Fishermans Bend Urban Ecology Strategy: Biodiversity Report

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Executive Summary

This report details a set of planning recommendations for creating biodiverse precincts in Fishermans Bend, along with the methods and rationale used to determine these recommendations.

Key biodiversity objectives were identified during a stakeholder workshop. These were used to identify target or umbrella species for modelling, the rationale being that if these species persisted within Fishermans Bend then the following objectives would have been achieved:

- A place that honours Indigenous culture
- A place with seven seasons
- A place known by its diverse ecosystems
- A place for the senses
- A place of shifting waters
- A place that's comfortable and beautiful in any weather

Opportunities for biodiversity actions were identified across the different precincts, based on the existing precinct plans. These were developed into two modelling scenarios: 1) a baseline scenario that included current plans for additional green spaces, streetscape and canopy cover, 2) a biodiverse scenario that included additional opportunities for biodiversity-enhanced green spaces, streetscapes, canopy cover and novel habitat additions such as a Green Link and Green Bridges.

Habitat requirements and potential barriers to movement or risks were identified for two species: Superb Fairy-wren and Growling Grass Frog. These were used to create resistance maps for each of the two future scenarios (baseline and biodiverse). Connectivity modelling demonstrated that both scenarios improved ecological connectivity across Fishermans Bend for both the fairy-wren and the frog. However, quantitative comparison showed the biodiverse scenario out-performed the baseline scenario, with ecological connectivity 4.5 times higher on average.

Recommendations

In order to deliver high-quality biodiversity outcomes, three overarching and fundamental principles should be considered when making planning decisions about Fishermans Bend:

- *Vegetation* - across all Fishermans Bend precincts, diversity of species, diversity of structure and nativeness of vegetation should be prioritised
- *Compatible/incompatible uses* - critical biodiversity enhancement actions should not be prioritised in places with vehicular transport, including public transport.
- *Biodiversity sensitive urban design* - the principles of BSUD (Garrard et al 2018) should be followed in every aspect of development, both within the private and public realms

Six key groups of detailed recommendations are provided as a roadmap for achieving the key biodiversity objectives for Fishermans Bend.

Acknowledgements

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1. Introduction

Scope of this report

This report describes a set of biodiversity planning recommendations for the Fishermans Bend renewal project in Melbourne, Australia. The biodiversity recommendations form part of an Urban Ecology Plan for the re-development, led by GHD. Throughout this process the ICON Science team have followed the principles of Biodiversity Sensitive Urban Design (described below) to identify ways that net benefits for biodiversity can be achieved at Fishermans Bend. The main aim of these recommendations is ensuring that the renewal project meets Goal Six of the eight Sustainability Goals laid out in the Fishermans Bend Framework ("Goal 6: A Biodiverse Community", DELWP 2018.) This report details the methods used to: 1) identify broad biodiversity objectives for Fishermans Bend; 2) select target "umbrella" species that can used to achieve the biodiversity objectives; and 3) undertake quantitative modelling of the ecological connectivity created by different planning scenarios for Fishermans Bend. Based on resource requirements of the umbrella species and the results of our analysis, we make 11 biodiversity recommendations that support the achievement of key biodiversity objectives for Fishermans Bend.

Biodiversity Sensitive Urban Design

Biodiversity Sensitive Urban Design (BSUD) is a protocol for urban design that aims to create urban areas that are a net benefit to native species and ecosystems through the provision of essential habitat and food resources (Garrard et al. 2018). BSUD represents a new approach to urban biodiversity conservation that seeks to achieve biodiversity benefits on site, within the urban matrix. This contrasts with the standard offsetting approach, which reduces the opportunity for urban residents to engage with nature and, at the same time, delivers questionable ecological outcomes (Maron et al. 2016). Given the highly modified nature of the Fishermans Bend site, biodiversity sensitive design that aims to restore and recover ecological function will be required to deliver *A Biodiverse Community* at the site.

BSUD links urban design to measurable biodiversity outcomes, providing a flexible framework for developers and planners to consider biodiversity alongside socio-economic considerations, early in the development process. The decision process underpinning BSUD is shown in Figure 1. Briefly, the process involves documenting biodiversity values, identifying biodiversity and development objectives, identifying potential BSUD actions, assessing those actions and reaching a final decision regarding a design for the site that best meets biodiversity and socio-economic objectives.

To achieve on-site biodiversity benefits, BSUD must mitigate the detrimental impacts of urbanization, while encouraging community stewardship of biodiversity by facilitating positive human–nature interactions. We have distilled relevant ecological knowledge for addressing the impacts of urbanization into five BSUD principles (Garrard et al. 2018):

(1) Maintain and introduce habitat

New developments can be planned to avoid habitat loss by prioritizing development in areas of low ecological value (Bekessy et al. 2012). At highly modified sites, retaining and protecting existing vegetation during the development process critical for biodiversity (Hostetler 2012; Ikin et al. 2015). Habitat can be enhanced or created in existing urban areas by using native plant species and increasing vegetation complexity (Ikin et al. 2015; Threlfall et al. 2016), adding green infrastructure (Williams et al. 2014) or incorporating critical resources and habitat analogues, such as habitat walls (Lundholm & Richardson 2010). Residential gardens can be significant habitat, so resident-led wildlife gardening programs can make a valuable contribution to biodiversity (Goddard et al. 2010).

Figure 1. Biodiversity sensitive urban design describes a decision-making process in which biodiversity objectives are considered alongside other socio-economic development objectives, early in the planning process. From Garrard et al. (2018)

(2) Facilitate dispersal

Dispersal can be facilitated by adding animal movement infrastructure (Taylor & Goldingay 2012) or establishing habitat connectivity corridors through private and public land (Goddard et al. 2010). Care should be taken to avoid inadvertently facilitating the spread of invasive weeds and pests.

(3) Minimize threats and anthropogenic disturbances

The impact of weeds and exotic predators can be reduced by landscaping with indigenous plants and establishing pet containment programs (Ikin et al. 2015). Increased runoff and nutrient loads can be mitigated by vegetated swales and rain gardens which, with consideration, can also deliver additional biodiversity benefits through the provision of habitat or other key resouces. The impact of noise and light pollution can be mitigated by sound barriers (although take care that this does not affect dispersal), temporary road closures and dimming or reconfiguring streetlights (Gaston et al. 2012).

(4) Facilitate natural ecological processes

The disruptive effects of urbanization on natural cycles, ecological processes and disturbance regimes (Grimm et al. 2008) can be mitigated by providing adequate resources for target species, protecting and enhancing pollinator habitat, and planning to safely enable natural disturbance events such as ecological fire and flooding.

(5) Improve potential for positive human–nature interactions

Cities are human environments and public engagement is key to successful conservation (Cooper et al. 2007). 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 (Ikin et al. 2015) or potential ecosystem disservices.

Why BSUD?

Biodiversity Sensitive Urban Design is designed to bring back and care for nature in the places people live, work, play and travel. An emerging body of research is revealing that this notion of ‘everyday nature’ plays a critical role for the future liveability of cities, beyond concerns for biodiversity. The numerous co-benefits of implementing BSUD are highlighted in Figure 2 and are outlined below.

Community health and wellbeing

Nature in cities delivers a remarkable range of human health and well-being benefits. In 1984, Roger Ulrich published the first study to suggest these benefits, when he chanced upon a link between improved surgical healing times and a view of nature. Since then, numerous studies have revealed a multitude of benefits to interacting with nature in our daily lives. Children living in streets with trees will have lower incidence of asthma (Lovasi et al. 2008) and allergies (Hanski et al. 2012) and those with nature in their schoolyards will have improved cognitive development (Dadvand et al., 2015)and lower incidence of ADHD (Faber Taylor & Kuo 2011). Adults are less likely to die from heart disease, diabetes and cancer (Kuo et al. 2015). If you are lucky enough to have regular contact with nature, you will sleep better, have reduced stress levels, reduced risk of poor mental health, a better social life and improved self-esteem and empowerment (Kuo et al. 2015). Indeed, you are more likely to live longer and have better general health and well-being in a city with more biodiversity.

Future proofing our cities in the face of climate change

Cities are warmer than adjacent suburban and rural environments due to the 'urban heat island effect' (Rizwan et al. 2008). This pervasive global phenomenon exacerbates the major threat that heat stress poses to human health and well-being in many cities. The heat wave and fires in Melbourne 2009 that contributed to the deaths of over 500 people is a potent example. Climate change will further aggravate the impacts of the heat island effect, increasing the severity and frequency of extreme weather events (IPCC 2012). Rising sea levels, variable rainfall patterns and destructive cyclones will continue to threaten homes and medical infrastructure whilst compromising the supply of energy and fresh, potable water. In turn, these impacts increase the risks of infectious diseases and mental disorders (WHO 2015). Vegetation in and around cities can deliver a range of ecosystem services critical for climate change adaptation and mitigation. Through evapotranspiration, shading and reflectance, the vegetation present in urban green spaces can cool cities substantially, at least partly ameliorating the heat island effect (Bowler et al. 2010). Greening interventions have the potential to cool cities by up to eight degrees in summer (Doick 2013), importantly reducing overnight temperatures, which is a key determinant of heat-related mortality (UK Dept Health 2008). Vegetation in cities can provide other important climate change adaptation services including alleviating the impacts of flooding by reducing peaks in storm-water runoff (Xiao & McPherson 2002) and providing shelter from extreme weather events (Abdollahi, Ning & Appeaning 2000). Finally, vegetation in cities can play a significant role in mitigating climate change impacts by sequestering greenhouse gases (cities can store as much carbon per unit area as tropical forests (Churkina et al. 2010)) and reducing energy consumption for cooling and heating (Coutts et al. 2007).

Cities are hotspots for threatened species

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). A recent survey of Australian cities, found that, per unit area, cities supported more than three times as many threatened species (Ives et al., 2016). Some species are found only in cities, while others rely on cities for key food and habitat resources. The future of many threatened species will depend on actions to accommodate their needs within city boundaries, making cities justifiable locations for serious investment in nature conservation for its own sake.

An emerging body of evidence suggests that green spaces with a higher diversity of species deliver greater health, well-being and social benefits than less diverse spaces (Fuller et al. 2007). Many of the positive benefits of urban greening arise from interaction with structurally complex and biodiverse green space. Furthermore, structural and species diversity will improve the robustness of green infrastructure in the face of threats from extreme weather events, disease and insect predation. Hence, it's not just 'greenness', but also 'biodiversity' that should be the focus of urban re-naturing strategies.

Re-enchanting people with nature

Miller (2005) describes the "extinction of experience" that has occurred in cities around the world, as residents have become increasingly disconnected from the natural realm: children who don't know where milk comes from, adults who can identify hundreds of company logos, but only a handful of native plants, and adolescents who are less able to identify a bird by its call than the type of automatic weapon by its report. This trend is all the more significant given the increasingly urbanizing world that we live in; it's predicted that 66% of the world population will live in cities by 2050 (United Nations 2014).

Creating opportunities in cities for every day doses of 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, create sense of place and expose urban residents to the myriad health and well-being benefits provided by nature. These interactions may be passive, or may involve caring for, restoring and monitoring nature. They may further provide a common purpose that builds a sense of community and belonging. As an example, wildlife gardening programs can generate enormous amounts of social capital (Mumaw & Bekessy, 2017). For children, re-enchantment with nature could be key to solving the increasing incidence of pervasive behavioural problems (Louv 2005). Critically, engaging people with nature in cities will be key to generating the social license for biodiversity conservation in other parts of the landscape.

Connecting with Indigenous history and culture

Cities often occur in locations where Indigenous cultures have traditionally thrived, frequently alongside high levels of biodiversity (Mercer et al. 2015). These are often places where natural resources have been used and cultivated in a sustainable way for thousands of years. Indeed, many ecosystems rely on traditional land management practices to maintain high levels of diversity; Aboriginal fire regimes in Australia are a good example (Bird et al. 2008). Traditional knowledge of landscape pattern and processes, hydrological cycles and species and ecosystem management are highly relevant to town planning. Many modern cities owe their foundations to historical Indigenous settlements (for example, Mexico City is founded on the capital of the Aztec Empire, Tenochtitlan). Yet Indigenous knowledge, past and present, is rarely utilized in urban planning processes (Stuart & Thompson-Fawcett 2010).

The potential for engaging Indigenous people in the planning, design, implementation and governance of urban re-naturing is substantial. In practice, this could mean using culturally significant species, such as traditional foods and medicines (eg. engagement with Rasta herbalists in Cape Town to cultivate medicinal plants in communal gardens), reflecting Indigenous understanding of landscape and seasons in urban design (eg. incorporating the Wurundjeri seven seasons in playground design in Princes Park), developing programs such as 'caring for country' and Indigenous ranger programs to engage Indigenous populations in the management of urban parks (City of Melbourne 2016), and prioritizing Indigenous groups in urban governance (eg. The city council of Auckland, New Zealand has an independent Maori Statutory Board and Pacific People Advisory Council to ensure the consideration of Maori and Pacific Islander interests, priorities and values within urban planning (Mercer et al. 2015)).

Engagement of this kind may present a way of improving lives and retaining traditional knowledge for urban Indigenous populations (Mercer et al. 2015). Furthermore, traditional knowledge has proven to contribute to higher quality of urban life) and could improve the success of initiatives to generate 'everyday nature'. Connecting urban residents to Indigenous history and culture through urban re-naturing programs has the potential to create respectful attitudes and pride in local Indigenous knowledge.

Financial benefits

There have been numerous compelling studies of the economic case for urban greening. Urban greening initiatives have been shown to improve property values, reduce maintenance costs, protect drainage systems and reduce energy consumption. Greening in business districts increases community pride and positive perceptions of the area, drawing customers to businesses and increasing retail activity, while at the same time increasing workplace productivity. The potential for tourism operations, such as wildlife sanctuaries, fenced areas for reintroductions of threatened species and education facilities is substantial. To highlight just a couple of examples of studies demonstrating these links, Wolf et al. (2015) found that the value of urban forests in the United States is estimated at $11.7 billion dollars in avoided health care costs annually. A PhD candidate in the School of Geography Planning and Environmental Management at the University of Queensland, made a similar study for her PhD, of the local government area of the City of Brisbane. She found that in calendar year 2010, Brisbane's street trees generated property-value benefits of $29 million – more than twice the cost of planting and maintaining them.

Alignment with key policies

The objectives of BSUD are aligned with policies at all levels of Government, including the Victorian Government Biodiversity Strategy (2017), which calls for 'Increased opportunities for all Victorians to have daily connections with nature' and the Victorian Public Health and Wellbeing Plan which recognises that 'interacting with nature contributes to a reduction in chronic disease risk factors, increases social inclusion and builds strong communities'. At the Federal level, the Australian Government Nature Strategy (2018-2030) includes a specific goal to 'enrich cities and towns with nature'. At the local government level, The City of Melbourne's *Nature in the City* Strategy aims to 'create a more diverse, connected, and resilient natural environment' by, amongst other things, 'improving ecosystem health and biodiversity' and 'developing a more ecologically connected landscape'. The Council is committed to demonstrating 'local and global leadership in conserving biodiversity and creating and sustaining healthy urban ecosystems' (The City of Melbourne, 2017). The City of Port Phillip in their *Sustainable Environment Strategy 2018-2028* envision a 'greener, cooler, more liveable City' in which 'a diverse range of birds, insects and animals live in public space and on private land'; a vision that will be enabled by expanding their urban forest and increasing biodiversity corridors (City of Port Phillip 2018).

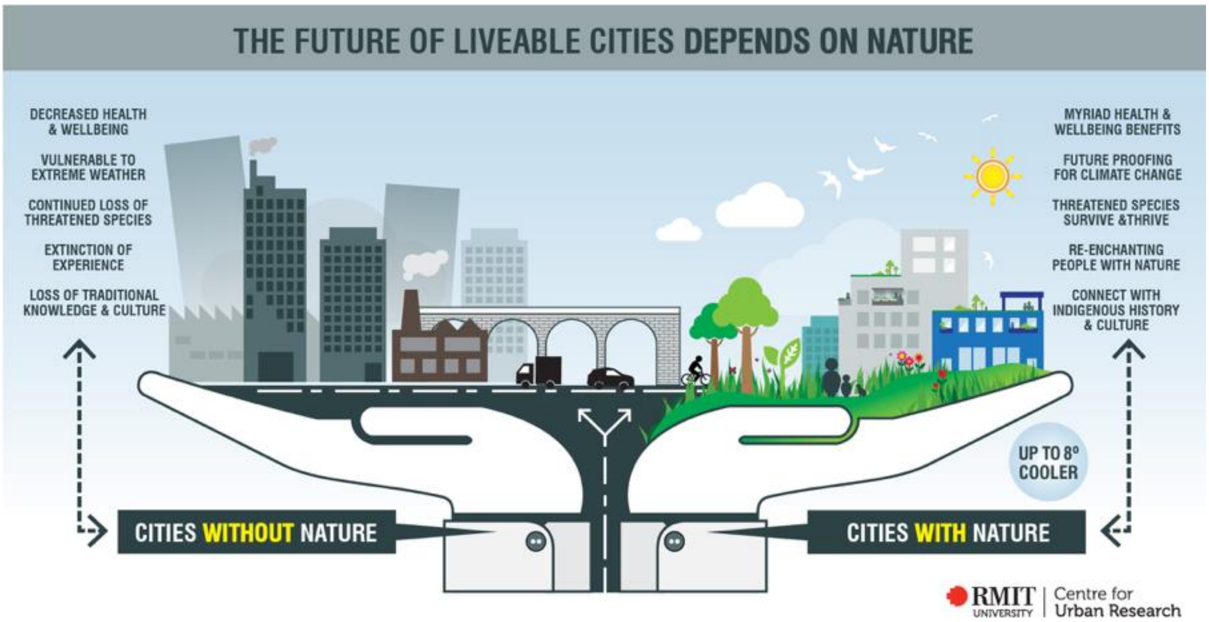


Figure 2. An emerging body of research is revealing the critical role of 'everyday nature' for the future liveability of cities. Improving contact with nature in cities is a compelling public health intervention, with an impressive array of benefits to health and well-being. Furthermore, vegetation in and around cities can deliver a range of ecosystem services critical for climate change adaptation and mitigation. Cities are often hotpots for threatened species and are justifiable locations for serious investment in nature conservation for its own sake. Creating 'everyday nature' has the potential to re-enchant people with nature and connect urban residents to Indigenous history and culture.

2. Biodiversity Objectives for Fishermans Bend

Stakeholder workshop

On 22nd May 2019, we held a stakeholder workshop to identify biodiversity objectives for Fishermans Bend. The workshop was hosted by the Fishermans Bend Taskforce (FBT) and included stakeholders from FBT (DEDJTR), DELWP, City of Melbourne, City of Port Phillip, Boon Wurrung Foundation, Westgate Biodiversity, Port Phillip Eco Centre, The University of Melbourne, RMIT, and GHD. The aims of the workshop were to:

1. Identify shared themes relating to how Fishermans Bend should look, sound and feel; and
2. Translate these themes into a set of target animal species to act as a means for achieving shared objectives (Figure 3).

Diverse stakeholders at the Biodiversity Workshop. Fishermans Bend Taskforce, 22 May 2019.

Shared themes were identified in a visioning exercise, in which stakeholders in small groups were asked to think about how they would like Fishermans Bend to look, sound and feel in the future, with reference to nature. For example, we asked the participants to imagine walking to a job interview or taking the kids to footie practise on a Saturday morning. In this exercise, the visions conceptualised by stakeholders were prompted by a series of realistic scenarios describing everyday events that may take place on the site in the future. Common themes were identified by the entire group based on feedback and discussion of the visions described by individual smaller groups.

While the shared themes provide important overarching biodiversity objectives for the site, more refined objectives are required for quantitative biodiversity modelling. Target, or model species, which require specific resources and threat mitigation, can be used to inform both general and precise design recommendations for the site. Furthermore, by carefully selecting a suite of target species with a range of habitat requirements, we can be certain that the overarching biodiversity objectives will have been achieved when the chosen subset of target species are living within Fishermans Bend.

In the second session of the workshop, stakeholders were briefed on a number of potential (feasible) target species, which were identified prior to the workshop based on their ecological requirements and potential for community engagement (see Mata et al. 2016). During small group discussions, participants 'assessed' potential species based on whether they provide opportunities or challenges with respect to the broad biodiversity themes identified in the first session. After a broader group discussion, in which some stakeholders presented additional potential target species, stakeholders voted to determine priority target species for Fishermans Bend.

The strength of this approach for determining biodiversity objectives for Fishermans Bend is that it translates the values and visions of key stakeholders into explicit targets and design recommendations.

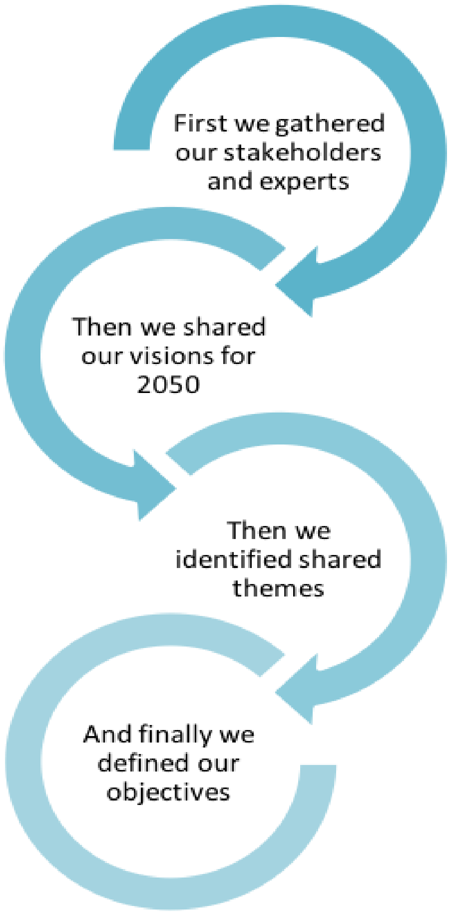


Figure 3. Schematic of the biodiversity objectives-setting process

Biodiversity objectives & shared themes

Biodiversity describes all the animal and plant life occurring in a space or habitat (including people). Inherently complex, planning for biodiversity must account for multiple types of organisms within a space and all their respective living requirements. This encompasses physical (abiotic) factors, such as access to water, light, heat and shelter, and biological (biotic) factors, such as food availability, nesting sites and conspecific mates. Because of these multi-layered planning aspects, rather than focus on specific targets for one or two species, we developed objectives which relate to the overall condition of Fishermans Bend ("look, sound and feel", see above). These biodiversity objectives, identified by stakeholders in the visioning exercise, are as follows:

A place that honours Indigenous culture

The habitats of this area reflect Indigenous knowledge and stories, in their design, naming and function. This overarching objective guides all other objectives.

A place with seven seasons
Constant seasonal change is reflected in our flora and fauna, how we use places, and how water appears in the landscape.

A place known by its diverse ecosystems
Local ecosystems and species are a core part of each precinct's identity and function. Local habitat helps you know where you are and where you're going.

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'.

A place of shifting waters
Water is part of the landscape – both freshwater and brackish, ephemeral and permanent.

A place that's comfortable and beautiful in any weather
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 microclimates, so every area teems with life.

These objectives build on but go beyond the key goals articulated in Goal 6 of the Fishermans Bend Framework, reflecting a level of ambition that is appropriate for the scale and potential of the site, which could be an exemplar of world's best practice in sustainable urban development.

The seven target species or groups identified during the workshop were: Superb fairy-wren (*Malurus cyaneus*), Growling grass frog (*Litoria raniformis*), Blue-banded bee (*Amigella* sp.), Brolga (*Grus rubicunda*), Fungi species, White mangrove (*Avicennia marina*) and Blue-tongue lizard (*Tiliqua scinoides*). The consensus during the workshop was that, given these species' various resource requirements, their return to and persistence in Fishermans Bend then would serve as a useful indicator that the stated biodiversity objectives had been achieved. A brief introduction to the resource requirements for these seven species is included in Appendix A. It was also agreed that two of these species would be selected for the initial connectivity modelling process, in order to 1) identify opportunities for habitat addition during the renewal and 2) quantify the different development scenarios from a species return perspective.

Model species: Superb fairy-wren
The Superb fairy-wren (*Malurus cyaneus*) is a small, native bird species of south-eastern Australia that is relatively well adapted to living in urban environments. It is insectivorous and is known as an edge species - it forages for insects in low vegetation and grassed areas which are fringe 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 (Parsons et al. 2008).

Its habitat preferences and resource requirements in urban environments are relatively well studied (see Parsons et al. 2008) and are summarised below.

Shelter
Fairy-wrens require an extensive shrub layer (up to 4m high) for nesting and shelter from predators.

Food
Fairy-wrens are insectivorous. They like to forage in low grassed areas close to mid-storey shrubs for shelter. Evidence suggests that it is important that the shrub layer is predominately native plants (Parsons et al. 2008).

Habitat
In urban environments, superb fairy-wrens are found in sites with an extensive native shrub and native tree layer with an understory of grasses. They use the full spectrum of vegetation structure, from trees through to grasses, but spend the majority of their time in the shrub layer, which they use for shelter and nesting. They prefer areas that have a dense layer of native shrubs surrounding grassy areas. Research has found them to be absent in urban environments with few shrubs in total or in sites dominated by exotic shrub species (Parsons et al. 2008).

Threat Mitigation
Genetic fitness of the species can be compromised if Superb Fairy-wren family territories are isolated (and there is therefore no genetic flow into or from a population). The planting of native shrubs and trees in suburban habitats surrounding existing Superb Fairy-wren territories (ie. Westgate Park) 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).

Predation by cats is also a threat in urban environments. Cats catch most birds in spring and summer, at times when birds are breeding and the young are leaving the nests. 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 and also by planting shrubs in protective thickets of 3 or more (Parsons ND).

Urban areas with little or no native trees or shrubs will present a major barrier to the persistence of this species (Parsons et al. 2008). Fairy-wrens will persist in grassed environments, but only if the grassed areas occur in conjunction with a native shrub layer.

Potential for habitat/threat mitigation analogues
There is scope to use novel habitats and exotic species for shelter for this species – they have previously used exotic species such as lantana and blackberries in urban environments. However, while it is possible that exotic species or novel structures could provide a sheltering function, they will not provide foraging or nesting habitat.

Model species: Growling grass frog

The Growling grass frog (*Litoria raniformis*) is a large diurnal frog that was declared 'endangered' under the Victorian Flora and Fauna Guarantee Act in 2002 due to sudden and substantial declines across much of its range. Remaining populations are isolated to the greater Melbourne area and across areas in south western Victoria.

Habitat

The species uses ponds or creeks with slow-flowing fresh or brackish water. Ideally, the frog requires a range of waterbodies, varying in temperature and salinity as warmer, more saline ponds can be used by the frog to shed chytrid fungus, which is a key threat to the species. Waterbodies designed for the frog should have grassy, weedy or reedy edges, as well as:

- tall emergent (e.g. Spike Rush) vegetation to give protection to the adult frogs from predators;
- floating attached (e.g. Running Marshflower) vegetation to protect the tadpoles;
- submerged and emergent vegetation, as well as feathery and non-feathery (e.g. Swamp Crassula and Pondweed) vegetation to supply egg laying sites and protection for the tadpoles;
- sunny areas for basking;
- rocks and logs for the frog to shelter during the day and over winter months; and
- grassy areas between ponds to allow movement (DEH 2012)

Threat Mitigation

Cats are a key threat to the species, so a cat containment policy is essential for maintaining the species on site. There is precedent for such policies in the ACT; however, research indicates that strategic communication may be necessary to ensure policy success (McLeod et al. 2015; Elliott et al. 2019).

Concrete lips on the edges of roads can decrease the risk of collision with vehicles.

Potential for habitat/threat mitigation analogues

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 through:

- grassy and vegetated corridors between water bodies;
- underpasses below roads (these must be kept moist and have a grill on top to allow light penetration. It's also recommended to provide concrete 'funnels' to direct the frog to use underpasses); and
- non-vegetated drains/swales.

3. Connectivity modelling

Methods

Ecological Connectivity in urban spaces

Three key things are required for healthy populations of native wildlife to thrive within urban spaces: consumable resources such as food and water, shelter for refuge or nesting and safe ways to move between these things. Animals need to move in order to forage, find mates and disperse after successful breeding (Nathan et al., 2008). Within urban landscapes, desirable habitat may be in highly fragmented patches, be prone to high levels of disturbance and can be interspersed with a range of land uses that may be hostile to the organism moving across them (Evans et al., 2017). Ecological connectivity theory is increasingly being used within conservation science as a way to mitigate the impacts of habitat loss and fragmentation on biodiversity (Tischendorf & 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), essentially 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 & Burel, 2008). Within an urban planning context, ecological connectivity is analogous to the "walkability" of a landscape for human residents (Parris et al., 2018). Measures of connectivity provide a way to quantify the effect that different urban planning scenarios might have on the ability of animal species (either currently present or anticipated to occur) to move across the area. Some methods may also allow the identification of key movement corridors and areas where connectivity is particularly low (Kindlmann & Burel, 2008; Beier et al., 2011). Based on land use information (spatial data), the landscape is classified into areas of habitat (a range of vegetation types and water resources, depending on the species) and barriers (for example roads and buildings) (Kindlmann & Burel, 2008). A threshold distance is usually applied to determine which habitat patches are connected, which is often based on an animal's average dispersal or gap-crossing capability (Lechner et al., 2017).

To inform the Fishermans Bend Urban Ecology Strategy, we measured existing connectivity within the Fishermans Bend area and the surrounding landscape for the growling grass frog and superb fairy-wren. We then used the existing precinct plans to identify areas where potential habitat or new barriers to movement were being added to the landscape (baseline scenario). Finally, we chose areas suitable for further development of suitable habitat patches and ways in which any barriers to movement might be mitigated (best-case or biodiverse scenario). For each of the future planning scenarios we re-calculated connectivity for both species. We used a circuit theory approach to measure connectivity as this allows the spatial identification of key areas to preserve or improve connectivity (McCrae et al., 2008; Dickson et al., 2018).

Land use mapping

Detailed habitat and resource requirements were defined for each of the two model species. These were based on a review of the published literature and consultation with two additional species-specific experts. The existing literature also informed the selection of appropriate gap crossing abilities for the two species.

Superb fairy-wren
Habitat → All understorey vegetation (e.g. shrubs & grasses); tree canopy and turf less than 10m from understorey vegetation.
Barriers → Major roads wider than 15m, buildings higher than 10m and the Yarra River.
Gap-crossing distance → 1500m
Based on information from White et al., 2005; Watson et al., 2008 and Parsons et al., 2008.

Growling grass frog
Habitat → All water features and creeks; understorey vegetation and turf less than 10m from water resources.
Barriers → Roads wider than 5m, all buildings, and the Yarra River.
Gap-crossing distance → 1000m
Based on information from Heard et al., 2010, Heard et al., 2012 and Hale et al 2013.

Geospatial data on existing land use and the current precinct plans were provided by GHD and the Cities of Melbourne and Port Phillip (Figure 4). For the biodiverse scenario, where future land use was still unknown, potential new habitat for both species was modelled by adding the following to the existing spatial layers (also see figure 4):

- Understorey garden beds added to all new parks across Fishermans Bend;
- Permanent water features added to four large parks across Fishermans Bend;
- Understorey vegetation and "soft edges" added to all planned ephemeral waterways (rain gardens or swales);
- Understorey vegetation added to the "local" streets within the new precincts;
- Understorey vegetation, rain gardens and tree canopy added to the "Green Link" pedestrian and cycle way through the Employment Precinct;
- 28 car park spaces (in parking lots rather than roads within the Employment Precinct were converted to parklets containing both tree canopy and understorey vegetation;
- Two "Green Bridges" added where cycle ways cross the Westgate Freeway;
- One "Animal Underpass" added beneath Todd Road to provide a link for terrestrial species; and
- Conversion of the area currently known as the Go Kart site to a large park with native vegetation, similar to the existing Westgate Park.

Some of these new features were spatially targeted to improve future ecological connectivity in areas identified as having low connectivity in the existing and baseline connectivity models (see below). Examples of these habitat layers can be seen as maps in Appendix B.

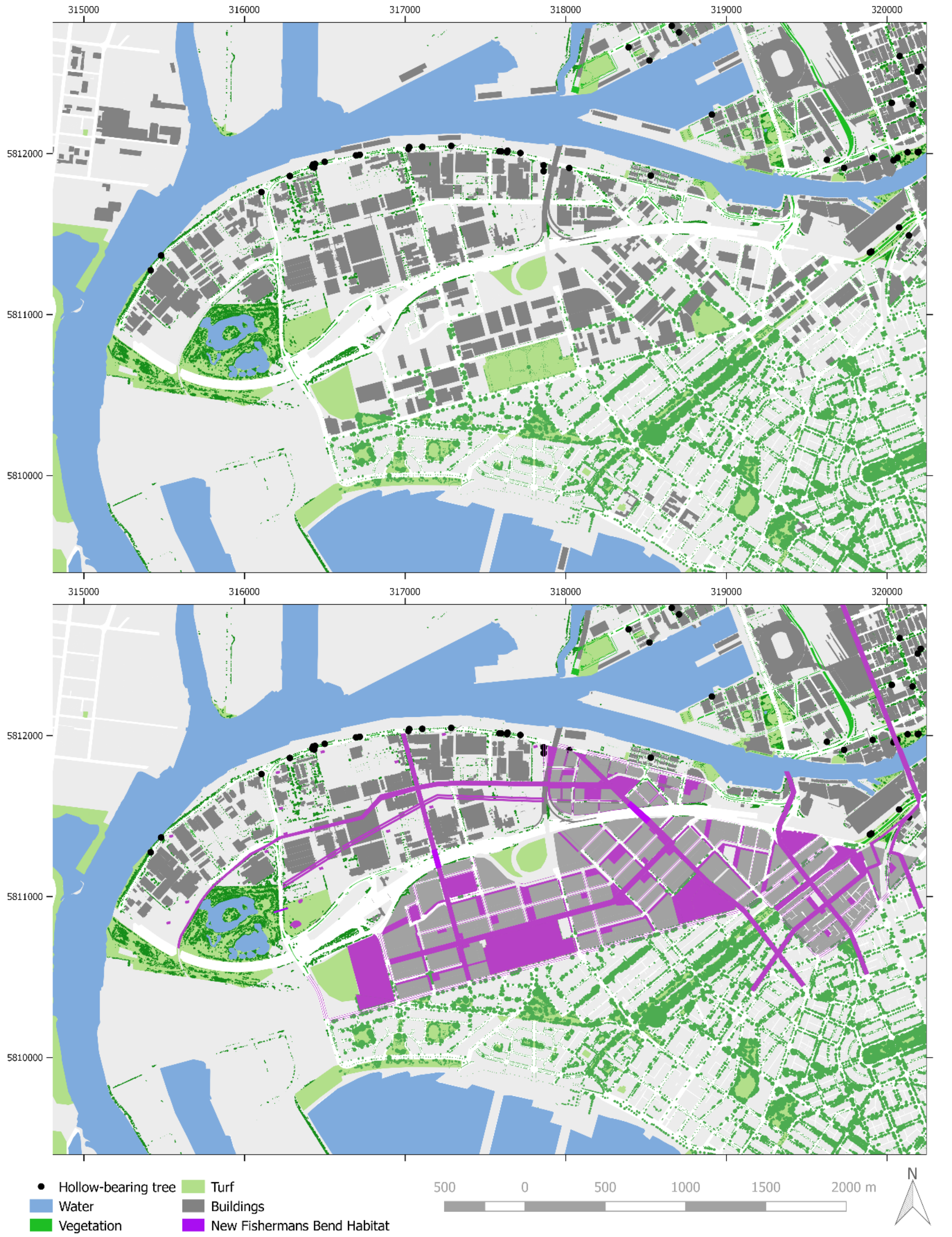


Figure 4. Maps showing existing vegetation and buildings in the Fishermans Bend area (top) and the main areas of proposed new parks and buildings (bottom).

Resistance modelling

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 (Spear et al., 2010; Peterman et al., 2014). 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). There are several different methods for parameterising resistance values: using field data such as population surveys, telemetry or landscape genetics; testing a range of resistance values using model optimisation; or expert opinion/literature review where the resistance of different land uses are inferred from ecological knowledge (Spear et al., 2010). Given the timeframe for this project and the lack of relevant field data, we chose to use existing ecological knowledge to parameterise resistance for the superb fairy-wren and growling grass frog.

Resistance values were assigned differently for our two target species to account for their different resource and habitat requirements and their different movement capabilities. We followed a similar rationale to Grafius et al. (2017), who assigned resistance based on land use. Core habitat patches (appropriate vegetation or water features in parks) were given a resistance value of 0 and these patches act as sources/destinations in the later connectivity model. Table 1 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 and modified with the additional “distance to habitat” rasters and “barrier” (road/building) rasters as appropriate. The final resistance rasters based on existing habitat for both species can be seen in Figure 5. Resistance surfaces were also created for the two alternative future modelling scenarios (baseline and best-case biodiverse scenarios as described above).

Table 1. Calculation of resistance surface from different land use classes in Fishermans Bend. Resistance values were decided using a similar rationale to that used by Grafius et al. (2017), based on the habitat requirements of each species and their movement capabilities (from White et al., 2005; Watson et al., 2008; Heard et al., 2012; Hale et al., 2013). *This land use class is not present in the existing landscape.

	Class/feature in existing landscape	**Assigned resistance value (R)**	**Base-line scenario**	**Best scenario**	**Justification**
Superb Fairy-wren *Malarus cyaneus*					
(SFW)	Core habitat (in WGP & RBG)	0	One new habitat patch	Plus patches in new large parks	Parks provide source populations
	All other understorey vegetation	1	Road understorey	Green Links plus new understorey	Key resource for SFW
	Tree canopy < 10m from understorey	2	Worst trees <10m from under	Best trees <10m from understorey	Used less frequently by SFW, but can provide cover and food
	Turf < 10m from understorey	2	Same as above	New park turf < 10m from understorey	
	All other green spaces and canopy	5	New parks, but fewer additional trees	New parks, green bridges and maximum number of trees	Not a SFW resource, but not a barrier
	Pervious surface	15			Not a movement barrier, open space crossing risk
	All impervious surfaces	30			Correlates with minor roads and car parks
	Buildings > than 10m in height	50	All additional buildings	All additional buildings	Barrier to movement
	Land more than 750m from R = 0 or R = 1	Initial + 50			Gap crossing ability = how close habitat patches need to be
	Major roads and the Yarra River	Total barrier		Gaps in WG Freeway!	Impassable
Growling grass frog *Litoria raniformis*					
(GGF)	Core habitat (in WGP & RBG)	0		3 new pond patches, plus veg	Parks provide potentially stable populations
	Water and understorey < 10m from water	1		Ponds plus new understorey	Key resource for GGF
	Ephemeral water*	5	Road side water plus the roadside understorey	Roadside water, plus the green link drain and the underpass	Used less frequently by GGF, but could provide connectivity
	All other green spaces	10	New parks	New parks plus the green link	Not a GGF resource, but not a barrier
	Pervious surface	25			Not a movement barrier, but risky to cross
	All impervious surfaces (inc. buildings)	50			Correlates with minor roads and car parks
	Land more than 500m from R = 0, R = 1	Initial + 50			Gap crossing ability = how close habitat patches need to be
	Minor roads > 5m wide	Initial + 20	New 22m roads	New 22m roads	Barrier to movement
	Major roads and the Yarra River	Total barrier			Impassable

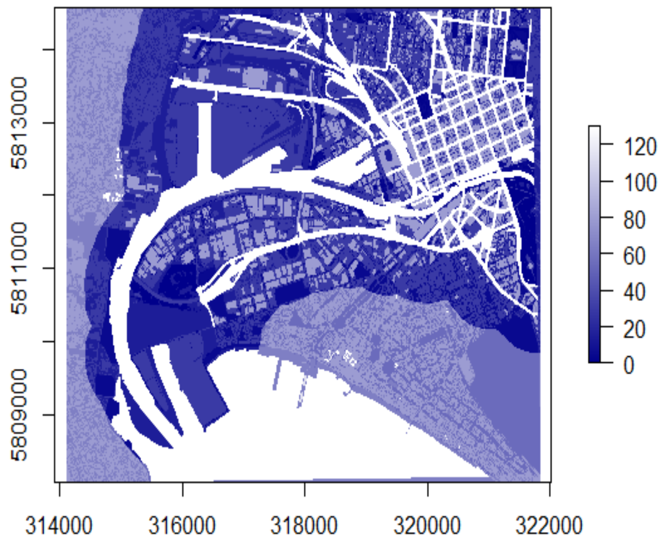


Figure 5a. Resistance map for the superb fairywren. Darker colours show areas of lower resistance, lighter colours are high resistance.

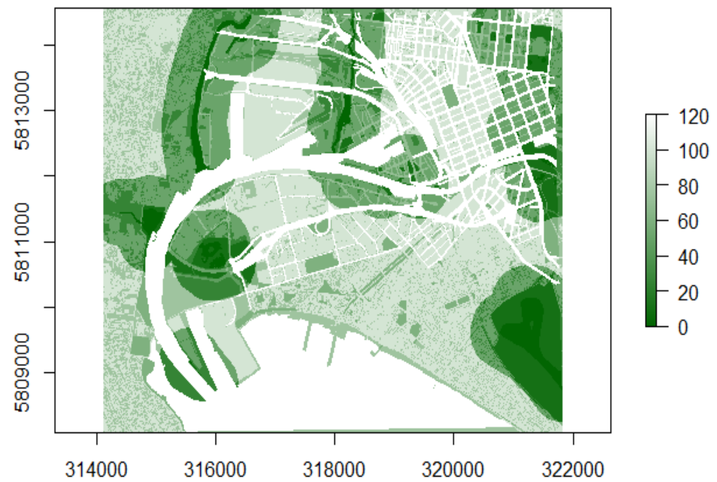


Figure 5b. Resistance map for the growling grass frog. Darker colours show areas of lower resistance, lighter colours are areas with higher resistance.

Circuitscape models

Ecological connectivity for the Fishermans Bend area was calculated using *Circuitscape 4.0* (McRae et al., 2008; McRae et al., 2016). This software uses resistance surfaces to compute total resistance between all possible 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 (current) 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 habitat, baseline and best biodiverse future scenarios for Fishermans Bend) were used alongside the locations of core habitat (focal nodes) which were considered as focal nodes within the circuit model (Table 1). 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, 1000 random coordinates were generated across the Fishermans Bend area. At each random location the cumulative current generated by Circuitscape was extracted, allowing the mean current (a measure of connectivity) across the site to be calculated for each scenario.

Results

For each of the target species, existing connectivity was compared to connectivity under two future scenarios for Fishermans Bend: one with baseline addition of habitat based on the existing plans for the area and one with a best-case addition of habitat. Whilst both future scenario models showed reduced overall resistance and increased connectivity across the landscape (Table 2 and Figure 8), the best-case biodiverse scenario out-performed the baseline. Mean connectivity for the superb fairy-wren was 2.5 times greater in the biodiverse scenario than in the baseline scenario. For the growling grass frog mean connectivity was 6.5 times greater in the biodiverse scenario. These increases were due to the targeted addition of critical new habitat connections. Of particular importance were the “green bridges” used to mitigate the extreme barrier effect of the Westgate Freeway for the superb fairy-wren (see panel D Figure 6) and the “green link” in the employment precinct for the growling grass frog (panel D of Figure 7). The best-case biodiverse scenario for superb fairy-wren represents the provision of at least 2.82km^2 (24% area cover) of good quality understorey vegetation and connected green space in the Fishermans Bend area. The best-case biodiverse scenario for growling grass frog represents the provision of 1.59km^2 (14% area cover) of waterbodies, ephemeral waterways, understorey vegetation and turf.

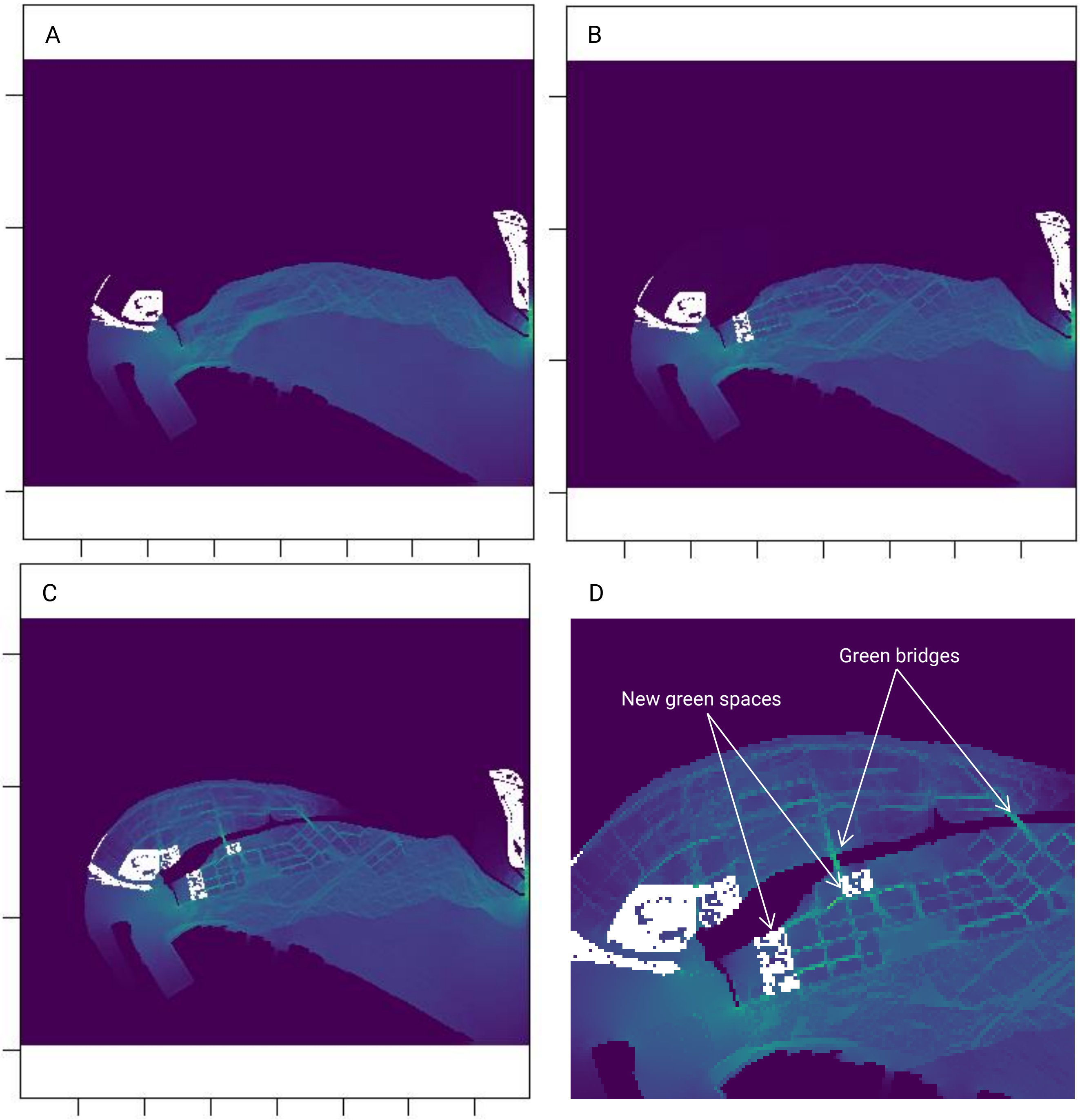


Figure 6. Connectivity maps for the superb fairy-wren showing cumulative current for existing habitat (a), two future scenarios for Fishermans Bend: baseline (b), biodiverse (c) and detail of the best-case scenario connectivity highlighting the green bridges and additional green spaces (d). Lighter colours show greater flow of current (increased connectivity) across the landscape.

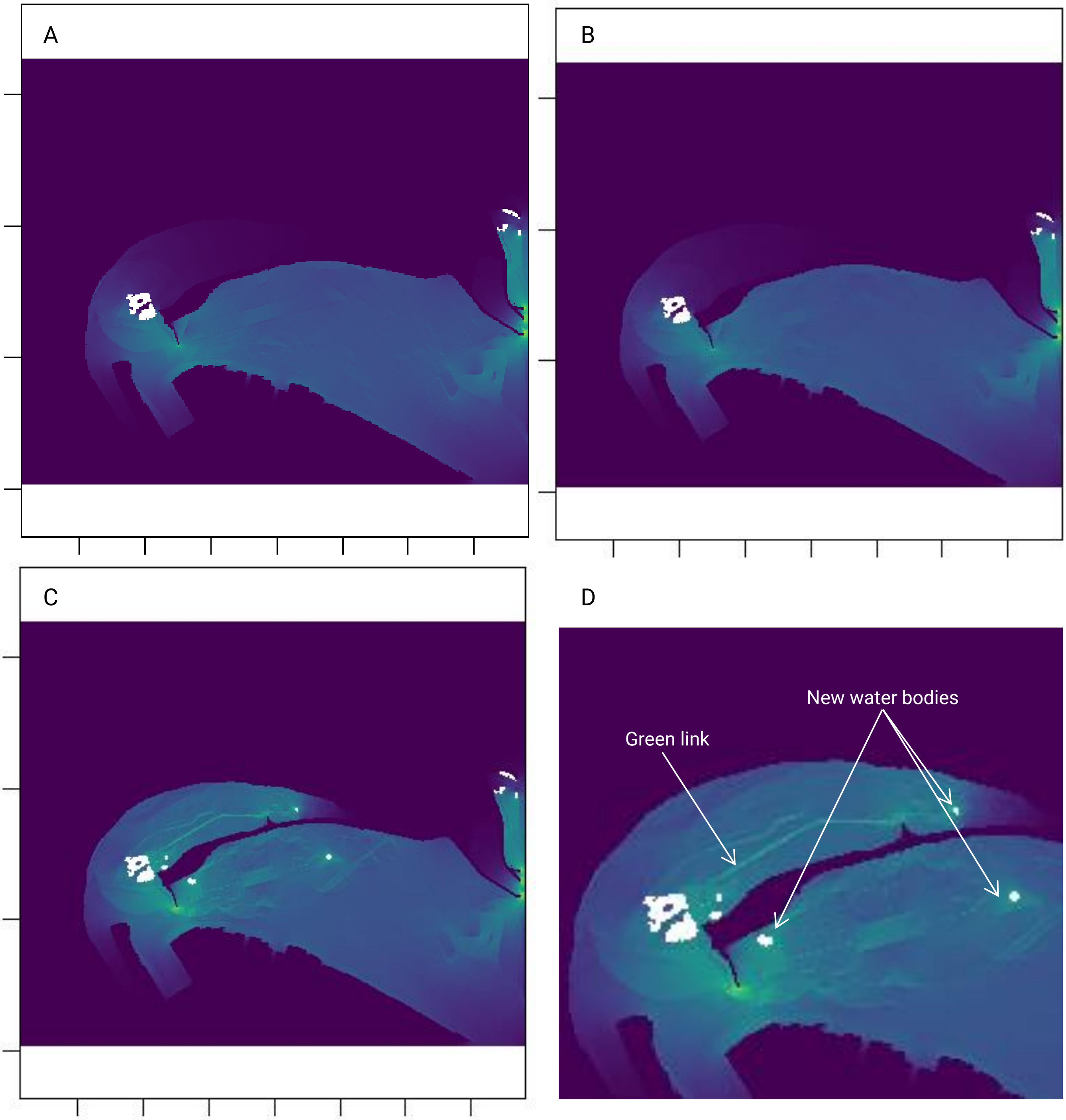


Figure 7. Connectivity maps for the growling grass frog showing cumulative current for existing habitat (a), two future scenarios for Fishermans Bend: baseline (b), biodiverse (c) and detail of the best-case scenario connectivity highlighting the green link and additional water bodies (d). Lighter colours show greater flow of current (increased connectivity) across the landscape.

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

	Habitat scenario	Pairwise resistance	% change	Mean current	SD
Superb fairy-wren	Existing	318.1		0.03	0.16
	Baseline	286.5	-9.9	0.07	0.35
	Biodiverse	265.2	-16.6	0.17	0.79
Growling grass frog	Existing	984.8		0.01	0.11
	Baseline	979.5	-0.5	0.01	0.11
	Biodiverse	882.1	-10.4	0.10	0.60

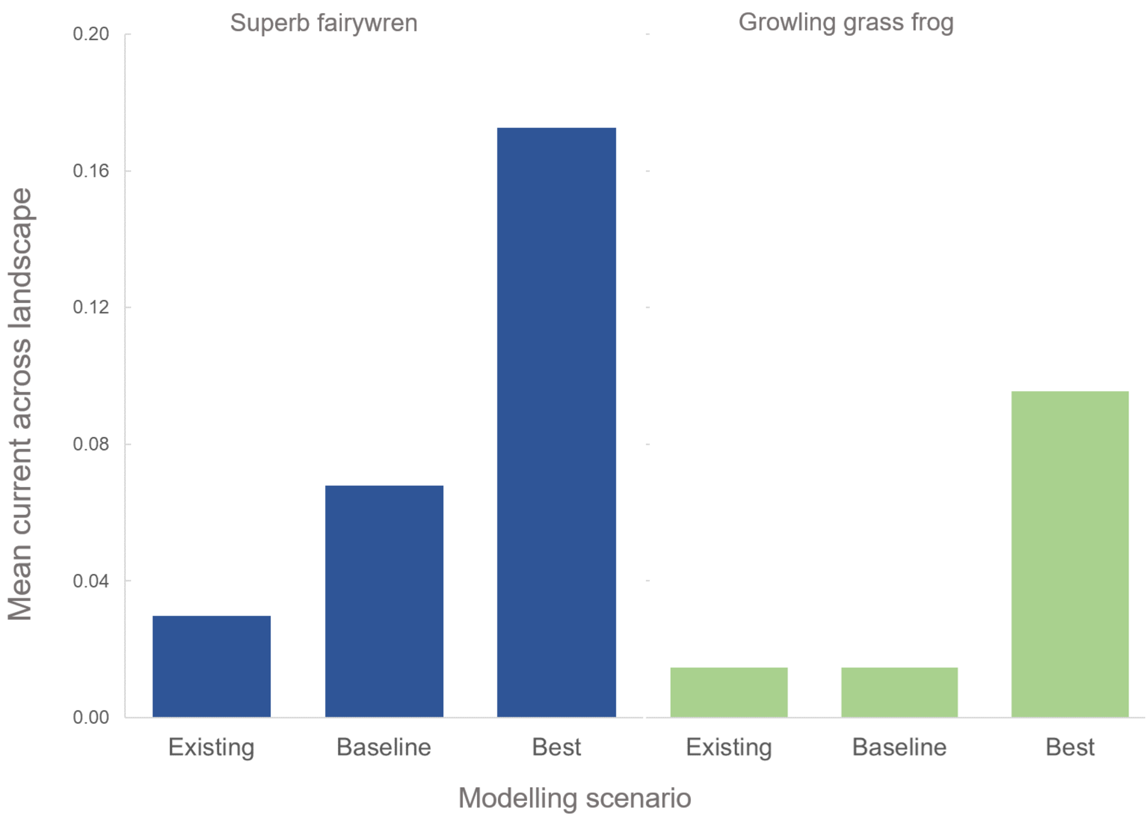


Figure 8. Mean connectivity calculated from each of the cumulative current maps measuring existing connectivity. Shows the increase in cumulative current across the landscape as land use classes are altered to reduce resistance to movement in the two future scenarios for Fishermans Bend. Key differences between the 'Baseline' and 'Best biodiverse' future scenarios are the addition of Green Bridges, a green link in the employment precinct, an animal underpass to connect additional new green spaces in the 'biodiverse' future scenario.

4. Biodiversity Recommendations

Based on our research and modelling, we have developed specific recommendations relating to key urban landscape features (Table 3), which we have distilled into 6 key groups. In making these recommendations, we note that there are 3 overarching and fundamental principles that should be considered when making planning decisions about the site. In order to deliver high-quality biodiversity outcomes in urban environments, the following fundamental principles need to be considered when making planning decisions:

Compatible/incompatible uses

Most native animal species will not regularly utilise areas immediately next to major vehicular transport routes. Therefore, critical biodiversity enhancement actions should not be prioritised in places with vehicular transport, including public transport. While enhancements and green infrastructure such as trees and other vegetation may provide some supplementary biodiversity benefits (and certainly some important human health and wellbeing benefits) along major transport routes, these corridors are not suitable for the provision of meaningful biodiversity outcomes. 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 incompatible with biodiversity, however mixed-use areas may be possible with careful and considered planning. Land uses compatible with biodiversity include active transport, nature play, passive recreation and low volume transport routes such as neighbourhood streets.

Vegetation

Across all Fishermans Bend precincts, diversity of species, diversity of structure and nativeness of vegetation should be prioritised. Vegetation should be able 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 management and addition, as well as detailed guidance on suitable species for the area.

Biodiversity sensitive urban design

The principles of BSUD (Garrard et al 2018) should be followed in every aspect of development, both within the private and public realms. This will 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 planned decision-support tools such as Green Star, Green Factor and BESS may be useful, but would require review and enhancement to adequately consider and meet biodiversity objectives for the site. Guidance should be sought from ecological experts about species choice, vegetation structure and design of novel habitats.

Key recommendations for achieving biodiversity objectives

1. *A dedicated Green Link in the Employment Precinct* is required to ensure ecological connectivity across the site. This contributes to multiple levels of biodiversity infrastructure and significantly improves ecological connectivity across Fishermans Bend. To retain ecological value, this link is compatible with active transport and passive recreation, but should be separate from major vehicular transport, including public transport.
2. *The contribution of green spaces and streetscapes to biodiversity should be maximised*, especially those that have other primary uses. This can be done by seeking to enhance ecological function in any greenspace to deliver multiple outcomes through, for example, enhancing streetscapes with structurally-diverse vegetation, or including structurally-diverse garden beds around active transport and sporting ovals.
3. *Biodiverse freeway overpasses/bridges* are required to mitigate significant barriers to animal movement presented by major roads (Westgate Freeway and Todd Road). Without these, achieving biodiversity objectives in the Employment Precinct is extremely unlikely. Biodiverse overpasses are compatible with active transport with some careful planning.
4. *Identify and protect existing vegetation*. Vegetation is key to biodiversity enhancement in Fishermans Bend. Existing vegetation is valuable because it provides: instantaneous resources that can be immediately utilised by target species (as well as numerous other instantaneous benefits such as cooling, and restorative well-being effects); and critical information about which parts of this highly modified site are currently suitable for hosting vegetation. Yet, to date, trees within the public realm are the only vegetation to have been assessed. A comprehensive assessment of the quantity and quality of all existing vegetation across the site is required prior to planning and development.
5. *Investigation of mechanisms to ensure the long-term protection of biodiversity assets*, including through regulation, maintenance and management. Existing vegetation protection regulations may not be sufficient to ensure the ongoing protection of planted vegetation and constructed ecosystems as will be necessary to achieve biodiversity objectives at Fishermans Bend. Novel funding and governance arrangements could be considered here (e.g. NSW BAM; Green Bonds).
6. *Investigation and development of mechanisms to manage key threats to biodiversity*, i.e. local laws that address, cat containment, pesticide use and speed limits.

Table 3 provides a detailed summary of all our biodiversity recommendations, including how they relate to the seven target species and address the identified biodiversity objectives for Fishermans Bend. In addition, Appendix B contains examples of similar green infrastructure or novel habitat analogues from Australian and international projects and shows examples of how some of the biodiversity actions could be positioned spatially across Fishermans Bend.

Table 3. Detailed recommendations for creating a biodiverse Fishermans Bend. Each recommendation (numbered in bold) has specific actions (in italics). The table shows which of the target species each recommendation will benefit and which biodiversity objectives it fulfils. GGF = growling grass frog. SFW = superb fairy-wren, BBB = blue banded bee. BTL = blue tongue lizard.

Broad Recommendation *Specific Action(s)*	Species	Objective(s)	Notes/Description	References	Synergies with other specialties
Public Realm					
1. Inclusion of water within the landscape *Permanent water bodies in all new parks* *Ephemeral waterways along streets*	GGF, Fungi, Mangroves Brolga GGF, Fungi	All objectives	In all new parks. Should have soft edges and vegetation within and at the edge of the water. Variation in salinity & temperature preferred Along relevant streets and in the Green Link. Should have permeable surfaces and vegetation to allow the formation of rain gardens.	Heard et al. 2012, Hale et al. 2013	Urban Heat, Melbourne Water, Drainage & Flood Strategy
2. Diverse native understorey vegetation *Inclusion in all new parks, gardens, parklets and podiums* *Along the length of all street linear parks, green bridges and the green link*	All species	One, Two, Three & Five	Clumps of dense, native shrubs in garden beds with a mixture of different heights and structures. Flowering native plants used as much as possible Should include native grasses (0-0.8m height) and shrubs (0.5-2m height). Suggested shrubs include Hakea, Bursaria, Melaleuca, Acacia and Lomandra species Can also be included as planter boxes and raised beds Separated from path/cycleways by turf buffer	White et al. 2005, Watson et al. 2008, Stevens et al. 2012, Haddad et al. 1999, Koenig et al. 2001, Souter et al. 2007, Parsons et al. 2008	Urban Heat, Urban Wind, Urban Forest

3. Canopy trees *Street trees and trees in linear parks & the green link* *Trees in parks and gardens*	BBB, SFW BBB, SFW & Fungi	One, Two, Three & Five	Existing hollow bearing trees should be preserved Street trees should be spaced <10m apart, to guarantee continuous canopy cover & variation in establishment All canopy trees should be predominantly native providing a mixture of vegetation structures (low & high canopy) and services (flowers, hollows, dense foliage)	Campbelltown CC Grafius et al 2017 Watson et al. 2008, Lowry & Lill 2007 Lees & Peres 2009, Wilson 2013	Urban Heat, Urban Wind, Urban Forest
4. Green bridges *Planned path & cycleways over the freeway can be vegetated*	BBB, SFW, BTL	Two, Three & Five	Melbourne's High Line! Keep bike and pathways to one side of the bridge. Turf buffer between garden beds and pathways. Follow same recommendations as #2 but height of shrubs dependent on bridge side & wind. Prioritise native, flowering understorey vegetation.		Urban Heat, Urban Wind, Architects, Urban Planners
5. Animal underpass(es) *Connecting Westgate Park with new parks, under Todd Road*	GGF, BTL, Fungi	One, Two & Three	0.5 - 1m wide, 50cm deep. Gridded underpass to allow light penetration. Should have a permeable base to allow water drainage and vegetation growth. Ideally be kept moist or wet. Should also include a lipped drift fence/funnel for directing animal movement and preventing casualties. Open onto understorey garden beds in the connected parks.	Grilo et al. 2011, Aresco 2005, Heard et al. 2012, Hale et al. 2013, Souter et al 2007,	

6. Creation of an iconic new park	All species, except Mangroves	All objectives	Containing two new permanent water bodies (billabongs). Animal underpass connection with WG Park. Should be native vegetation focused with mature woodland stands and large contiguous understorey patches. Should have walking paths & boardwalks with information boards. Understorey & canopy planting to match recommendations #2 & #3	See recommendations #1 #2 & #3	Urban Heat, Urban Wind, Urban Forest, Landscape architects
7. Built form and other infrastructure					
Green walls and green roofs	BBB & Fungi	Two, Three & Five	Consider green walls and roofs or roof-top parks on all buildings. These should have significant soil layer and water retention to allow dense vegetation. Planting guidelines should follow	Madre et al 2015, Braaker et al 2014	Urban planners, Landscape architects
Anti bird-strike glass	SFW & Brolga	Two	Particularly for all new multi-storey buildings.	Garrard et al 2018	Urban heat, Urban Wind
Novel habitat analogues	BBB, BTL & Fungi	Two	Inclusion of artificial cavities in buildings, rockeries & wood piles/mulch in gardens and parks. Seeding native mistletoe in upper canopy of street trees to increase diversity of form Seeding native mistletoe in upper canopy of street trees to increase diversity of form	Garrard et al 2018	Urban forest, Architects
Eco-street lighting	GGF, BBB, SFW & BTL	Two	Long wavelength LED lights, possibly with scheduled periods of darkness in appropriate places	Longcore et al 2018, Davies et al. 2017	

Mid-rise architecture	All species	Five	Prioritise buildings of 5 - 7 storeys or fewer	Garrard et al 2018	
Opportunities for interaction with everyday nature		One, Two, Three & Five	Semi-private courtyards, pathways and benches in linear parks and green spaces, lookouts over billabongs and information boards		
Private Realm	(All general built form and green space recommendations match the public realm)				
1. Podium gardens					
Lower storey roof-top gardens at base of office blocks	BBB	Two, Three & Five	Containing both canopy and dense understorey, following planting guidance as in recommendations #2 & #3	Madre et al 2015, Braaker et al 2014	Urban Heat, Urban Wind
2. Parking space conversion					
Parking lot spaces	SFW, BBB, GGF, BTL & Fungi	Two, Three & Five	In parking lots of 10 or more spaces, at least 2 spaces converted into garden beds and/or planters. Follow planting guidelines in recommendations #2 & #3	Watson et al. 2008, Stevens et al. 2012, Souter et al 2007	Urban Heat, Urban Wind, Urban Forest
Curb outstands			Convert roadside parking spaces into parklets with understorey vegetation and trees		
3. Green Link					
New habitat & cycling corridor	All species	All objectives	Similar arrangement to the Green Bridge, with contiguous native habitat (trees and understorey) placed on one side, buffered by truf and then the cycle path. Flowering species prioritised. Follow recommendations #2 & #3	See recommendations #1 #2 & #3	Urban Heat, Urban Forest, Melbourne

			Should contain small permanent pools to act as "stepping-stones" for amphibians and ephemeral rain gardens for stormwater drainage along the length of the corridor. Follow recommendation #1		Water, Drainage & Flood strategy
4. Residential areas					
Planter pot provision for all residences	BBB	All objectives	Planters should contain at least two small flowering shrubs per balcony/private garden	See recommendations #1 #2 & #3	Urban heat Urban wind Architects Landscape architects
Shared gardens and courtyards	BBB, GGF SFW, BTL & Fungi		Native vegetation with varied heights (follow recommendation #2). Water-features in non-enclosed courtyards		
Mid-rise architecture	All species	Five	Prioritise buildings of 5-7 storeys or fewer	Garrard et al 2018	
Information boards inside blocks		One & Two	Showcasing the Indigenous culture, habitat & wildlife that can be found in the area		

BBB = Blue banded bee
GGF = Growling grass frog
SFW = Superb fairy-wren
BTL = Blue-tongued lizard

5. Conclusions and further work

This project represents an unprecedented opportunity to develop an urban area where biodiversity thrives rather than being removed or side-lined. If successfully implemented, we believe BSUD has the potential to substantially improve the value of the 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 vision and recommendations we have generated for Fishermans Bend have the potential to position Melbourne as a world-leader in creating the green, biodiverse cities of the future.

The co-benefits of a biodiverse Fishermans Bend to liveability, human health and well-being and the achievement of other environmental sustainability goals will be substantial.

By considering shared human visions for the future of Fishermans Bend, we were able to target our recommendations to achieving liveable and desirable precincts. Following our recommendations will lead to a Fishermans Bend which provides **diverse ecosystems** for many different species, relief for workers and residents from the urban jungle by stimulating all the **senses** and providing **comfortable** shelter from all weather extremes. By including and retaining **water** within the landscape we will ensure **seasonal changes** can be experienced, which will further contribute to residents' sense of place and **community** within the area.

The urban landscape is ecologically fragmented, but the design of a network of corridors and quality habitat patches could lead to Fishermans Bend having a significant positive contribution on Melbourne's urban biodiversity (Beninde, Veith, & Hochkirch, 2015).

Next steps

Planning for biodiversity is complex and requires multiple levels of expertise. This report is an important first step, but in order to successfully achieve the biodiversity objectives set out by key Fishermans Bend stakeholders, further work is required to:

- Develop specific, detailed biodiversity requirements for Precinct Plans *as they are being developed* (*ad hoc* biodiversity plans developed after the fact will not achieve biodiversity outcomes efficiently or effectively). This will require an interdisciplinary team with both ecological and planning expertise.
- Assess the quantity and quality of all existing vegetation across the entire Fishermans Bend renewal site, including the Employment Precinct. This will require dedicated resources for a team that can assess the capacity of the existing vegetation to contribute to multiple liveability and biodiversity outcomes.
- Conduct follow-up modelling to assess connectivity for Superb fairy-wren, Growling grass frog and other target species under a greater range of future planning scenarios. Additional modelling is required to assess or prioritise, for example, different spatial locations of the Green Link and additional green spaces as more spatially-explicit land use plans for the precincts emerge.
- Develop new or enhance existing decision-support tools and guidelines so that they are fit-for-purpose. This includes:
    - The evolution of tools like Green Factor, BES and Green Star to better deliver biodiversity outcomes; and

    - Interpretation and publication of BSUD guidelines so that they are appropriate for building and planning professionals.
- Investigate potential links between biodiversity and Indigenous engagement through, for example, improved recognition of the importance of Traditional Owner relationship to Country. This will require dedicated resources to respectfully engage with Wurundjeri Woi Wurrung and Boon Wurrung Traditional Owner Corporations.
- Work with architects to determine how best to include novel habitat analogues in new buildings (e.g. nest bricks and cavities) and work with landscape architects and local botanists to refine a planting palette for each precinct.

6. References

Abdollahi, K., Ning, Z., Appeaning A. (2000) *Global climate change and the urban forest*. Franklin Press, Baton Rouge.

Aresco, M.J. (2005). Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. Journal of Wildlife Management 69: 689-699.

Beier, P., Spencer, W., Baldwin, R. F., & Mcrae, B. H. (2011). Toward Best Practices for Developing Regional Connectivity Maps. *Conservation Biology*, 25(5), 879–892. https://doi.org/10.1111/j.1523-1739.2011.01716.x

Bekessy, S.A., White, M., Gordon, A., Moilanen, A., McCarthy, M.A. & Wintle, B.A. (2012). Transparent planning for biodiversity and development in the urban fringe. *Landscape and Urban Planning.* 108: 140-149.

Beninde, J., Veith, M., & Hochkirch, A. (2015). Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters*, 18(6), 581–592. https://doi.org/10.1111/ele.12427

Bird, R.B. et al. (2008) The "fire stick farming" hypothesis: Australian Aboriginal foraging strategies, biodiversity, and anthropogenic fire mosaics. *Proceedings of the National Academy of Sciences*, 105: 14796–14801.

Bowler, D.E., Buyung-Ali, L., Knight, T.M., Pullin, A.S. (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence*. Landscape and Urban Plannin*g, 97: 147–155.

Braaker, S. , Ghazoul, J. , Obrist, M. K. and Moretti, M. (2014), Habitat connectivity shapes urban arthropod communities: the key role of green roofs. *Ecology*, 95: 1010-1021. doi:10.1890/13-0705.1

Churkina, G., Brown, D.G., Keoleian, G. (2010) Carbon stored in human settlements: the conterminous United States, 16: 135–43.

City of Melbourne (2016) *Caring for Country: An Urban Application*, (www.nespurban.edu.au/resources/CaringforCountryReport_Apr2016.pdf).

City of Melbourne (2017) *Nature in the city - thriving biodiversity and healthy ecosystems*.

City of Port Phillip (2018) *A Sustainable Future - The City of Port Phillip's Sustainable Environment Strategy 2018-2028*.

Cooper, C. B., J. Dickinson, T. Phillips, and R. Bonney. 2007. Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society* 12(2): 11

Coutts, A., Beringer, J., N Tapper, N. (2007) Impact of increasing urban density on local climate: Spatial and temporal variations in the surface energy balance in Melbourne, Australia. *Journal of Applied Meteorology and Climatology*, 46: 477-493.

Crooks, K.R. & Sanjayan, M. (2006) *Connectivity Conservation*. Cambridge University Press, New York.

Davies, T. W., Bennie, J. , Cruse, D. , Blumgart, D. , Inger, R. and Gaston, K. J. (2017), Multiple night-time light-emitting diode lighting strategies impact grassland invertebrate assemblages. *Glob Change Biol*, 23: 2641-2648. doi:10.1111/gcb.13615

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., … Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. Proceedings of the National Academy of Sciences of the United States of America, 112(26), 7937–7942. https://doi.org/10.1073/pnas.1503402112

Department of Environment and Energy, Australia (2017) *Australia's strategy for nature (Draft) 2018-2030*, Commonwealth of Australia

Dickson, B. G., Albano, C. M., Anantharaman, R., Beier, P., Fargione, J., Graves, T. A., … Mcrae, B. (2018). Circuit-theory applications to connectivity science and conservation, 33(2), 239–249. https://doi.org/10.1111/cobi.13230

Doick, K., Hutchings, T. (2013) *Air temperature regulation by urban trees and green infrastructure*, Forestry Research, Forestry Commission, UK, 10 pp. (http://www.forestry.gov.uk/pdf/FCRN012.pdf/$file/FCRN012.pdf)

Elliott, A., Howell, T.J., McLeod, E.M. and Bennett, P.C., 2019. Perceptions of Responsible Cat Ownership Behaviors among a Convenience Sample of Australians. *Animals*, 9(9), 703.

Evans, B. S., Kilpatrick, A. M., Hurlbert, A. H., & Marra, P. P. (2017). Dispersal in the Urban Matrix: Assessing the Influence of Landscape Permeability on the Settlement Patterns of Breeding Songbirds. Frontiers in Ecology and Evolution, 5(June). https://doi.org/10.3389/fevo.2017.00063

Faber Taylor, A., Kuo, F.E. (2011), Could Exposure to Everyday Green Spaces Help Treat ADHD? Evidence from Children's Play Settings. *Applied Psychology: Health and Well-being* 3: 281–303.

Fishermans Bend Framework. The next chapter in Melbourne's growth story (2018) The State of Victoria, Department of Environment, Land, Water and Planning.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H. and Gaston, K.J. (2007) Psychological benefits of green space increase with biodiversity. *Biology Letters*, 3: 390–394.

Garrard GE, Williams NSG, Mata L, Thomas J & Bekessy SA (2018) Biodiversity sensitive urban design. *Conservation Letters*. 11: e12411.

Gaston, K.J., Davies, T.W., Bennie, J. & Hopkins, J. (2012). REVIEW: Reducing the ecological consequences of night-time light pollution: options and developments. *J. Appl. Ecol.*, 49, 1256-1266.

Goddard, M.A., Dougill, A.J. & Benton, T.G. (2010). Scaling up from gardens: biodiversity conservation in urban environments. Trend Ecol. Evol., 25, 90-98.

Grafius, D. R., Corstanje, R., Siriwardena, G. M., Plummer, K. E., & Harris, J. A. (2017). A bird's eye view: using circuit theory to study urban landscape connectivity for birds. *Landscape Ecology*, 32 1771–1787. https://doi.org/10.1007/s10980-017-0548-1

Grilo C., Bissonette JA., & Cramer PC. (2011) Mitigation measures to reduce impacts on biodiversity. In: Highways: Construction, Management, and Maintenance, Nova Science Publishers.

Grimm, N.B., Faeth, S.H., Golubiewski, N.E., et al. (2008). Global change and the ecology of cities. *Science*, 319, 756-760.

Haddad NM. (1999) Corridor and distance effects on interpatch movements: A landscape experiment with butterflies. *Ecological Applications* 9: 612-622.

Hale JM, Heard GW, Smith KL, Parris KM, Austin JJ, Kearney M, Melville J. (2013) Structure and fragmentation of growling grass frog metapopulations. *Conservation Genetics* 14: 313-322.

Hanski, I., von Hertzen, L., Fyhrquist, N., Koskinen, K., Torppa, K., Laatikainen, T., Karisola, P., Auvinen, P., Paulin, L., Mäkelä, M.J. and Vartiainen, E. (2012) Environmental biodiversity, human microbiota, and allergy are interrelated. *Proceedings of the National Academy of Sciences*, 109: 8334-8339.

Heard GW, Scroggie M, Malone B. (2012) Classical metapopulation theory as a useful paradigm for the conservation of an endangered amphibian. *Biological Conservation* 148: 156-166.

Hijmans, RJ. (2019). raster: Geographic Data Analysis and Modelling. R package version 3.0-2. https://CRAN.R-project.org/package=raster

Hostetler ME (2012) *The Green Leap. A primer for conserving biodiversity in subdivision development*. University of California Press, Berkeley & Los Angeles.

Ikin, K., Le Roux, D.S., Rayner, L., Villaseñor, N.R., Eyles, K., Gibbons, P., Manning, A.D. & Lindenmayer, D.B. (2015). Key lessons for achieving biodiversity-sensitive cities and towns. *Ecological Management & Restoration*, 16, 206–214.

Intergovernmental Panel on Climate Change (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, C. B. Field, et al. Eds. (Cambridge, UK: Cambridge University Press, Cambridge,).

Ives, C. D., Lentini, P. E., Threlfall, C. G., Ikin, K., Shanahan, D. F., Garrard, G. E., … Kendal, D. (2016). Cities are hotspots for threatened species. Global Ecology and Biogeography, 25(1), 117–126. https://doi.org/10.1111/geb.12404

Kindlmann, P., & Burel, F. (2008). Connectivity measures: A review. Landscape Ecology, 23(8), 879–890. https://doi.org/10.1007/s10980-008-9245-4

Koenig J, Shine R, Glenn S. (2001) The ecology of an Australian reptile icon: How do blue-tongue lizards (*Tiliqua scincoides*) survive in suburbia. *Wildlife Research* 28: 215-227.

Kuo, M. (2015) How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Frontiers in Psychology*, 6: 1093.

Lechner, A. M., Sprod, D., Carter, O., & Lefroy, E. C. (2017). Characterising landscape connectivity for conservation planning using a dispersal guild approach. Landscape Ecology, 32(1), 99–113. https://doi.org/10.1007/s10980-016-0431-5

Lees A, Peres C. (2009) Gap-crossing movements predict species occupancy in Amazonian forest fragments. *Oikos* 118: 280-290.

Longcore, T, Rodríguez, A, Witherington, B, Penniman, JF, Herf, L, Herf, M. Rapid assessment of lamp spectrum to quantify ecological effects of light at night. *J Exp Zool*. 2018; 329: 511–521. https://doi.org/10.1002/jez.2184

Louv, R. (2005) *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*, Algonquin.

Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A. (2008) Children living in areas with more street trees have lower prevalence of asthma. *Journal of Epidemiology & Community Health*: 62, 647–649.

Luck, G.W. (2007) A review of the relationships between human population density and biodiversity. *Biological Reviews*, 82: 607–645.

Lundholm, J.T. & Richardson, P.J. (2010). MINI-REVIEW: habitat analogues for reconciliation ecology in urban and industrial environments. *J. Appl. Ecol.*, 47, 966-975.

F. Madre, P. Clergeau, N. Machon, A. Vergnes Building biodiversity: vegetated façades as habitats for spider and beetle assemblages *Glob. Ecol. Conserv.*, 3 (2015), pp. 222-233

Maron M, Ives CD, Kujala H, Bull JW, Maseyk F, Bekessy SA, Gordon A, Watson JEM, Lentini P, Gibbons P, Possingham HP, Hobbs RJ, Keith DA, Wintle BA, Evans MC. (2016) Taming a wicked problem: resolving controversies in biodiversity offset¬ting. *BioScience*, 66: 489-498.

Mata L, Garrard GE, Hahs AK, Bolitho J, Chambers L, Clemann N, Faulkner R, Foster J, Harris GJ, Kutt A, McMaster D, McMullan-Fisher S, Menkhorst P, Read C, Sinclair S, Sparks D, Stajsic V, Tsyrlin E, West M, Parris K, Bekessy SA. (2016) *Target species for rewilding, monitoring and public engagement in the City of Melbourne*. Report prepared for the City of Melbourne's Urban Sustainability Branch.

McLeod, L. J., Hine, D. W. and Bengsen, A. J., 2015. Born to roam? Surveying cat owners in Tasmania, Australia, to identify the drivers and barriers to cat containment, *Preventive Veterinary Medicine*, 122(3): 339-344.

McRae, B.H., V.B. Shah, and A. Edelman. 2016. Circuitscape: Modelling Landscape Connectivity to Promote Conservation and Human Health. The Nature Conservancy, Fort Collins, CO. 14 pp.

McRae, B.H., V.B. Shah, and T.K. Mohapatra. 2013. Circuitscape 4 User Guide. The Nature Conservancy. http://www.circuitscape.org.

McRae BH, Dickson BG, Keitt TH, Shah VB. (2008) Using circuit theory to model connectivity in ecology, evolution and conservation. *Ecology* 89: 2712-2724.

Mercer, H., Figueroa, V., Mader, A., Hillel, M. (2015) *Input from UNU-IAS, UN-Habitat, UNEP. Eight Examples of Using Indigenous Knowledge for Urban Biodiversity*. (http://www.sustainablecitiescollective.com/nature-cities/1043231/bright-side-indigenous-urbanization-biodiversity).

Mumaw, L., & Bekessy, S. (2017). Wildlife gardening for collaborative public – private biodiversity conservation. Australasian Journal of Environmental Management, 24(3), 242–260. https://doi.org/10.1080/14486563.2017.1309695

Nassauer, J.I., 1995. Messy ecosystems, orderly frames. *Landscape Journal*, 14: 161-170.

Nathan, R., Getz, W., Revilla, E., Holyoak, M., Kadmon, R., Saltz, D., & Smouse, P. E. (2008). A movement ecology paradigm for unifying organismal movement research. Proceedings of the National Academy of Sciences of the United States of America, 105(49), 19052–19059.

Miller JR. 2005. Biodiversity conservation and the extinction of experience. *Trends in Ecology & Evolution*, 20: 430-434.

Parris, K. M., Amati, M., Bekessy, S. A., Dagenais, D., Fryd, O., Hahs, A. K., … Williams, N. S. G. (2018). The seven lamps of planning for biodiversity in the city. Cities, pp. 0–1. https://doi.org/10.1016/j.cities.2018.06.007

Parsons, H., French, K. O. & Major, R. E. (2008). The vegetation requirements of Superb Fairy-wrens (*Malurus cyaneus*) in non-urban edge and urbanised habitats. *Emu*, 108 283-291.

Parsons H (No date) Best practice guidelines for enhancing urban bird habitat: full scientific review. Birds in Backyards < http://www.birdsinbackyards.net/Full-Review-Scientific-Literature>

Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. *The R Journal* 10 (1), 439-446, https://doi.org/10.32614/RJ-2018-009

Peterman, W. E., Connette, G. M., Semlitsch, R. D., & Eggert, L. S. (2014). Ecological resistance surfaces predict fine-scale genetic differentiation in a terrestrial woodland salamander. Molecular Ecology, 23(10), 2402–2413. https://doi.org/10.1111/mec.12747

Rizwan, A.M., Dennis, Y.C.L., Liu, C.A. (2008) Review on the generation, determination and mitigation of Urban Heat Island. *Journal of Environmental Sciences*, 20: 120-128.

Ross, N. (2018). fasterize: Fast Polygon to Raster Conversion. R package version 1.0.0. https://CRAN.R-project.org/package=fasterize

The State of Victoria Department of Environment, Land, Water and Planning (2017) *Protecting Victoria's Environment – Biodiversity 2037*.

Souter NJ, Bull CM, Lethbridge MR, Hutchinson MN. (2007) Habitat requirements of the endangered pygmy bluetongue lizard, *Tiliqua adelaidensis*. *Biological Conservation* 135: 33-45.

Spear, S. F., Balkenhol, N., Fortin, M. J., McRae, B. H., & Scribner, K. (2010). Use of resistance surfaces for landscape genetic studies: Considerations for parameterization and analysis. Molecular Ecology, 19(17), 3576–3591. https://doi.org/10.1111/j.1365-294X.2010.04657.x

Stevens VM, Trochet A, Blanchet S, Moulherat S, Clobert J, Baguette M. (2012) Dispersal syndromes and the use of life-histories to predict dispersal. *Evolutionary Applications* 6: 630-642.

Stuart, K., Thompson-Fawcett, M. (2010) *Ta¯one Tupu Ora: Indigenous Knowledge and Sustainable Urban Design*, New Zealand Centre for Sustainable Cities, University of Otago, Wellington, New Zealand.

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. (1993). Connectivity Is a Vital Element of Landscape Structure. Oikos, 68(3), 571. https://doi.org/10.2307/3544927

Tischendorf, L., & Fahrig, L. (2000). On the usage and measurement of landscape connectivity. Oikos, 90(1), 7–19. https://doi.org/10.1034/j.1600-0706.2000.900102.x

Taylor, B.D. & Goldingay, R.L. (2012). Facilitated movement over major roads is required to minimise extinction risk in an urban metapopulation of a gliding mammal. *Wildlife Res.*, 39, 685-695.

Threlfall, C.G., Williams, N.S.G., Hahs, A.K. & Livesley, S.J. (2016) Approaches to urban vegetation management and the impacts on urban bird and bat assemblages. *Landsc. Urban Plan.*, 153, 28-39.

UK Department of Health (2008) *Heatwave Plan for England. Protecting health and reducing harm from extreme heat and heatwaves*. NHS, Department of Health, London.

United Nations, Department of Economic and Social Affairs, Population Division (2014) *World Urbanization Prospects: The 2014 Revision*, *Highlights* (ST/ESA/SER.A/352).

Watson J, Freudenberger D, Paull D. (2008) An assessment of the focal-species approach for conserving birds in variegated landscapes in South-eastern Australia. *Conservation Biology* 15: 1364-1373.

White JG, Antos MJ, Fitzsimons JA, Palmer GC. (2005) Non-uniform bird assemblages in urban environments: the influence of streetscape vegetation. *Landscape and Urban Planning* 71: 123-135.

Wilson CM. (2013) The roosting and foraging requirements of insectivorous bats in an urban environment. PhD thesis, School of Botany, The University of Melbourne.

Williams, N.S.G., Lundholm, J. & Scott MacIvor, J. (2014). FORUM: do green roofs help urban biodiversity conservation? *Journal of Applied Ecology*, 51: 1643-1649.

Wolf KL, Measells MK, Grado SC, Robbins AST (2015), 'Economic values of metro nature health benefits: A life course approach', *Urban Forestry and Urban Greening*, 14:694-701

World Health Organisation, Climate change and health (2015). Fact sheet Number 266 (http://www.who.int/mediacentre/factsheets/fs266/en/).

Xiao, Q., McPherson, G. (2002) Rainfall interception by Santa Monica's urban forest. *Urban Ecosystems*, 6: 291-302.

1. Appendices

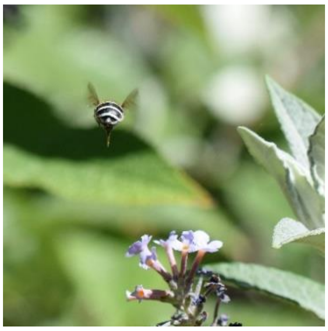
A. Seven target species and descriptions from workshop slide

Superb Fairywren (*Malarus cyaneus*)

Habitat requirements:
- Dense vegetation cover including low shrubs
- Safe spaces for foraging on the ground
- Habitat connected by corridors

Design implications:
- Mid-storey shrubs and ground cover (<200cm high)
- Connections with Westgate Park, along roads
- Place habitat to facilitate human encounters

Blue banded bee (*Amegilla* sp.)



Habitat requirements:
- Diverse mid-storey flowering plants (with some blue flowers ideally, including native Dianella sp.)
- Vegetation placed in sheltered, sunny areas
- Long-stemmed plants
- Nesting areas of soft sandstone, mud-brick or mortar

Design implications
- Open garden beds planted with flowering plants (50-100cm height)
- Sandstone blocks or patches of masonry

Growling Grass Frog (*Litoria raniformis*)

Habitat requirements:
- Ponds or creeks with slow-flowing fresh water
- Grassy/weedy/reedy edges and vegetation patches within water
- Safe connection to Westgate Park
- Sunny areas within the waterbody

Design implications
- Some permanent & ephemeral freshwater
- Aquatic vegetation: Low (<50cm high) vegetation around water
- Sunny road underpasses

Brolga (*Grus rubicunda*)

Habitat requirements
- Large open wetland (saline or freshwater)
- Mudflats, grassy areas, low vegetation or herbaceous veg
- Some distance (approx. 200m buffer) from human disturbance
- Clear airspace (without powerlines)

Design implications

-Large ephemeral wetland area on edge of development

Fungi (various species)
Habitat requirements
- Damp soil
-Eucalyptus trees, fallen logs, dead plant matter/mulch
- Shade

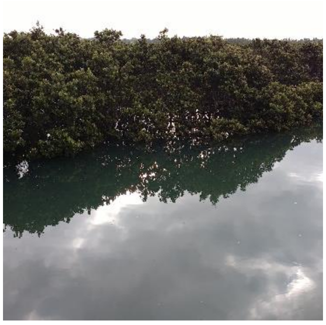
Design implications
- Contiguous soils with the ability to hold water or reliably damp patches of ground
- Eucalypts
- Capacity to tolerate/embrace leaf litter and fallen vegetation matter on the ground

Blue-tongue Lizard (*Tiliqua scinoides*)

Habitat requirements
- Tussocky grasses
- Leaf litter
- Hiding places (rocks/logs)
- Open ground for basking
- Away from busy roads!

Design implications
- Low-storey (<50cm) vegetation
- Rocks or logs nearby for shelter and nesting
- Road underpasses and/or low traffic roads

White mangroves (*Avicennia marina*)



Habitat requirements
- Clean, saltwater and freshwater, saline mudflats
-Tidal zone allowing for both full inundation and air exposure
- Shelter from waves and root/seedling damage

Design implications
- Edge or inlet tidal wetland areas
- Boat ramps or jetties to protect from disturbance by vehicles
- Provision of boardwalks for human access

B. Proposed habitat additions to Fishermans Bend

This appendix illustrates example spatial locations and illustrations of the different biodiversity actions modelled and recommended within this report.

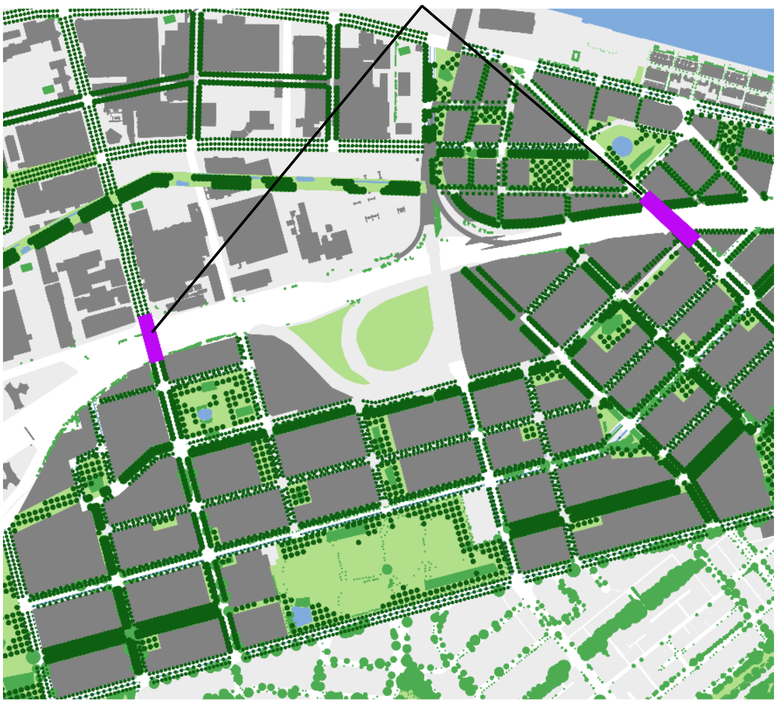
1. Diverse understorey garden beds added to all new parks across Fishermans Bend, new parklets and podiums and along all "local" streets. These plantings should provide a diverse set of structures at a range of heights. Priority should be given to native plants and flowering species which can provide important food for insects and birds.

2. Permanent water features added to four large parks across Fishermans Bend

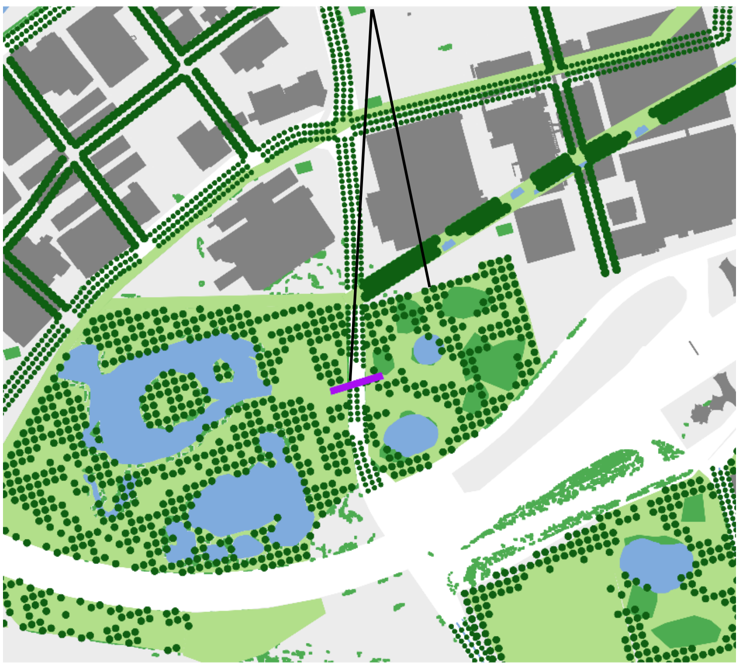
3. Understorey vegetation and "soft edges" added to all planned ephemeral waterways (rain gardens or swales). In the "best-case" modelling scenario these were added to all planned rain gardens and linear parks throughout the precincts.

4. Understorey vegetation, rain gardens and tree canopy added to the “Green Link” pedestrian and cycle way through the Employment Precinct. 28 car park spaces (in parking lots rather than roadside spaces) within the Employment Precinct were converted to parklets containing both tree canopy and understorey vegetation

5. Two “Green Bridges” added where cycle ways cross the Westgate Freeway

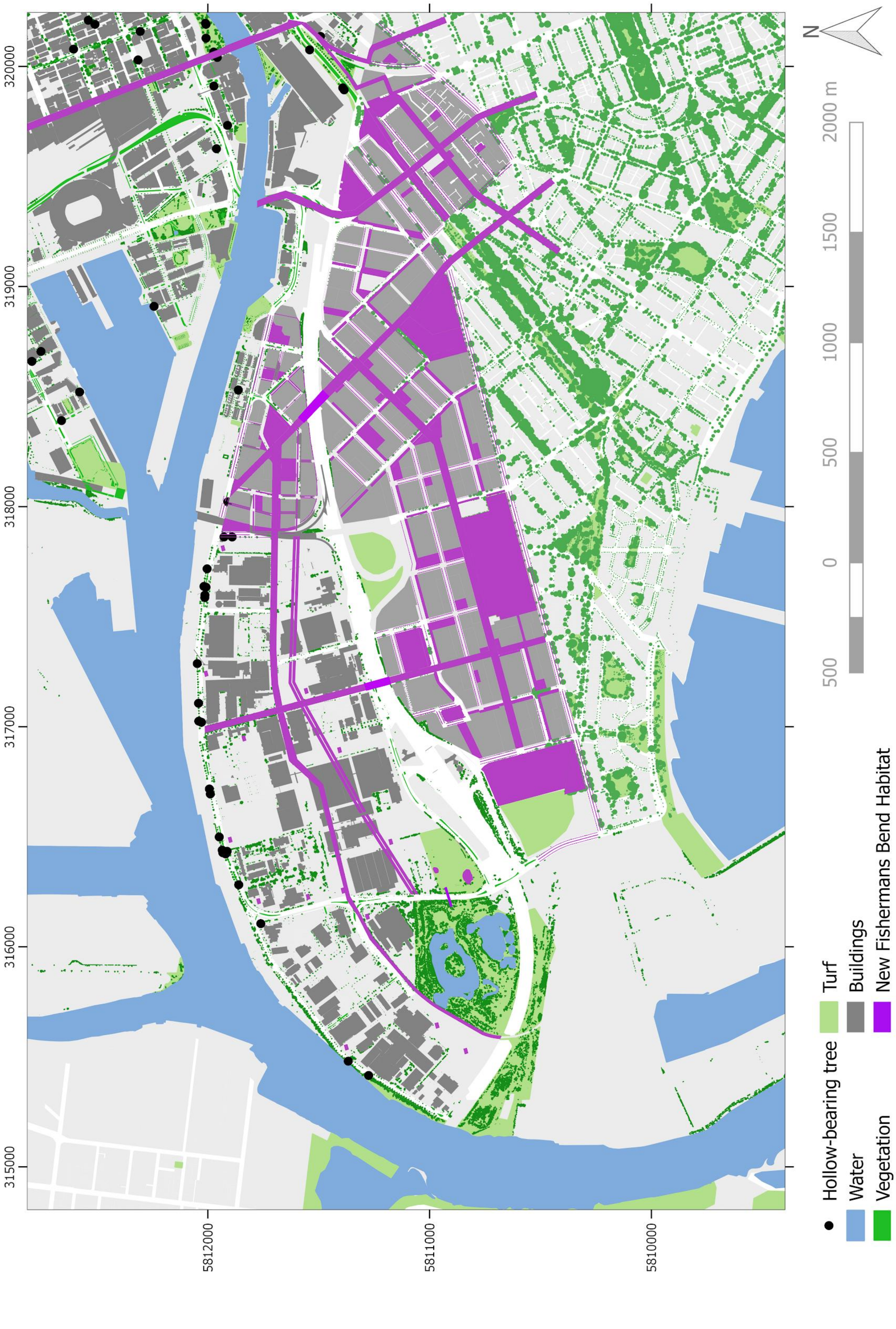


6. One “Animal underpass” added beneath Todd Road to provide a link for terrestrial species. This connects Westgate Park with the recommended conversion of the area currently known as the Go Kart site to a large park with native vegetation (similar to the existing Westgate Park).



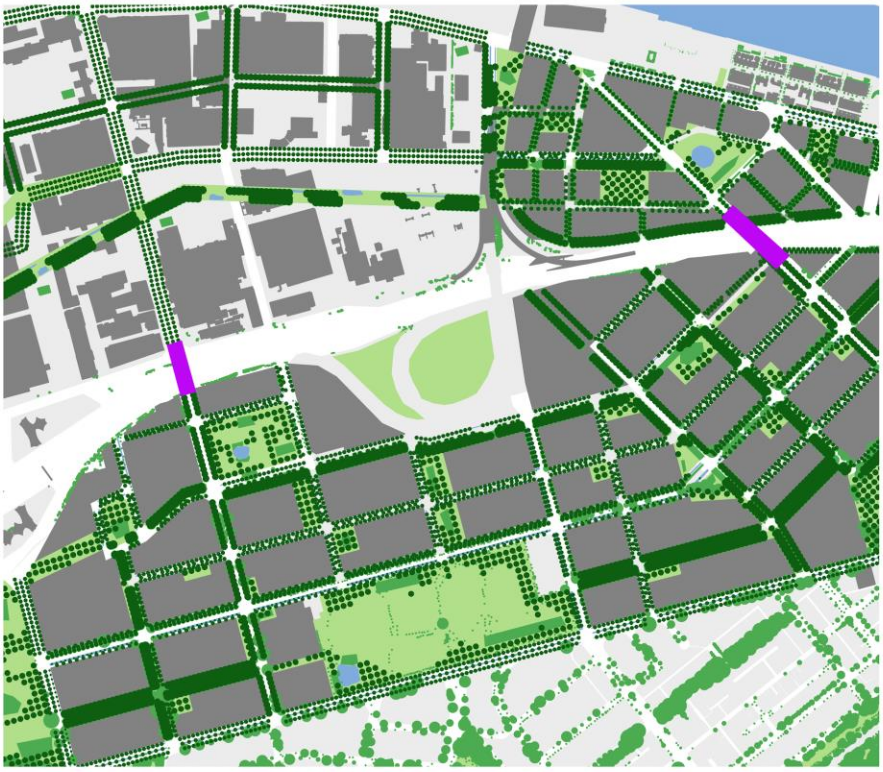
Existing land use map

New land use map

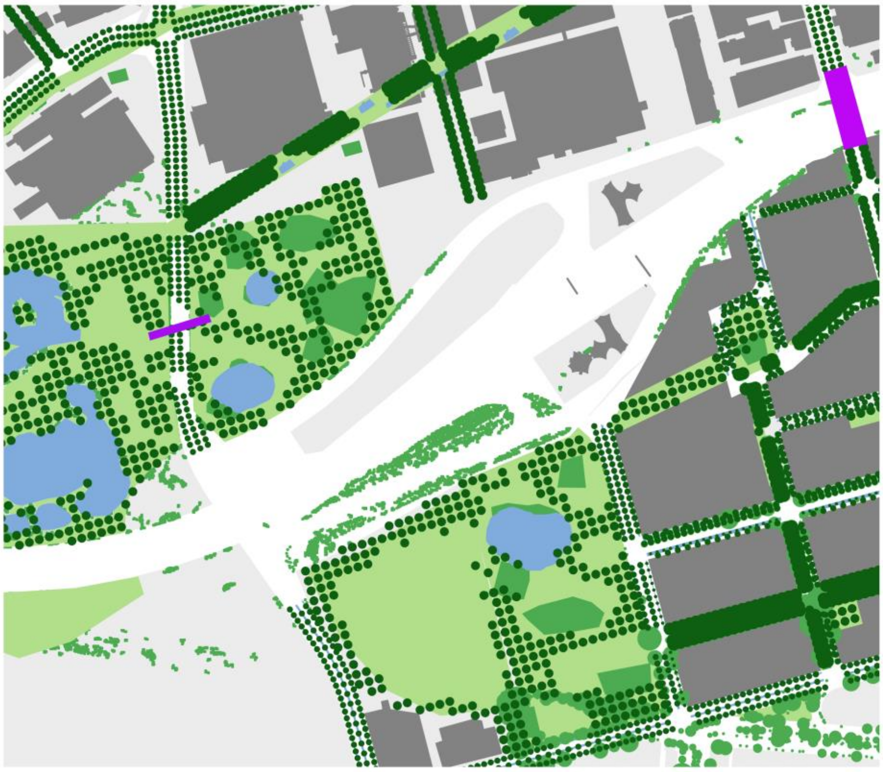


Employment precinct showing Green Link

Green Bridges over Westgate Freeway



Animal underpass below Todd Road, connecting Westgate Park and the new park in the GoKart centre area



Examples of different canopy covers, understorey areas and wetlands in parks