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Building biodiversity into the urban fabric: A case study in applying Biodiversity Sensitive Urban Design (BSUD)

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ABSTRACT

Biodiversity within cities is fundamental for human health and well-being, and delivers a wide range of critical ecosystem services. However, biodiversity is often viewed as an afterthought or final addition once an urban development nears completion. As such, provisions for biodiversity are typically tokenistic and do not achieve the experience of everyday nature that people need. Considering biodiversity requirements at the start of an urban development allows for strategic, intentional design with biodiversity enhancement in mind. Biodiversity Sensitive Urban Design (BSUD) is a protocol that aims to create urban areas that deliver on-site benefit to native species and ecosystems through the provision of essential habitat and food resources. Here we present a case study demonstrating how BSUD methods can be used to (a) encourage successful outcomes for nature, (b) improve the aesthetics and liveability of the urban form, and (c) engage stakeholders in a process that supports other aspects of urban design including park and streetscape design. Fishermans Bend (Melbourne) is the largest urban renewal project in Australia, and one of the first of this scale to explicitly include biodiversity targets. We outline the methods used to co-create biodiversity objectives with diverse stakeholders, and how these, combined with a quantitative analysis of their potential biodiversity impact, were translated into clear design and planning recommendations. We critically reflect on the success of this method for 1) communicating and facilitating provisions for biodiversity across different stakeholders and 2) providing clear messaging around biodiversity across different planning disciplines.

1. Introduction

1.1. Why consider biodiversity in urban planning?

Urban biodiversity is an often overlooked, but key component for both human wellbeing and successful nature conservation within cities, and as such provision for biodiversity urgently needs to be better integrated into the urban planning process (Parris et al., 2018). Living in highly urbanised areas is associated with multiple physical and mental health concerns (Shanahan et al., 2019). Urban nature has an important role in human physical and psychological health (Bratman et al., 2019; Hartig et al., 2014; Kondo et al., 2018; Shanahan et al., 2019) including improved respiratory & cardiac health (Hanski et al., 2012; Lovasi et al., 2008), improved childhood cognitive development (Dadvand et al., 2015; Taylor and Kuo, 2011) and improved mental health (Kuo, 2015). However, increasing urbanisation will lead to a decrease in opportunities to access and interact with nature (Miller, 2005).

Beyond human health and wellbeing, urban nature initiatives have also been shown to improve property values, reduce maintenance costs, protect drainage systems and reduce energy consumption (Crompton, 2001; Shafique et al., 2018; Williams et al., 2014). For example, (Wolf et al., 2015) found that the value of urban forests in the United States is estimated at $11.7 billion annually in avoided health care costs. As the climate continues to warm, the urban heat island effect will be further aggravated (Rizwan et al., 2008), along with an increased frequency of extreme weather events (IPCC 2012). Planting diverse vegetation will help future-proof cities in the face of climate change, cooling cities (Bowler et al., 2010; Coutts et al., 2007; Doick and Hutchings, 2013),

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controlling storm-water runoff (Xiao and McPherson, 2002), providing shelter (Abdollahi et al., 2000) and even helping with carbon sequestration (Churkina et al., 2010).

We consider urban nature, or urban biodiversity, to include a wide range of both animal and plant species within an area, building beyond the vegetation-only focus of urban greenspace or greening (Taylor and Hochuli, 2017). Many of the human benefits gained from urban greening arise from interaction with structurally-complex and biodiverse green spaces, with a higher diversity of species delivering greater health, well-being and social benefits (Aerts et al., 2018; Parajuli et al., 2020; Schebella et al., 2019; Wolf et al., 2017). Beyond the health & social benefits of nature, there is often citizen demand for higher levels of biodiversity, a trend that persists across diverse sociocultural groups (Fischer et al., 2018). Creating every-day experiences of urban nature provides an unparalleled opportunity to re-enchant people with biodiversity, restore the frequency and strength by which human city-dwellers interact with plants and animals and create a sense of place. They may further provide a common purpose that builds a sense of community and belonging (Hartig et al., 2014; Rasidi et al., 2018; Shanahan et al., 2019). As an example, wildlife gardening programs can generate enormous amounts of social capital (Mumaw and Bekessy, 2017).

Urbanisation is one of the biggest threats to biodiversity, contributing to habitat loss, fragmentation, disturbance and pollution in nations around the world (Mcdonald et al., 2008; Miller, 2005; Shwartz et al., 2014). However, the potential of cities to contribute to global biodiversity conservation is now being recognised (Blaustein, 2013; Miller and Hobbs, 2002; Soanes et al., 2019; Threlfall and Kendal, 2018). Cities around the world host numerous threatened plant and animal species. Indeed, threatened species are often over-represented in cities, which tend to be located in areas of naturally high biodiversity (Luck, 2007; MoÈrtberg and Wallentinus, 2000; Parris et al., 2018; Schwartz et al., 2002; Soanes and Lentini, 2019). A survey of Australian cities found that 30 % of threatened species have distributions overlapping with cities (Ives et al., 2016). Some species are found only in cities, while others rely on urban areas for key food and habitat resources. The future of many threatened species will depend on actions to accommodate their needs within city boundaries (Soanes and Lentini, 2019), making cities justifiable locations for serious investment in nature conservation for its own sake.

1.2. What is Biodiversity Sensitive Urban Design?

To achieve beneficial outcomes for both people and urban nature it is important to integrate appropriate, biodiversity-focussed design protocols into mainstream urban planning and development. Integration of biodiversity in urban design and strategic planning is currently inadequate and this is exacerbated by challenges such as institutional constraints, socioeconomic considerations, an absence of clear policies and assessment targets for urban biodiversity and conflicts between stakeholders and the public (Haaland and van den Bosch, 2015; Nilon et al., 2017; Oke et al., 2021; Zuniga-Teran et al., 2020). Garrard et al. (2018) propose Biodiversity Sensitive Urban Design (BSUD) as a protocol that aims to create urban areas which have a net benefit to native species and ecological communities through the provision of essential habitat and food resources. The BSUD framework allows any trade-offs between biodiversity-benefiting actions and development-specific, socioeconomic goals to take place in a transparent and explicit way. BSUD represents a new approach to biodiversity conservation and restoration during urban developments that seeks to achieve on-site biodiversity benefits, within the urban matrix. This contrasts with the standard off-setting (off-site) approach, which reduces the opportunity for urban residents to engage with nature and risks causing off-setting cascades, leading to an overall depletion of biodiversity (Maron et al., 2016). BSUD links urban design to measurable biodiversity outcomes, providing a flexible framework for developers and planners to consider provision for biodiversity alongside socio-economic considerations, early in the development process.

To achieve on-site biodiversity benefits, BSUD must mitigate the detrimental impacts of urbanization on ecosystems, while encouraging community stewardship of biodiversity by facilitating positive human–nature interactions. Relevant ecological knowledge for addressing the impacts of urbanization is distilled into five BSUD principles (Garrard et al., 2018): maintain and introduce habitat; facilitate dispersal of plants and animals, minimize threats and anthropogenic disturbances; facilitate natural ecological processes and improve the potential for positive human-nature interactions. New developments can be planned to avoid habitat loss by protecting and enhancing existing vegetation. They can also create new habitat by adding complex and diverse native flowering vegetation, water sources, wood and stone refugia (Grimm et al., 2008; Bekessy et al., 2012; Hostetler et al., 2011; Ikin et al., 2015; Threlfall et al., 2016; Williams et al., 2014). Novel habitat analogues such as artificial nesting cavities can also be considered, along with encouraging wildlife gardening in residential gardens (Goddard et al., 2010). This supports natural ecological processes by providing resources for target species beyond traditional “green infrastructure”. Creative urban design can help facilitate local stewardship of biodiversity by providing “cues to care”(Nassauer, 1995), creating opportunities for positive interactions with nature, and addressing conflicts between biodiversity and safety objectives (Ashley et al., 2009; Hastings and Beattie, 2006; Gaston et al., 2012; Ikin et al., 2015). BSUD is intended to bring back and care for nature in the places people live, work, play and travel. An emerging body of research shows that ‘everyday nature’ plays a critical role for the future liveability of cities(Birch et al., 2020; Bratman et al., 2019; Colding et al., 2020; Giusti and Samuelsson, 2020; Harvey et al., 2020; Miller, 2005).

1.3. BSUD in action

Implementing BSUD takes place in five stages, defined by Garrard et al. (2018): 1) characterising the site-specific biodiversity values, 2) identifying development and biodiversity focused objectives, 3) assessing relevant ecological knowledge to inform specific biodiversity actions, 4) quantifying the impact of these actions on biodiversity and 5) determining which actions best satisfy all objectives. The aim of this study was to record the first real-world application of the BSUD framework and identify key challenges to overcome when working collaboratively across urban planning disciplines. Here we detail the process of applying the BSUD framework in the context of Fishermans Bend, a large urban renewal site in Australia. We describe the methods used to identify specific biodiversity objectives and design actions relevant to the development, the connectivity modelling used to assess the contribution of these actions, and the communication of explicit design and planning recommendations for the area.

2. Methods

The BSUD framework follows a linear process where each step informs the next (Fig. 1). This process is reflected in how we present our methods and results below, where we will give the methods and outcomes for each step separately. This is a real-world implementation of BSUD, which took place under the typical time and resource constraints associated with using ecological theory to provide a practical solution. As such it is not an idealised conceptualisation of applied BSUD, but it reveals how genuine challenges were overcome and demonstrates the key benefits of following the framework in a real-world application. Implementation of BSUD was undertaken as part of a larger integrated program of works to consider biodiversity, heat, wind, urban forestry and stormwater management, to inform requirements for streetscapes, open spaces and the private realm across the entire precinct.

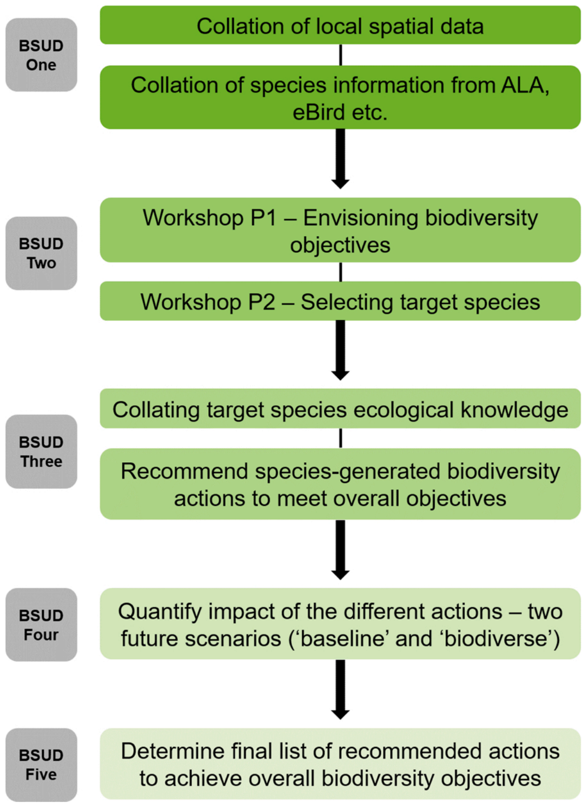

Fig. 1. Flow diagram demonstrating the process of applying the BSUD framework in the Fishermans Bend case study.

2.1. *Study location: Fishermans Bend, Melbourne, Australia*

We use the largest urban renewal project in Australia as a case study for integrating BSUD into a mainstream planning project. Fishermans Bend lies to the south east of Melbourne's CBD, running along a sweeping curve of Port Phillip Bay at the mouth of the Yarra River (Fig. 2). The Fishermans Bend district is managed by two local councils (City of Melbourne and City of Port Phillip), but is also comprised of various private and public properties controlled by businesses, water authorities and state government. Fishermans Bend is a broad-scale urban renewal project; at 480 ha, the biggest of its kind in Australia. The development will transform five precincts from low-scale industry and warehouses into mixed-use residential and commercial neighbourhoods by 2050 (DELWP 2018). Development is being overseen by The Fishermans Bend Taskforce, a diverse committee of government and other local stakeholders. Following a comprehensive resident and stakeholder engagement period and advocacy from urban conservation experts, the overarching development plan (the Fishermans Bend Framework, hereafter "the Framework") articulates eight explicit Sustainability Goals; Goal Six is to achieve "A Biodiverse Community" through the "creation of habitat opportunities for indigenous flora and fauna" and establishment of "green links" (DELWP 2018, p61). Because it considers biodiversity from the outset, Fishermans Bend presents a unique opportunity to apply the BSUD framework to identify focussed objectives for the site and develop a set of detailed recommendations to inform subsequent planning and development of the site.

The existing Fishermans Bend precincts are a mixture of industrial, commercial and residential areas with one large, native vegetation green space on the western side of the development area (Westgate Park). Outside this park area, the existing habitat resources are highly fragmented and of very low quality, with other green spaces consisting mainly of turf (Fig. 2). Due to the timescale of this project, we were not able to conduct any ecological surveys of the area before starting the BSUD process, however we collated data on the existing biodiversity value of Fishermans Bend from a range of resources (Fig. 1). Several team members had previously conducted ornithological, entomological and botanical surveys in Westgate Park and the surrounding 2 km radius. This information was supplemented by species records from the Atlas of Living Australia, eBird lists (Sullivan et al., 2009) and BioBlitz data from the City of Melbourne open data portal (City of Melbourne, 2016). This information was used to create the shortlist of suitable target species for use in the BSUD workshop.

2.2. *Identifying biodiversity objectives*

Planning for biodiversity should account for multiple types of organisms that currently live or could exist on a site and all their respective living requirements. This encompasses physical (abiotic) factors, such as access to water, light, and shelter, and biological (biotic) factors, such as food availability, nesting sites and conspecific mates. Because of these multi-layered planning aspects, focussing on the objectives for one or two species can be hard for non-specialists who are usually not familiar with local ecology. Instead, we first aimed to develop objectives which related to the overall condition of Fishermans Bend (the "look, sound and feel" of the different spaces). This values-based approach to objective setting is accessible to non-specialists, allowing an inclusive decision-making process and engaging a wide range of people (Keeney, 1994). For example, if local stakeholders envisioned seeing flowering plants in future Fishermans Bend, we then need to identify a target species to design for that would require the presence of flowering plants (e.g. an insect pollinator).

Conservation that engages stakeholder and fosters ownership of decisions increases the chance of long-term success (LaChapelle and McCool, 2005; Sketch et al., 2020). Biodiversity objectives for Fishermans Bend were identified in a stakeholder workshop on 22nd May 2019. The workshop was hosted by the Fishermans Bend Taskforce (FBT) and included stakeholders from the Victorian Government (Department of Environment, Land, Water and Planning, DELWP), local Governments (City of Melbourne, City of Port Phillip), Traditional Owners (Boon Wurrung Foundation), local environment groups (Westgate Biodiversity, Port Phillip Eco Centre) and ecological researchers (including experts in entomology, ornithology, mammology, botany and landscape ecology, from the University of Melbourne andRMIT University). Our aims for the workshop were to a) identify shared themes relating to how future Fishermans Bend should look, sound and feel to human inhabitants, and b) translate these themes into a set of target animal species that would act as a vehicle for achieving shared objectives.

In the first part of the workshop, shared themes were identified in a visioning exercise. In small groups, we asked stakeholders to think about how they would like Fishermans Bend to look, sound and feel in the future, with reference to nature. In this exercise, we prompted the participants using a series of realistic scenarios describing everyday events that may take place on the site in the future. For example, we asked the participants to imagine walking to a job interview or taking their children to sports practise. Box 1 shows an example of one of the prompts used in this visioning exercise. We asked the participants to focus on sensory experiences in the story – how a runner in Fishermans Bend might perceive a biodiverse, thriving Fisherman's Bend using all their senses. Common themes were then identified by the entire group based on feedback and discussion of the visions described by individual smaller groups.

While the shared themes provided important overarching biodiversity objectives for the site, more refined objectives are required for a quantitative assessment of biodiversity outcomes. In the second part of the workshop, we briefed the stakeholders on twelve ecologically feasible target species, which were identified prior to the workshop based on their ecological requirements and potential for community engagement and presence within Fishermans Bend or the surrounding

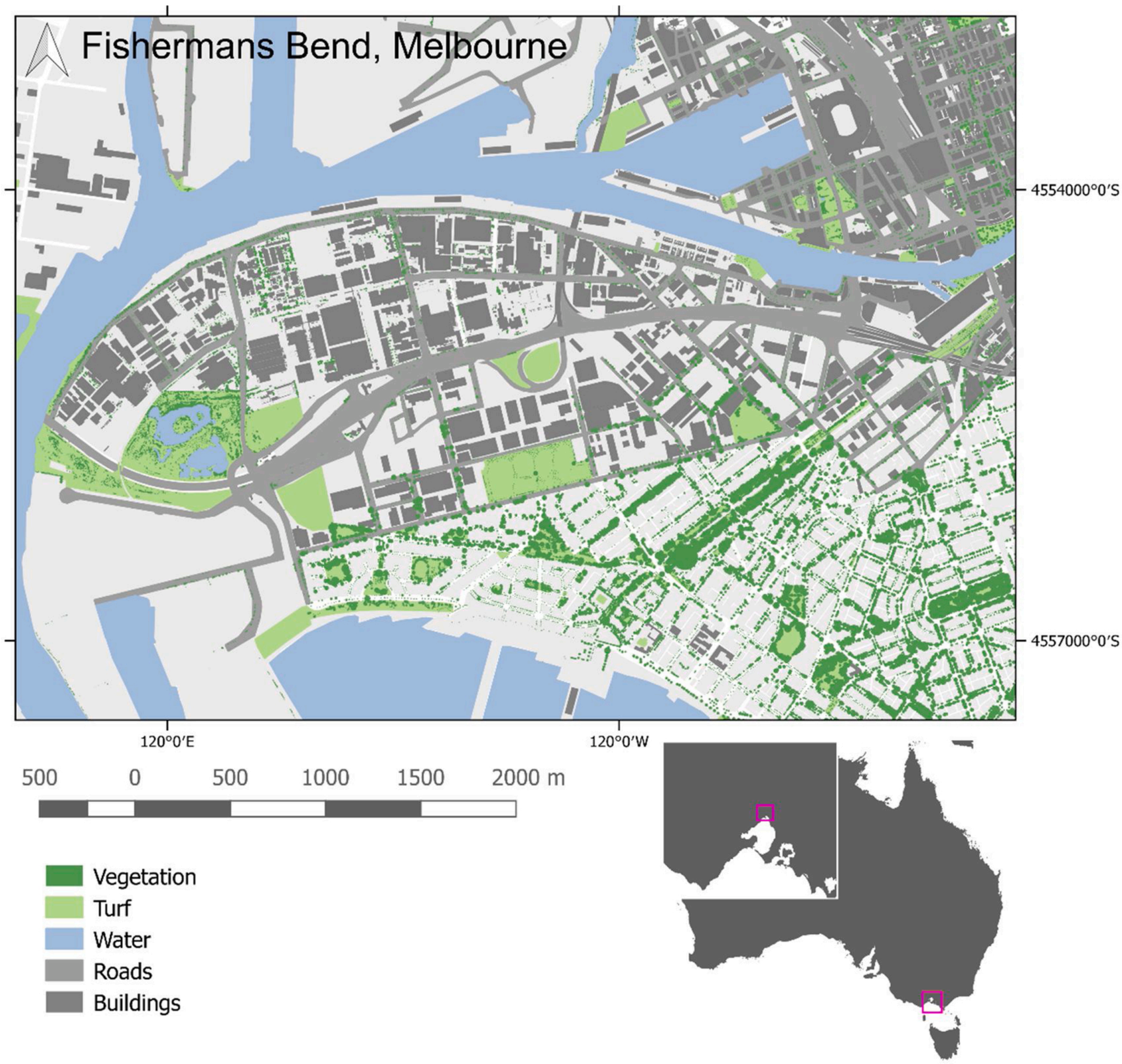

Fig. 2. Map showing the Fishermans Bend development area and location within Greater Melbourne and Australia (inset).

Box 1
Example visioning prompt.

Your mission: Have a really, really good run

"Executive life is demanding, even in the 2050s, and with average Australian life expectancies now pushing towards 170 you are still considered young at 61 – and you want to stay healthy for the century of life ahead of you. You moved over to Fishermans Bend from Canada after a fantastic honeymoon here in the 2040s. You chose a home in the buzzing Sandridge Precinct for its beautiful green corridors and walkability, but today you're set on a good 15km run. As you lace your running shoes, you decide on a route through a wetland area – you're hoping to spot a few of your favourite birds on the way."

area (Supplementary Material A, see also Mata et al. 2016). We chose to use a target species approach to achieve our overarching biodiversity objectives as a set of distinct species would allow us to design specifically for those species' ecological needs, producing the set of detailed actions needed by developers and urban planners (Apfelbeck et al., 2019). This differs from the traditional way target species have been used in non-urban conservation, as the species are not being used as surrogates for the entire novel ecosystem. In urban developments, a target species rather than a whole ecological community approach is useful for the translation of ecological theory into applied design solutions, and also allows non-specialist participation, potentially improving long-term biodiversity outcomes by fostering ownership over the decision-making process (Apfelbeck, 2020; Mata et al., 2020).

The suite of species presented to the workshop participants needed a wide range of resource requirements including open wetlands, native woodland, flowering garden beds, and hollow-bearing trees. The twelve

Table 1
Demonstration of how the five BSUD principles are linked to specific planning recommendations, through the relevant ecological knowledge for different target animal species. More examples of the BSUD recommendations for Fishermans Bend can be found in Supplementary Materials D.

BSUD Principle	Ecological requirements	Example planning & design recommendations	References
Maintain & introduce habitat	Growling grass frog - wetlands/waterbodies - water-side vegetation - logs & rocks for shelter	- Permanent natural water bodies in parks - Rain gardens/vegetated swales on streets	Heard et al., 2010, 2012; Hale et al., 2013
Facilitate dispersal	Superb fairy-wren - dense native shrubs provide cover & nest sites - roads block movement between habitat patches - habitat patches < 750 m apart	- Native garden beds with diverse & dense vegetation structure in green spaces & linear parks - Vegetated "green bridge" structures for major roads - Habitat "stepping-stones" or "corridors"	Parsons, 2008; Harrisson et al., 2013; Braschler et al., 2020.
Minimize threats & disturbances	Blue-tongue lizard - Cats & dogs are predators - Vehicle collision causes mortality	- Legislate for responsible pet ownership - Roadside boundaries & crossing structures or underpasses to connect parks	Aresco, 2005; Barratt, 1997; Grilo et al., 2010; Woinarski et al., 2018.
Facilitate natural ecological processes	Blue-banded bee (pollinator) - native flowering plants - flower resources present though different seasons - limit pesticide spraying	- Provide many different plant species to supply flower food resources throughout the year - Legislate garden management plans to reduce spraying	Brown et al., 2020; Gross, 2018; Koyama et al., 2018; Wood and Goulson, 2017.
Improve potential human-nature interactions	All species - create "every day" ways to view local wildlife - integrate nature & people	- Shared spaces such as native vegetation around sports grounds or active transport links - Informative signs to promote connections & dispel conflict	Ikin et al., 2015; Miller, 2005; Ryan et al., 1998

species focussed on locally indigenous animals, and covered a wide taxonomic diversity: three invertebrates, two frogs, two reptiles, two mammals and three bird species. During small group discussions, participants 'assessed' the potential species based on whether they provided opportunities or challenges with respect to the overarching biodiversity objectives identified in the first session. After a broader group discussion, in which some stakeholders presented additional potential target species not on the original shortlist, all stakeholders voted to determine a shortlist of seven priority species for Fishermans Bend. The specific resource and threat mitigation requirements for these species would inform general and precise design guidelines for the site, while two species from the seven were chosen for spatial modelling.

2.3. Identifying BSUD actions

Detailed resource requirements were defined for each of the two model species (Supp. Mat. B). We used a range of information sources to identify the specific habitat requirements and movement ability for each species. This included reviewing the published literature (for the chosen animals and closely related groups) and relevant conservation management plans, and consulting two species-specific ecological experts. The results of this review process were used to determine exact inputs for the connectivity models used in the evaluation step of the BSUD framework.

To create the necessary set of comprehensive design recommendations for Fishermans Bend we also characterized the resource requirements and potential threats for all seven of the priority species within the context of the area (Supp. Mat. A). We followed the five principles of BSUD to generate a road map for achieving the overall biodiversity objectives (Garrard et al., 2018). Translating the BSUD principles into meaningful urban planning recommendations required careful cross-disciplinary communication with precinct planners, landscape architects and urban foresters (Parris et al., 2018; Bush & Doyon, 2019). Table 1 demonstrates how these five BSUD principles were translated into specific planning & design recommendations, using relevant ecological information for an example target species.

2.4. Evaluating actions using spatial modelling

Following the identification of suitable biodiversity actions, the next step in the BSUD framework is to assess the ecological contributions of these actions. This can be done using numerous metrics (Garrard et al., 2018); we used a connectivity modelling approach to quantify the effect of our recommendations on the two model species (McRae et al., 2016). Ecological connectivity theory is increasingly used within conservation science to understand and mitigate the impacts of habitat loss and fragmentation on biodiversity (Tischendorf and Fahrig, 2000);Crooks & Sanjayen 2006). Ecological connectivity can be described as "the degree to which landscape facilitates or impedes movement of organisms among patches'' (Taylor et al., 1993). Connectivity is a measure of how easily an animal can move around a landscape, based on the size and arrangement of habitat patches and the capacity of the intermediate space or "matrix" to act as a barrier to movement (Kindlmann and Burel, 2008). Greater landscape connectivity improves species persistence (Hanski, 1999; Moilanen and Hanski, 2001). We chose connectivity over other methods for quantifying biodiversity improvement as it not only accounts for changes in habitat availability, but also helps to quantify the extent to which peoples' access to everyday nature is being improved.

Many of our recommendations for Fishermans Bend are based on adding or enhancing existing habitat resources in parks and roadsides around the area. Connectivity modelling allows us to directly measure the landscape-level improvement of these specific interventions on the model species based on species-specific movement behaviours across different land uses (Calabrese and Fagan, 2004; Correa Ayram et al., 2016; LaPoint et al., 2015; Lynch, 2019; McRae et al., 2016). We used an ecological connectivity analysis to compare two different development scenarios with the existing conditions in Fishermans Bend.

To inform the Fishermans Bend Biodiversity Strategy, we measured existing connectivity within the Fishermans Bend area and the surrounding landscape for two model species: growling grass frog (*Litoria raniformis*) and superb fairy-wren (*Malurus cyaneus*). These species were selected on the basis that they would act as 'umbrellas' for all seven Fishermans Bend target species (Roberge and Angelstam, 2004). Using a short-range dispersing aquatic species and a more mobile terrestrial species as model organisms means that their ecological requirements, when met, will also provide resources for a suite of additional biota (Branton and Richardson, 2011; Ward et al., 2020). The frog and fairy-wren ecological requirements are fully described in the "*Ecologically relevant BSUD actions*" section below.

We used the existing Fishermans Bend precinct plans to identify areas where potential habitat or new barriers to movement were being added to the landscape. This formed a "baseline" future scenario (Fig. 3.A), which reflected the connectivity outcomes expected from current plans for the site. We also developed a "biodiverse" future scenario, in which the additional BUSD actions identified for each target species were included (Fig. 3.B). The "biodiverse" scenario incorporated several major habitat additions such as a green link, an additional native vegetation park and several new waterbodies (see Fig. 3 and Supplementary Materials D). For each of the planning scenarios (existing conditions and two future scenarios) we estimated landscape connectivity for both species. We used a circuit theory approach to measure connectivity as this allows the spatial identification of key areas where connectivity should be preserved or improved (Dickson et al., 2019; McRae et al., 2008). Maps produced using this method are easily interpreted by non-specialists, therefore they can form an important communication tool for engaging with diverse stakeholders.

Geospatial data on existing land use were provided by the Cities of Melbourne and Port Phillip, (Fig. 2) and the Fishermans Bend Taskforce shared the initial precinct plans. Resistance surfaces were created before calculating landscape level connectivity for the two target species. Resistance surfaces are a method for quantifying how easily an animal may move across each type of land use class (Peterman et al., 2014; Spear et al., 2010). Areas with good habitat coverage for a particular species are assigned a low resistance value, whilst areas which may act as barriers to movement are assigned a higher resistance value (Grafius et al., 2017). Given the timeframe for this project and the lack of relevant field data, we used existing ecological knowledge to parameterise resistance of different land uses for the superb fairy-wren and growling grass frog (following guidance from Spear et al., 2010). Resistance values were assigned differently for our two target species to account for their different resource and habitat requirements and their different movement capabilities (Hale et al., 2013; Harrisson et al., 2013; Heard et al., 2012; Watson et al., 2008; White et al., 2005). We followed a similar rationale to Grafius et al. (2017), who assigned resistance based on land use. Core habitat patches (appropriate vegetation or water

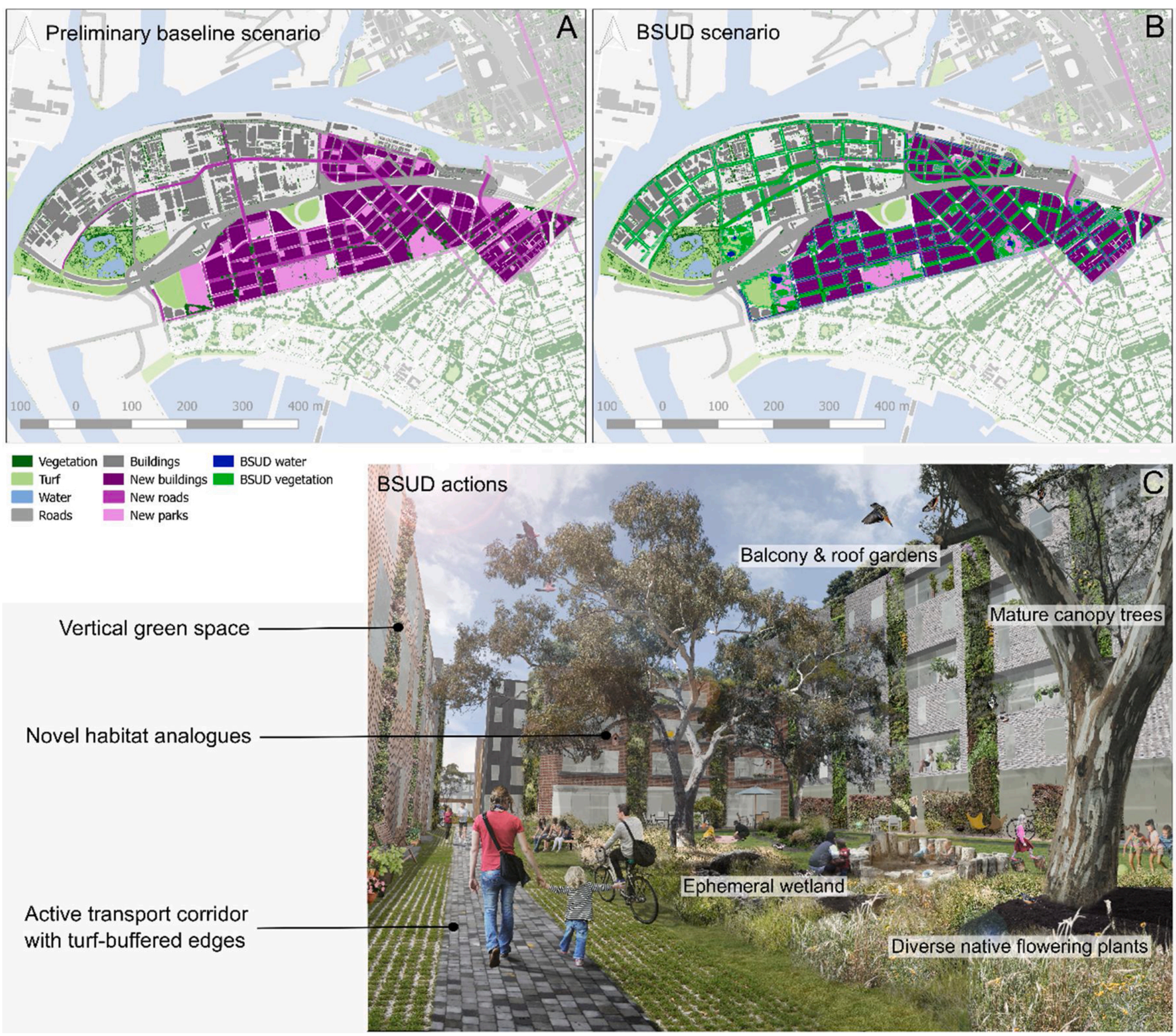

Fig. 3. Map showing the Fishermans Bend development area under the preliminary scenario used for the baseline connectivity model (A), the BSUD created biodiverse scenario (B) and an example of how the BSUD recommendations could be implemented in a residential area with a small park and active transport link (C). In the maps, purple areas show the existing development plans. Bright green and blue colours show where we recommend creating additional habitat resources. This additional habitat is in the form of green spaces, street trees, linear parks and roadway vegetation. The recommendations also included key habitat linkages across major road barriers. Panel C demonstrates how implementing BSUD can achieve "every-day nature" experiences for residents of Fishermans Bend. Artistic renderings produced by the authors in collaboration with C Horwill, J Ware & M Baracco from RMIT's School of Architecture and Design. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

features in parks) were given a resistance value of 0 and these patches act as sources/destinations in the connectivity model. Supplementary Materials C provides detailed information about the values assigned to each land use and the modifiers used to account for barriers and inter-patch distances within the landscape. To assign values to spatial data, each shapefile was first converted to a raster using the raster (Hijmans, 2019), sf (Pebesma, 2018) and fasterize (Ross, 2018) packages in R version 3.6.0 (The R Foundation, 2019). These rasters were then combined into one overall land use raster, which was then modified with an additional "distance to habitat" raster, representing the target species' estimated movement ability. (Supp. Mat. B). For illustration, the final resistance rasters based on existing habitat for both species can be seen in Supplementary Materials C. Following the same method, resistance surfaces were also created for the two alternative future modelling scenarios (baseline and biodiverse scenarios as described above).

Ecological connectivity for the Fishermans Bend area was calculated using Circuitscape 4.0 (McRae et al., 2008, 2016). This software uses resistance surfaces to compute total resistance between nodes within a landscape. In this way animal movement across the landscape is considered analogous to the flow of current in an electrical circuit. All possible pathways for animal movement are modelled to find the path of least resistance. The cumulative current for each pixel within the landscape can then be quantified, allowing comparison of different resistance surfaces. Resistance surfaces for each of the three modelling scenarios (existing condition, baseline and biodiverse future scenarios) were used alongside the locations of core habitat which were considered as focal nodes within the circuit model (Supp. Mat. B). Cumulative and maximum current was calculated in Circuitscape using the pairwise mode, where connectivity is iteratively calculated between all pairs of focal nodes (McRae et al., 2013). To quantify the connectivity for the two species in the existing landscape and two different planning scenarios, 3000 random coordinates were generated across the Fishermans Bend area. At each random location the cumulative current (calculated using Circuitscape) was extracted, allowing the mean current across the site to be calculated for each scenario, providing a measure of overall connectivity. We also computed the mean current from only those locations outside the parks and green spaces in each scenario to generate an estimate of connectivity without these circuit nodes.

3. Results

3.1. Biodiversity objectives for Fishermans Bend

The stakeholder engagement workshop identified six biodiversity objectives for the Fishermans Bend development. These objectives reflect a more accessible way of communicating the meaning of biodiversity to a broad audience, beyond the traditional measures typically used in ecology and conservation. These objectives are framed from a human perspective, reflecting what people who will live and work in the area would experience in their everyday life. As they were developed at the outset of a larger strategic investigation, the biodiversity objectives set the tone and framing for parallel investigations into heat, wind and urban forestry. The six biodiversity objectives for Fishermans Bend are as follows:

1. *A place that honours Indigenous culture* - The different spaces and habitats of the area should reflect Indigenous knowledge and stories. This should be apparent in their design, naming and function. This is an overarching objective which guides all other objectives.
2. *A place with seven seasons* - Constant seasonal change should be reflected in the flora and fauna, how places and spaces are used, and how water appears in the landscape. Seven seasons reflect both the Indigenous knowledge of local climate and better encapsulates the actual ecosystem phases in Fishermans Bend.
3. *A place known by its diverse ecosystems* - Local ecosystems and species help to identify each of the five Fishermans Bend precincts. Local habitat helps with place-making and a sense of direction when travelling through the area.
4. *A place for the senses* - Habitat areas offer scents, colours and sensations, which bring daily delight but also opportunities to feel relief and escape from the 'concrete jungle'.
5. *A place of shifting waters* – As a former area of swampland, wetlands, and periodic inundation, water is a key part of Fishermans Bend. Freshwater and brackish, ephemeral and permanent, water must be accepted within the landscape design.
6. *A place that is comfortable and beautiful in any weather* – Diverse habitat offers a range of microclimates – from shaded to open, from wet to dry and from breezy to sheltered. Species and landscape designs are selected to correspond to microclimate.

Of the twelve shortlisted species presented at the stakeholder workshop, five were chosen as biodiversity targets to guide biodiversity planning and design. These were superb fairy-wren (*Malurus cyaneus*), growling grass frog (*Litoria raniformis*), blue-banded bee (*Amigella* spp.), brolga (*Grus rubicunda*) and blue-tongue lizard (*Tiliqua scinoides*). Participants also proposed two additional taxa during the workshop: fungi, and white mangrove (*Avicennia marina*). Given these seven species' various resource requirements, their return to and persistence in Fishermans Bend will serve as an indicator that the overall biodiversity objectives have been achieved. Supplementary Material D details exactly how each species-generated biodiversity action meets one or more of the corresponding overarching biodiversity objectives.

3.2. Ecologically relevant BSUD actions

Using the BSUD framework to generate planning recommendations for Fishermans Bend from the collated ecological data we concentrated on translating the requirements of the seven target species into clear urban planning and design goals (examples provided in Table 1). These actions were linked to both the corresponding target species and biodiversity objectives (Supp. Mat. D) and, where appropriate, mapped spatially within the Fishermans Bend development area. (Fig. 3B). Fig. 3C provides a visual example of how these recommendations could be implemented in a residential area with a small park and active transport link. The full set of recommendations for all seven species are detailed in Supplementary Materials D; here we explain the ecology and corresponding planning considerations for the two species selected for modelling.

The superb fairy-wren (*Malerus cyaneus*) is a small, native bird species of south-eastern Australia that is somewhat well-adapted to living in urban environments. As an insectivorous bird species known to forage in low vegetation and grassed areas fringed by a dense, scrubby mid-storey, the superb fairy-wren is a relatively weak flier and is dependent on native shrubs for shelter and nesting sites (Harrisson et al., 2013;Parsons et al. 2008). The planting of native shrubs and trees in suburban habitats surrounding existing superb fairy-wren territories, such as the well-established Westgate Park in Fishermans Bend, could increase connectivity between territories and potentially allow the spread of superb fairy-wrens in urban areas through the establishment of new territories (Parsons et al. 2008). A major road network runs across the Fishermans Bend site, providing a significant barrier to movement and potential mortality risk (Coffin, 2007;Forman et al., 2003; Taylor and Goldingay, 2010). Vegetated crossing structures could provide a possible approach to reduce the population fragmentation effects of this main road (Braschler et al., 2020); Harrisson et al., 2013).

The growling grass frog (*Litoria raniformis*) is a large diurnal frog listed as endangered in Victoria (under the *Victorian Flora and Fauna Guarantee Act 1998,* 2002) and nationally vulnerable (under the *Environment Protection and Biodiversity Act 1999*) due to sudden and substantial population declines across much of its range (Hale et al., 2013; Hamer and Organ, 2008). Remaining populations in Victoria are isolated to the greater Melbourne area and across areas in the south west of the State. This species uses ponds or creeks with slow-flowing fresh or brackish water. This frog requires a range of waterbodies, varying in temperature and salinity as warmer, more saline ponds can be used by the growling grass frog to shed chytrid fungus, which is a key threat to the species. Waterbodies designed for this frog should have grassy, weedy or reedy edges, with submerged, floating and emergent vegetation. These waterbodies should be surrounded by grassy areas to allow movement between ponds and have rocks and logs available for shelter (Heard et al., 2008). The probability of the species persisting on sites and recolonising vacant wetlands is strongly positively related to connectivity (Heard et al., 2010). Connectivity can be provided by creating vegetated corridors between sites, making use of drains or swales. Concrete lips on the edges of roads and purpose-build crossing structures (funnelled underpasses) can decrease the risk of collision with vehicles (Aresco 2005; Grilo et al., 2010). Predation by cats is major a threat to both the fairy-wren and the frog (Barratt, 1997; Loss et al., 2013; Woinarski et al., 2018). The threat of cat predation can be mitigated through cat containment policies that require cats to be either indoors or in contained outdoor cat runs at all times (Elliott et al., 2019; McLeod et al., 2015). There is precedent for such policies in the Australian Capital Territory (Australian Capital Territory, 2020).

Based on the habitat, resource and threat mitigation requirements for these two species and ecological information on the five other target species, we identified four fundamental requirements for Fishermans Bend to guide biodiversity planning for the development of the site. We also developed 21 specific biodiversity recommendations for the site (Supp. Mat. D). These provide an appropriate level of design detail to inform the relevant urban planning departments for the site. The four fundamental BSUD requirements are as follows:

1 *Retain existing vegetation.* Vegetation is key to biodiversity enhancement in Fishermans Bend. Existing vegetation is valuable because it provides instant resources (such as tree-hollows for nesting birds) that can be immediately utilised by target species (as well as numerous other instantaneous benefits such as cooling, and restorative well-being effects). Existing vegetation also provides critical information about which parts of this highly modified site are currently suitable for hosting vegetation (Fig. 2C).
2 *Create a green active transport link.* The creation of a dedicated corridor or “green link” through the main employment precinct will also act as an active transport corridor to ensure ecological connectivity across the site. This contributes to multiple levels of biodiversity infrastructure. This link would comprise a linear park, or chain of small parks, containing diverse native vegetation and ephemeral waterbodies (or rain gardens). To retain ecological value, the link is compatible with active transport and passive recreation, but should be separate from major vehicular transport, including public transport (Fig. 2B). New development interfacing the corridor will provide additional commercial and community engagement opportunities overlooking a biodiverse rich and stimulating landscape.
3 *Enhance existing green space/infrastructure.* The contribution of green spaces and streetscapes to biodiversity should be maximised throughout the redevelopment, especially in spaces with other primary uses (such as sports grounds). This can be done by seeking to enhance the ecological function of any green space to deliver multiple outcomes. For example, enhancing streetscapes with structurally-diverse native vegetation, or including structurally-diverse garden beds around active transport and sporting ovals (Fig. 2C).
4 *Facilitate dispersal across major barriers.* Biodiverse freeway overpasses/bridges are required to mitigate significant barriers to animal movement presented by major roads that bisect the area. Without these, achieving the main biodiversity objectives is extremely unlikely. Biodiverse overpasses, or “green bridges” are compatible with active transport with some careful planning (Fig. 3B).

Twenty-one specific BSUD recommendations (Supp. Mat. D) are grouped into eleven key actions. These actions work together to achieve the overarching biodiversity objectives:

1 Include and enhance water in the landscape
2 Plant diverse native understorey vegetation
3 Plant diverse canopy trees
4 Create “green bridges” across major roads
5 Create animal underpasses to connect parks for terrestrial species
6 Create a new, biodiversity focussed park
7 Consider biodiversity in the built form across the site
8 Create biodiverse podium gardens on office and apartment blocks
9 Convert parking spaces to parks
10 Create a “green link” for people and nature to connect precincts and parks
11 Provide guidance on management of, and resources for, biodiversity in, on and around residential buildings

3.3. *Quantifying potential impact of the BSUD actions*

For each of the two model species, existing connectivity was compared to connectivity under two future scenarios for Fishermans Bend. Both future scenarios showed reduced overall resistance to movement and increased connectivity across the landscape (Table 2 and Figs. 4 & 5). However, when considering mean connectivity, the biodiverse scenario (produced using the BSUD framework) out-performed the baseline scenario (the preliminary development plans for Fishermans Bend) by 2.5 times for the fairy wren and 8 times for the growling grass frog (Table 2). When considering the connectivity of the intervening landscape outside existing and future potential parks or green spaces, the biodiverse scenario again out-performed the baseline scenario (Table 2, Fig. 6). These increases were due to the addition of critical new habitat connections. Of particular importance for the superb fairy-wren were the “green bridges” used to mitigate the extreme barrier effect of the major road system that bisects the Fishermans Bend area (the Westgate Freeway, see panel D, Fig. 2). The “green link” in the employment precinct was key for the growling grass frog (panel D of Fig. 4). The biodiverse scenario for the superb fairy-wren also represents the provision of at least 2.82 km^2 (24 % area cover) of good quality understorey vegetation and green space in the Fishermans Bend area. The biodiverse scenario for growling grass frog represents the provision of 1.59 km^2 (14 % area cover) of waterbodies, ephemeral waterways, understorey vegetation and turf.

Table 2
Summary results from the connectivity analysis using Circuitscape, showing the different habitat scenarios for each of the two target species. Mean overall landscape current can be interpreted as mean connectivity across the landscape, which increases as overall landscape resistance decreases.

	Habitat scenario	Overall pairwise resistance	% change	Mean overall current (St. dev.)	Mean current (sampled outside parks) (St. dev.)
Superb fairy-wren	Existing	318.1		0.05 (0.22)	0.002 (0.003)
	Baseline	286.5	−9.9	0.12 (0.47)	0.003 (0.007)
	Biodiverse	265.2	−16.6	0.31 (1.04)	0.015 (0.03)
Growling grass frog	Existing	984.8		0.02 (0.14)	0.002 (0.002)
	Baseline	979.5	−0.5	0.02 (0.14)	0.002 (0.02)
	Biodiverse	882.1	−10.4	0.16 (0.79)	0.034 (0.03)

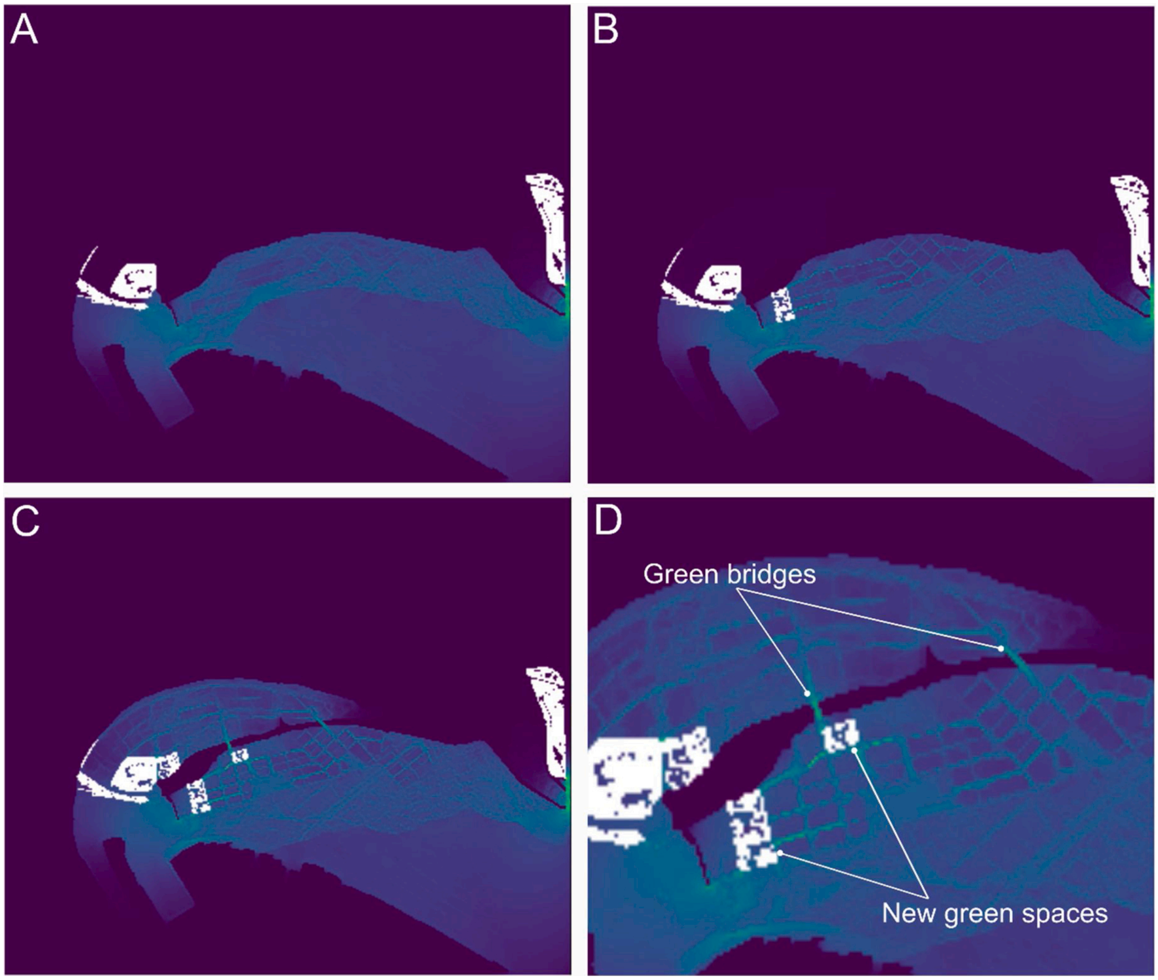

Fig. 4. Connectivity maps for the superb fairy-wren (*Malarus cyaneus*) showing cumulative current for existing habitat (a), two future scenarios for Fishermans Bend: baseline (b), biodiverse (c) and detail of the best-case scenario connectivity highlighting the BSUD actions including two "green bridges" and additional green spaces (d). Lighter colours show greater flow of current (increased connectivity) across the landscape. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4. Discussion

We present the first application of the BSUD framework in a real-world scenario, demonstrating that comprehensive planning for biodiversity is possible, even within a highly urbanised environment, under considerable time constraints. By identifying and planning for broad biodiversity objectives in Australia's largest urban renewal site, we should improve outcomes for native species. For our target species, these improvements provide between 2.5 and 8 times the landscape connectivity than would be provided by a development scenario that did not consider biodiversity objectives. Our recommendations will also increase the habitat & resources available for all target species in Fishermans Bend and lead to a reduction in threatening processes

4.1. Translation of biodiversity objectives into design and planning objectives

The strength of this approach for determining biodiversity objectives for Fishermans Bend is that it translates the high-level values and visions of key stakeholders into species targets and design recommendations. Based on our research, we developed specific BSUD actions relating to key urban landscape features in Fishermans Bend. However, three fundamental principles may be applied more broadly to planning decisions to deliver high-quality biodiversity outcomes in urban environments:

1 *Diverse vegetation.* For all canopy, mid-storey and understorey plantings, ecological outcomes will be enhanced when the diversity of species, diversity of structure and nativeness of vegetation are maximised (Beninde et al., 2015; Threlfall et al., 2016, 2015). Plantings should aim to provide multiple resources for animal species, including shelter (e.g. dense, protective shrubs), food (e.g. flowers/fruits) and nesting sites (e.g. tree cavities). Further consideration of the optimal spatial arrangement of biodiverse vegetation (i.e. through targeted modelling of emerging precinct plans and designs), soil depth, water requirements and width of plantings is required to deliver biodiversity outcomes through vegetation, as well as detailed guidance on suitable species for the area.

2 *Compatible/incompatible uses.* Most native animal species will not regularly utilise areas immediately next to major vehicular transport routes (Forman et al., 2003; Coffin, 2007; Taylor and Goldingay, 2010). Therefore, critical biodiversity enhancement actions should not be prioritised in places with high volumes of vehicular transport, including public transport. While enhancements and green infrastructure such as trees and other vegetation may provide some supplementary biodiversity benefits along major transport routes, these corridors are not suitable for the provision of meaningful biodiversity outcomes (Coffin, 2007; Holderegger and Di Giulio, 2010). Areas with high volume public use, such as sports grounds or high use active spaces and uses with high levels of noise and light at night may also be incompatible with biodiversity; however, mixed-use areas can deliver

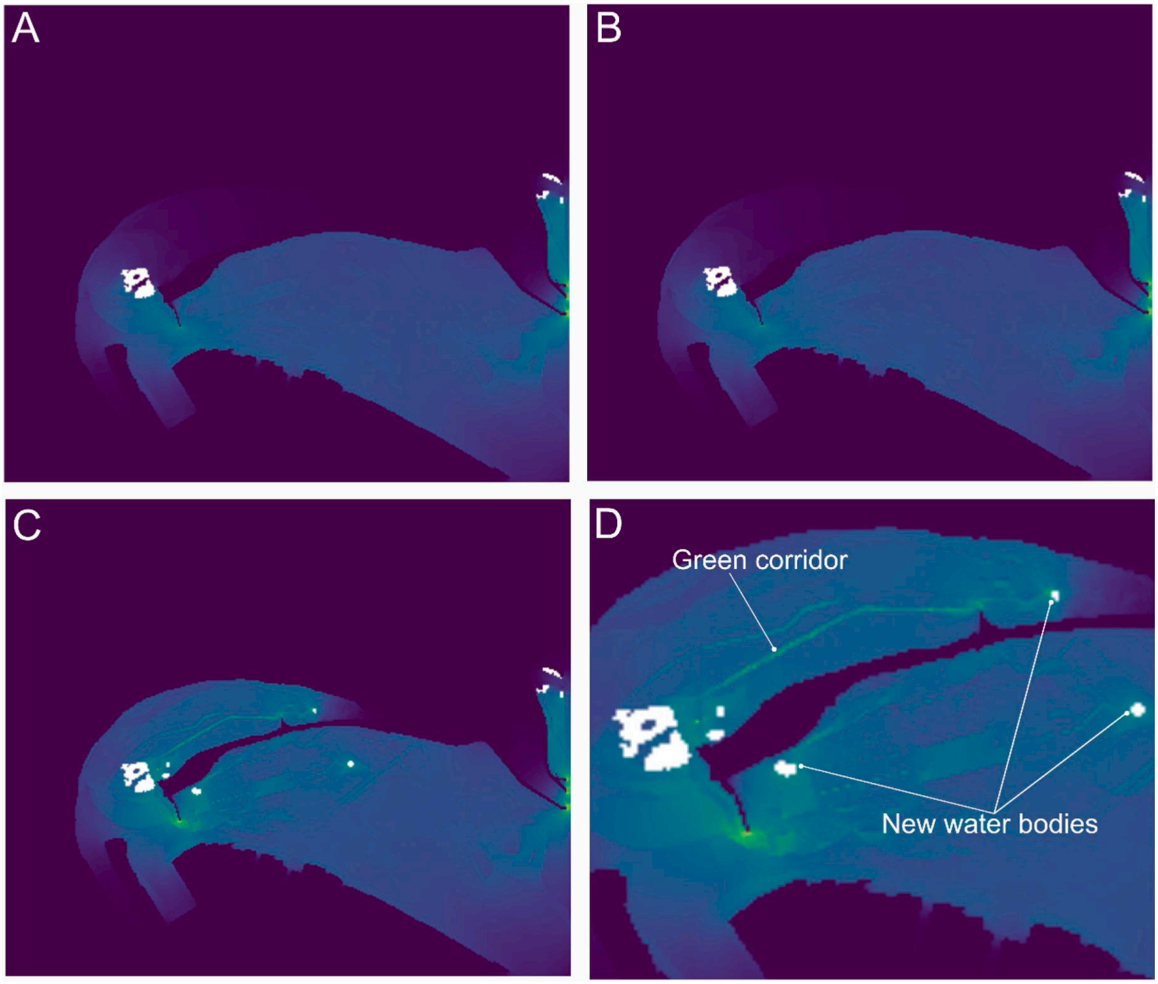

Fig. 5. Connectivity maps for the growling grass frog (*Litoria raniformis*) showing cumulative current for existing habitat (a), two future scenarios for Fishermans Bend: baseline (b), biodiverse (c) and detail of the best-case scenario connectivity highlighting the BSUD actions including a "green link" and additional water bodies (d). Lighter colours show greater flow of current (increased connectivity) across the landscape. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

biodiversity outcomes with careful and considered planning. Land uses compatible with biodiversity include active transport (walking and cycling), nature play, passive recreation and low volume transport routes such as neighbourhood streets (Lynch, 2019).

3 *Guidance needs to be systemised.* Following the principles of BSUD (Garrard et al., 2018), action within both the private and public realms is important. However, developments the size of Fishermans Bend likely require the preparation and publication of BSUD guidelines in a manner that is digestible to planners and developers, in collaboration with ecological experts. Existing and proposed assessment tools (such as Green Star, Green Factor and BESS in Australia) may be useful for sustainable development but would require review and enhancement to adequately consider and meet biodiversity objectives for the site, as none of these instruments link species persistence to design scenarios. Guidance should be sought from ecological experts about species choice, vegetation structure and design of novel habitats. Provision of systematic guidance and monitoring has been identified as a key factor for urban biodiversity planning (Haaland and van den Bosch, 2015; Nilon et al., 2017).

4.2. Potential of the BSUD process

The Fishermans Bend redevelopment represents an opportunity to develop an urban area in which biodiversity thrives rather than being removed or side-lined. If successfully implemented, BSUD has the potential to substantially improve the value of the Fishermans Bend site for biodiversity conservation; preserving remnant vegetation, enhancing degraded sites and bringing species back to the site that have been absent for some time. The results of our modelling indicate that these actions would increase connectivity for both the superb fairy-wren and growling grass frog. The urban landscape is ecologically fragmented, but the design of a network of corridors and quality habitat patches could lead to Fishermans Bend making a significant positive contribution to Melbourne's urban biodiversity (Beninde et al., 2015). The concept of connectivity is also used in metapopulation theory, where the probability of species persistence is linked to the degree of connectivity within a landscape (Hanski, 1999; Moilanen and Hanski, 2001). Studies demonstrate that greater landscape connectivity leads to better population viability through improved occupancy, dispersal ability and gene flow (e.g. Cruickshank et al., 2020; Grafius et al., 2017; Harrisson et al., 2013; Lynch, 2019 and many others). We used an ecological connectivity index approach for this BSUD application as one of the aims for Fishermans Bend is increasing people's access and interaction with nature. By using a connectivity index as a measure for the success of our BSUD recommendations rather than population viability analysis we a) avoided issues surrounding the lack of data needed for a population model and b) to some extent quantified how wildlife might share the matrix of land-uses with people.

While our ecological findings can provide recommendations for design and planning, tangible outcomes will only be achieved through

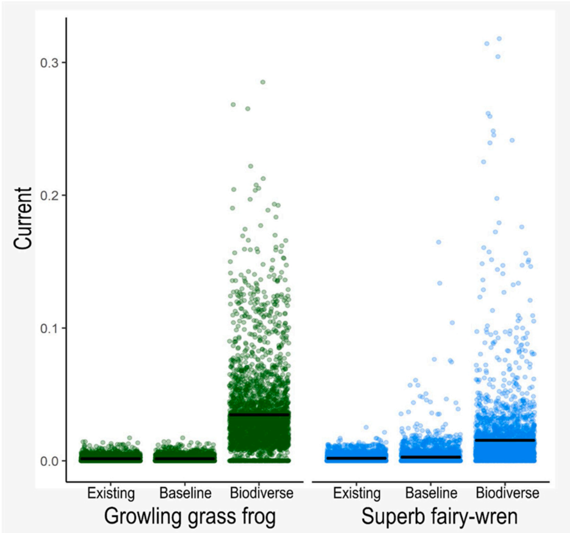

Fig. 6. Connectivity calculated from each of the cumulative current maps for each of the model species (growling grass frog, *Litoria raniformis* in green, superb fairy-wren, *Malarus cyaneus* in blue). Data from the existing landscape, and the two future scenarios, baseline and biodiverse is displayed with the mean current (black line). The samples shown here were taken from locations across the Fishermans Bend development area, but outside parks or green spaces. The increase in cumulative current across the landscape occurs as land use classes are altered, reducing resistance to movement in the two potential development scenarios for Fishermans Bend. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

effective implementation on the ground. Our recommendations were presented to the Fishermans Bend Taskforce (FBT) in a series of follow-up workshops where the biodiversity objectives were enthusiastically championed by a diverse range of participants. By considering shared human visions for the future of Fishermans Bend, we were able to target our recommendations towards creating liveable and desirable precincts. Engaging with a diverse set of stakeholders from the outset, and communicating in universally understood terms, we assembled a set of overarching biodiversity objectives for the development. These were understood by all and mutually agreed upon. This meant that when we presented our detailed actions for achieving the biodiversity objectives, we had already overcome one of the obstacles to urban biodiversity provision (Nilon et al., 2017).

Key challenges for successful urban biodiversity conservation include balancing human perceptions of biodiversity, ongoing management decisions and the needs of diverse stakeholders with ecological requirements (Aronson et al., 2017). Following the BSUD framework also allowed for clear translation of specific ecological requirements into urban planning and design recommendations, which could be integrated with other development objectives and targets. Early stakeholder engagement meant that people were on board with the detailed biodiversity targets and design recommendations that we developed later in the process. Participants clearly understood that prioritising biodiversity is necessary for delivering the overarching, co-developed vision for Fishermans Bend (Tribot et al., 2018). This clear communication allowed us to overcome another key barrier in urban biodiversity planning, leading to effective cross-disciplinary collaboration (Aronson et al., 2017; Soanes et al., 2019; Shwartz et al., 2014).

4.3. *Thoughts for the future*

Applying the BSUD framework to the Fishermans Bend development at the beginning of the planning and design process meant that biodiversity has remained a key consideration in strategic discussions. Biodiversity actions were considered holistically in the exploration of streetscape, open space and private realm requirements, combining with outcomes from parallel investigations into heat, wind and urban forestry. The influence of the biodiversity recommendations was strengthened through a collaborative effort involving researchers and private consultants, who each brought different skills and knowledge to the process. Working as a team increased the incorporation of biodiversity solutions within the broader scope. For example, early in the design process the experts focussing on mitigating heat and wind identified our vegetation and water design recommendations as ideal creative solutions for their own requirements. This experience indicates that there are many benefits from collaboration between the academic and consulting sectors.

There were elements of the BSUD framework that we could not apply in our work for the Fishermans Bend site. Partly this was due to the restricted time-frame available at this stage in the planning process. Limitations also arose from the lack of fine-grained biodiversity data for the site pre-development, which is required for BSUD, even on urban renewal sites. As planning for Fishermans Bend progresses, the BSUD framework should be applied at a smaller scale to individual land parcels, and here we encourage all future users to collect information on the existing biodiversity assets present (Garrard et al., 2018; Ikin et al., 2015; Parris et al., 2018).

Future work on the site could be substantially improved by incorporating modelling of a greater number of species, with a diversity of dispersal abilities. While we quantitatively evaluated the connectivity for the two target species under each scenario, including a population viability analysis would deliver a more comprehensive evaluation of species persistence. The two species tested have restricted dispersal capabilities and specific habitat requirements making extrapolation to other urban species more difficult. Furthermore, a wider range of scenarios could have been tested had more information been provided by the FBT on existing plans for the area. This would allow prioritisation of different spatial locations for the planned mixed-use and biodiversity focussed green spaces.

A key challenge in planning for urban biodiversity is a lack of target provision, which can help with goal setting and understanding when success has been achieved (Haaland and van den Bosch, 2015; Nilon et al., 2017; Shwartz et al., 2014). We did not have the data needed to provide quantitative recommendations (e.g. minimum % canopy cover or number of understorey garden beds) and we acknowledge that these numbers would provide the FBT with some simple goals to work towards. In addition, we encourage the exploration of different ways to communicate BSUD actions in a language that is appropriate for building and planning professionals. This also includes communicating where legislative changes need to be made. For example, ensuring mechanisms for the protection of existing and introduced biodiversity assets (through maintenance and management of threats) requires planning beyond the physical construction phase. Existing vegetation protection regulations may also not be sufficient to ensure the ongoing protection of planted vegetation and constructed ecosystems (Soanes and Lentini, 2019).

We incorporated Indigenous perspectives to the extent possible, given the time and resources available for us to undertake this research. Whilst we ensured Indigenous participation during our workshop, having Indigenous scholars as part of the research team would be preferable. Although the biodiversity actions we have recommended may reflect Indigenous culture and principles, without more substantial collaboration and involvement of Traditional Owners the first objective can only be partially achieved. There is potential to substantially improve the design of the site through deeper Indigenous engagement; for example through selecting culturally significant species to reintroduce to the site (Mata et al., 2020), incorporating principles of Caring for Country in landscape planning and site maintenance (City of Melbourne 2016) and educational signage to build knowledge and respect for Indigenous culture.

5. Conclusions

Planning for biodiversity is complex and requires multiple levels of expertise. Ecological knowledge can be leveraged and translated into easily communicated urban planning and design objectives through the BSUD process. Key stakeholders have verbally shown support for biodiversity objectives and solutions during workshops. The Fishermans Bend redevelopment is not due for completion until 2050, meaning that empirical assessment of the actual biodiversity benefits from this application of the BSUD framework is not yet possible. Application of BSUD principles in Fishermans Bend could play an important role in developing an evidence base for the ecological and socioeconomic outcomes that are possible in urban renewal development designed with nature as a key priority. Delivering BSUD in Fishermans Bend will provide much-needed opportunities for action-research to resolve outstanding question such as: Can we modify the spatial arrangement of urban vegetation to maximize daily interactions with nature and diversity of species? What type of vegetation is best for temperature regulation, psychological restoration or stormwater treatment? How successful were our attempts at developing nature-based solutions for planning conflicts? These and many more warrant ongoing investigation.

Author contributions

Holly Kirk: Conceptualisation, Methodology, Data curation, Formal analysis, Writing – original draft. **Georgia Garrard**: Conceptualisation, Methodology, Writing – original draft. **Thami Croeser**: Investigation, Methodology, Writing – review & editing. **Anna Backstrom**: Investigation, Writing – review & editing. **Katherine Berthon**: Investigation, Writing – review & editing. **Casey Furlong**: Writing – review & editing. **Joe Hurley**: Investigation, Methodology, Writing – review & editing. **Freya Thomas**: Investigation, Writing – review & editing. **Anissa Webb**: Writing – review & editing. **Sarah Bekessy**: Conceptualisation, Methodology, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug.2021.127176.

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