70% native trees over 5 m, 60% native shrubs and trees of 2–5 m, 50% native vegetation of 30 cm–2 m, 40% leaf litter, 30% natural water feature, 20% native vegetation below 30 cm and 15% rotting wood.

Appendix F.2. NZBF-R—Biodiversity Final Score ('Biodiversity Factor') Calculation Process

To calculate the final score, NZBF-R follows five programmed, automated steps embedded in the 'Results' sheet:

1. **Transfer of raw scores to the 'Results' sheet**: The summaries of the raw scores per category achieved, as calculated in the BAT sheet, are transferred onto the 'Summary' section of the 'Results' sheet for further processing.
2. **Calculating the proportion of each category**: The proportion of each category's raw score in relation to the maximum scores possible is calculated.
3. **Application of weights to the proportions**: The weights of each category, as assigned during the weighting exercise (see Table A4 for vegetation characteristic weights), are multiplied by the proportions assigned in step 2.

Table A4. NZBF-R Vegetation characteristics' normalised weightings.

NZBF-R Vegetation Characteristics	Weight Normalised
Non-permeable areas (e.g., asphalt or concrete pavement)	0
Lawn <= 10 cm height	0.19
Lawn > 10 cm height	0.34
Ground cover: loose stones	0.27
Ground cover: bark or leaf litter	0.57
Ground cover: bare soil	0.31
Vegetable garden	0.36
Flower bed	0.44
Wood piles; rotting wood	0.68

Table A4. *Cont.*

NZBF-R Vegetation Characteristics	Weight Normalised
Ground vegetation <30 cm: native	0.75
Ground vegetation <30 cm: non-native	0.45
Vegetation, 30 cm–2 m: native	0.86
Vegetation, 30 cm–2 m: non-native	0.57
Vegetation, 2–5 m: native	0.91
Vegetation, 2–5 m: non-native	0.62
Vegetation >5 m: native	1
Vegetation >5 m: non-native	0.68
Isolated tree, up to 2 m, native on non-permeable ground	0.55
Isolated tree, up to 2 m, non-native on non-permeable ground	0.36
Isolated tree, 2–5 m, native on non-permeable ground	0.62
Isolated tree, 2–5 m, non-native on non-permeable ground	0.41
Isolated tree, over 5 m, native on non-permeable ground	0.67
Isolated tree, over 5 m, non-native on non-permeable ground	0.46
Bioswales	0.55
Raingardens	0.59
Green roofs	0.62
Natural water features (lake, river, stream, wetland)	0.89
Artificial water feature (i.e., pond)	0.38

4. **Final category scores**: The result of step 3 are the final category scores, which represent the category's contribution (%) to the overall biodiversity score, taking into account their overall importance as reflected by their weights.
5. **Calculating biodiversity score and speedometer chart creation**: The final category scores are summarised to gain the NZBF-R biodiversity score, as a proportion (%) out of 100% (best possible NZBF-R biodiversity score). Four speedometer charts are created to visualise the results across the four category dimensions.

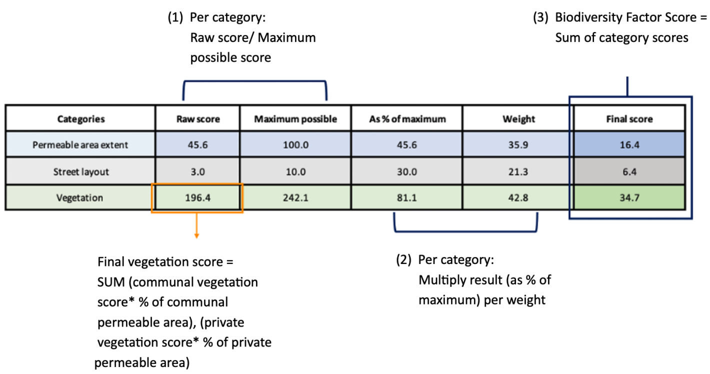

Figure A3. Step by step explanation of how the final Biodiversity Score is calculated. The final vegetation score is derived by summing the communal vegetation score multiplied (*) by the percentage of communal permeable area present, and the private vegetation score multiplied (*) by the percentage of private permeable space present.

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