Designing and managing biodiverse streetscapes: key lessons from the City of Melbourne

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Abstract

Underutilised public spaces such as streetscapes offer substantial opportunities to integrate habitats that increase biodiversity into existing urban landscapes and create more ecologically connected cities. Cooperation and collaboration from diverse stakeholders are paramount to achieving this because growing conditions for plants in streetscapes are often much harsher than remnant habitats or urban parks and little is known about the horticultural performance of many native understorey species in these novel urban environments. This paper describes how the City of Melbourne collaborated with researchers from the University of Melbourne to develop and test a suite of understorey plant species to increase streetscape biodiversity. To do so, we selected species using criteria from a horticultural planting guide which guided the design and creation of four streetscape plantings within the municipality. Here, we document the process and discuss lessons learnt from this project to assist other cities to design, construct and maintain streetscapes with successful, cost-effective plantings that improve urban biodiversity and aesthetic value. Key to the long-term success of these biodiverse plantings was thorough soil preparation and weed management before planting, and the implementation of a clear, ecologically sensitive management plan. To support this plan, suitably qualified and experienced landscape maintenance staff were essential, particularly those with horticultural knowledge and experience with indigenous and native plant species. Our project highlights the often conflicting needs of local authorities and ecological researchers and the necessary trade-offs needed to meet realistic goals and achieve successful project outcomes for creating more biodiverse urban landscapes.

Introduction

Urbanization is contributing to an unprecedented loss of global biodiversity (Aronson et al. 2014; McDonald et al. 2019). This is increasingly concerning as biodiversity not only has intrinsic value, but it underpins the delivery of critical ecosystem services that sustain healthy and liveable cities, such as climate regulation, pollination, provision of clean air and is embedded within many cultural values (Dearborn and Kark 2010). At the same time, cities can play an important role in the conservation of global and regional biodiversity (Aronson et al. 2014; Spotswood et al. 2021) and support a high diversity of species, including many that are threatened (Ives et al. 2016) and some that rely entirely on cites (Soanes and Lentini 2019).

Streetscape vegetation can provide a range of ecosystem service outcomes (Salmond et al. 2016; Säumel et al. 2016) and when managed well, is highly preferred to non-vegetated streetscapes by residents (Bonthoux et al. 2019). Typically, this is through the amenity and cooling of street trees but bioretention systems to improve water quality are also common on streets in many cities (Kazemi et al. 2011; Laurenson et al 2013). Increasingly, streetscapes are also being recognised as opportunities to improve habitat (White et al. 2005) and ecological connectivity (Fernandez-Juricic 2000).

The interdisciplinary challenge of conserving and restoring biodiversity in cities requires cooperation and collaboration from diverse stakeholders, including policy makers, land managers, scientists, and local

conservation and community organizations (Aronson et al. 2017). City governments are the managers of public urban green space. Consequently, they are well-positioned to improve urban ecosystems, demonstrate responsible stewardship and leadership (Aronson et al. 2017), and provide opportunities to educate and actively foster people's connections with nature (Dearborn and Kark 2010), which in turn is hoped will enhance pro-environmental behaviours for biodiversity conservation (Prévot et al. 2018).

This paper describes how the City of Melbourne, the central local government authority of Melbourne, Australia, collaborated with researchers at the University of Melbourne to develop and test a suite of understorey plant species in urban streetscape plantings and assess if they could increase faunal diversity. We describe the '*Streetscape Biodiversity Project*', the process of its development (Fig. 1) and the accompanying '*Urban Nature Planting Guide*' and then discuss key insights, challenges and lessons (Table 1) that could inform the development of similar programs in other cities.

Table 1

Summary of key lessons that have arisen from implementation of biodiverse streetscape plantings across the City of Melbourne

	Key lessons
Project objectives	• Balance stakeholder interests and expect trade-offs • Accept risk of planting failures and make contingencies
Project management	• Seek an experienced, skilled and open-minded project manager • Project is not 'business-as-usual' and decisions often need to be made instinctively • Ensure clear and frequent communication between stakeholders
Collaboration	• Collaboration required with stakeholders across many disciplinary backgrounds • Skillsets of local authorities or academic ecologists alone are not adequate
Project costs	• Consider long-term maintenance costs during project budget allocation • Expect high initial costs for long-term benefits
Plant selection	• Select species that will tolerate site conditions • Talk to local experts about indigenous/native plant-animal species interactions • Select species with ability to recruit spontaneously and establish self-sustaining populations
Planting design	• Group plant categories and ensure suitable densities • Original planting arrangement will likely change over time • Be capable of adapting planting arrangements in-situ • Re-visit completed sites to observe and evaluate planting success and failures to guide future planting designs
Plant procurement	• Order well in advance and/or contract grow unusual or uncommon species, particularly if needed in large quantities • Engage specialist contractors with strong indigenous/native horticultural skills • Ensure substituted species are reviewed and identified as suitable by project team • Inspect and verify plant stock prior to installation

	Key lessons
Site considerations	• Employ effective weed management practices during site preparation • Retrofitting site for biodiversity may be impractical • Consider implications of safety and traffic control on project costs
Horticultural skills and knowledge	• Maintenance staff typically contracted to manage streetscapes do not have skillset/experience to effectively manage these plantings • Upskilling staff may be necessary
Maintenance	• Consider maintenance during the design phase • Maintain sites using ecologically sensitive techniques • Share knowledge between horticultural maintenance teams and ecologists and adapt management accordingly • Establish long-term maintenance plan (5–10 years) to ensure ongoing integrity of planting
Project communication	• 'Internal champions' that advocate for these projects is important • Ensure transparent communication with public • Sharing findings increase capacity for project uptake by Council and others • Publicly accessible planting guide is a valuable resource

City of Melbourne (2017), has developed a 'Nature in the City' Strategy that aims to create and maintain healthy ecosystems and thriving biodiversity. A key target is to increase understorey habitat by 20% by 2027 on land managed by the City. However, the opportunities for establishing native understorey in the City's parks and gardens are limited because of the demand for passive recreation spaces and because heritage and landscape character considerations in the municipality's many historic places restrict the available plant palette to species typically planted in the late nineteenth century. Much of the remaining City-managed lands are streetscapes that are designed to prioritise vehicular and pedestrian access and safety ahead of biodiversity objectives. These streetscapes, however, can contain substantial amounts of public greenspace, including road verges, median strips, traffic islands, roundabouts and outstands (Marshall et al. 2019).

Increasing the structural complexity of understorey vegetation, and planting native species, has positive effects on bat, bird and insect communities in Melbourne (Threlfall et al. 2017, Mata et al. 2021). Therefore, establishing multiple layers of vegetation, which are normally absent on streets, by planting native understorey could provide many benefits to fauna, including a greater variety of foraging, breeding and sheltering resources (Tews et al. 2004; White et al. 2005). However, with the exception of remnant patches, complex, native vegetation is largely absent in urban landscapes (Le Roux et al. 2014; Aronson et al. 2017) and there are real or perceived barriers to its implementation on streets (Marshall et al. 2020).

For the City of Melbourne these have included potentially high construction and maintenance costs, safety concerns regarding dense vegetation and the risks of vegetation death due to the hostile growing conditions of streetscapes that would then result in negative public perceptions and further maintenance and renovation expenditure. There are also conflicting reports between Council's maintenance provider and internal Council experience on the performance of some native species in City gardens and doubts that additional plantings can increase fauna diversity. Nonetheless, the City continues to desire development of innovative solutions to meet their strategic biodiversity targets by exploring how native understorey can be successfully grown in streets.

Research And Development

Urban Nature Planting Guide research and development
The *Urban Nature Planting Guide* was initially developed by ecologists and horticulturalists from the University of Melbourne in response to the lack of public information on the performance of many native understorey species in urban environments and the consequent limited use of these species in public open spaces by landscape architects. The *Urban Nature Planting Guide* was intended for landscape architects and other urban design professionals. Its evidence-based recommendations can assist the design and plant selection of future streetscape renewal and similar projects to improve biodiversity and ecosystem services while being successful and cost effective.

Plant selection was based on a series of criteria that included: 1) ability to perform well in the streetscape, 2) horticultural attributes and 3) provision of important resources for target fauna. Streetscapes are hostile environments for plant growth. Altered soil structure and chemistry, reduced water availability and increased solar radiation (Volder 2010), coupled with the horticultural challenges of many Australian species, makes recreating the indigenous vegetation communities typical of local remnant habitats on streets impossible (Williams et al. 2009; Threlfall et al. 2015). Instead, a fundamental requirement for inclusion of plant species in the *Urban Nature Planting Guide* was tolerance of the environmental constraints of streetscapes. Plants were also selected based on having growth forms and lifecycles suitable for streetscapes, and for provision of important biodiversity resources for target fauna; this contrasts with many approaches to plant selection where ornamental and visual traits are of higher priority. Consequently, the majority of plants listed in the *Urban Nature Planting Guide* were perennial herbs, grasses and low-growing shrubs and most, but not all, were indigenous to the greater Melbourne area. The ability of native species to establish self-sustaining populations was also highly desirable as this could reduce maintenance costs and increase the likelihood of these plants spreading beyond the streetscape.

The City of Melbourne identified birds, bees and butterflies as priority target fauna because they were expected to receive greatest benefit from the biodiverse streetscape plantings and are of interest to the public. Plants were selected based on documented scientific evidence that they could provide important resources for target fauna, or alternatively, the expert opinion of researchers. Resources included nectar and pollen for pollinating insects (Latty and Threlfall 2016) and birds (Low 2002); larval food plants for

local butterflies (Kurylo et al. 2020); nesting material for birds (Pellissier et al. 2012) and solitary bees (Threlfall et al. 2015; Latty and Threlfall 2016); seed and fruit for birds; and protection for small birds in the form of dense, spiny shrubs (Adams 2015). The horticultural attributes and tolerances were obtained from the *Burnley Plant Guide* (University of Melbourne 2016) and the expert opinion of researchers involved in the project. A preliminary list of plant species was peer reviewed by internal and external expert horticulturalists. To promote biodiversity friendly urban plantings, the *Urban Nature Planting Guide* was then developed into a publicly-accessible online database (melbourne.vic.gov.au/plantingguide) with over 100 species, and including plant selection filters (e.g. based on growing conditions, plant characteristics and biodiversity attributes) to assist users to choose suitable species.

Design And Construction Of The Ecological Design Experiment

The ecological impact of planting species from the *Urban Nature Planting Guide* on streets was tested using a Before-After-Control-Impact (BACI) experiment (Eberhardt 1976). The diversity and abundance of target fauna were surveyed before and after planting species from the *Urban Nature Planting Guide* at four biodiversity 'impact' sites (Fig. 2), and at three similar 'control' sites selected for each impact site (n = 12). Impact sites were selected by balancing the concerns of scientists (e.g. that plantings should be close to existing habitat to increase the likelihood of colonisation), with the budget and resources available, and the existing schedule of streetscape upgrades. Control sites were as similar as possible to impact sites, but to better account for the variable and dynamic nature of the urban landscape, rather than the standard single paired control site we used three for each impact site. Plant performance assessments (i.e. health and appearance) were undertaken immediately after planting, and at 12-week intervals thereafter over a 12 month period.

Landscape architects from the City of Melbourne used the *Urban Nature Planting Guide* to prepare a planting plan for each streetscape. Rather than a prescriptive site-specific planting design and schedule outlining the location of every individual plant on site, these indicated generalized arrangements of plants using 'drifts' or groupings based on life form and growth characteristics, with varying densities and proportions (e.g. 15% medium shrubs, 15% small shrubs, 15% grasses/tussocks, 25% ground covers and 30% wildflowers). This planting strategy was adopted to minimise maintenance requirements (e.g. plants with comparable growth habits typically require similar maintenance inputs) and to place species together that provide similar resources. It also provided contractors the flexibility to respond to specific site conditions and plant availability.

Because the project was novel, complex and evolving, the construction of the streetscape plantings was supervised by a senior project manager with knowledge in horticulture, landscape management and streetscape projects. Site preparation differed from standard streetscape planting specifications and protocols. Sites were prepared to ensure that the soils favoured native plants, and one site also had irrigation installed. For example, at the Clowes Street site the existing bitumen footpath was dug up and

new topsoil imported (Fig. 2B). A 20 mm stone aggregate mulch to a depth of 50 mm was applied over the topsoil and herbicide spraying was used to eradicate weeds prior to planting.

The species planted were influenced by market availability. Consequently, they may have not been of local provenance even though that would have been desirable. Not all species selected from the *Urban Nature Planting Guide* for inclusion were available from suppliers at the time, and substitutions were made by the planting contractors without consultation with the internal project manager. In some cases, these substitutions were unsuitable for use or of poor quality, with many dying post-planting. This highlighted four key lessons: 1) species that are uncommon in cultivation, as many were, or are needed in large quantities and require longer production times, are best delivered through contract arrangements with nursery suppliers to avoid planting delays; 2) specialist contractors with horticultural knowledge and experience with native or indigenous species should be engaged by the project manager; 3) proposed substitutions by planting contractors need to be communicated to, and be approved by, those delivering the outcomes of the project; and 4) species identity and plant quality should be inspected and verified prior to installation. It is essential that the last two key lessons are clearly defined in the contractual agreement with the planting contractor.

Ultimately, construction across all sites was delayed by approximately one year. This was due to multiple factors, including ordering and administration, poor site preparation including inadequate herbicide application, planting season challenges, and uncertainty around budget cycles and project management. These challenges highlight the complexities of these types of projects and the need for an adequate project planning phase and careful project management, including having a project manager on board early to ensure that major delays are avoided.

The Importance Of Maintenance

A clear, affordable, long-term (5–10 years) maintenance plan that ensures delivery and persistence of the intended planting design and that outlines ecologically sensitive maintenance techniques, their frequency and timing, is required for success. Because of the experimental nature of the plantings, we accepted a higher risk of plant failures but intentionally integrated more 'risky' plants into the least publicly prominent sites. Approximately 16 hours of maintenance per month occurs across the four biodiverse streetscape sites combined. Maintenance is undertaken by an externally contracted horticultural operations team. Tasks include

- temporary retention of weeds (i.e. defined as 'unintentional plantings' for this project) that are considered highly beneficial to insects;
- fostering natural recruitment of plantings whenever possible through appropriate weed and pest management practices;
- reducing the frequency of pruning in order to retain habitat;

- spot spraying weeds only in open areas and edges to avoid off-target damage to native plants and insects;
- minimising soil disturbance;
- removing leaf litter only when it is clearly having a detrimental effect to plants;
- manual hand weeding; and
- deadheading of weeds to reduce weed-seed load.

Because the horticultural operations team is maintaining native vegetation for biodiversity outcomes, adequate plant identification skills and relevant horticultural knowledge is critical. Staff contracted to manage standard streetscapes and parks typically do not have the skillset or experience required to effectively manage diverse native plantings in urban settings. Overcoming this problem, for example through upskilling staff, would result in more effective maintenance and better, more cost-efficient project outcomes. Moreover, it is important to regularly share knowledge between horticultural maintenance teams and the ecologists monitoring the biodiversity values of the sites in order to adapt management as required.

Good soil preparation is essential to minimising the long-term costs of weed management. In some cases, retrofitting a streetscape site for biodiversity planting may be impractical due to high weed loads in the existing soil and the high cost of excavation and disposal. Herbicide spraying was used to eradicate weeds prior to planting but efforts were only partially successful due to persistent weed seedbanks in some retained soil and weed tubers in some imported soil. More effective weed management practices (e.g. repeated herbicide spraying commencing earlier on) implemented during site preparation would have substantially reduced overall costs. A critical evaluation of the weed flora present will help determine the weed treatments that will be most successful (e.g. scalping, herbicide applications or hand removal). Addressing these issues early will be valuable for informing stakeholders from other disciplines involved later throughout the project.

Location can also influence maintenance costs and ease. For instance, the stricter safety and traffic control requirements at the Arden Street site located on a median strip in the centre of a busy road (Fig. 2A), required additional maintenance resources. Traffic Management Plans need to be undertaken and the safety of maintenance staff needs to be considered early in the planning phase, and may limit site selection.

Analysis of total project costs over a five year period from project inception found that maintenance was the greatest cost (City of Melbourne 2020). The costs of maintaining urban planting projects are often underestimated. Ongoing maintenance forms a significant proportion of project costs and this needs to be given as much consideration as project construction costs when allocating budgets. This is particularly relevant when establishing diverse plantings which are typically more costly to maintain, especially when a variety of life forms and growth habits are used.

The Need For Clear And Frequent Project Communications

Planting diverse, native understorey in streetscapes was not a typical practice for City of Melbourne staff, or one that residents were familiar with. Consequently, clear and frequent communication between internal and external stakeholders across multiple disciplines and professions was necessary for project success and to mitigate potential risks. While there are inherent risks with novel projects, support from 'internal champions' who are willing to take those risks, and the acknowledgement that failure forms part of the learning process, are important to pursuing these projects in a local government context.

Communication with the community was also essential and efforts to engage the community are highly valuable. Signage was installed during the construction phase to keep the community informed of what was occurring and the plantings have been largely well-received. The clever and innovative native planting designs across the four sites have provoked curiosity from residents, many of whom ask the horticultural maintenance teams for advice or the names of plant species. Permanent plant labels may be a useful additional communication tool.

Communication, through sharing research data and evidence-based recommendations, is fundamental to strengthening collaborative networks, increasing capacity and reducing risks for local government authorities to implement and maintain these types of projects and, more broadly, to encourage and inspire others to devote efforts towards conserving urban biodiversity. To assist other cities both locally and internationally to undertake similar projects, this project was developed into a publicly accessible case study shared on the ICLEI's Cities with Nature platform (https://citieswithnature.org/city-profiles/Melbourne%20City%20Council). To date, the project and its results have been shared at local and international conferences and will also be detailed in a future scientific paper. Internally, the *Urban Nature Planting Guide* has been used by landscape architects on Council capital works planting projects but not with an experimental design intent. The *Urban Nature Planting Guide* has also been promoted to private landholders to increase biodiverse plantings in residential spaces.

Conclusion

Integrating evidence-based ecological knowledge into streetscape design and management is not standard practice and has proven challenging at times. This project has revealed that many obstacles may be encountered during the process. It has also demonstrated that positive outcomes can be realised when there is a fundamental shift in thinking. This has been demonstrated through increased community interest and positive feedback compared to standard streetscape upgrades, the key lessons learnt from the project described above, the establishment of horticulturally successful plantings, and promising biodiversity outcomes. Two years after planting there was substantial increases in the species richness and abundance of native bees at all impact sites, compared to both the before surveys and the control sites, and higher butterfly abundance and species richness at all impact sites relative to their paired control sites (N. Williams et al. unpublished data).

This project was initially proposed as an experimental design by researchers at the University of Melbourne. City of Melbourne's willingness to collaborate, support and embrace this novel project from the onset was integral for the project's success. Throughout the project, cooperation and collaboration with a diverse array of stakeholders and disciplines was pivotal to achieve common, shared goals and, ultimately, enhance project outcomes. Furthermore, our project highlights that adequate plant identification skills, experience and relevant horticultural knowledge of City staff and contractors was paramount to effectively manage diverse, native plantings in urban settings. We hope the project's key lessons and evidence-based recommendations (Table 1) foster a broader uptake of complex and native habitat plantings in streetscapes in other cities.

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Conflicts of interest/Competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this paper.

Availability of data and material

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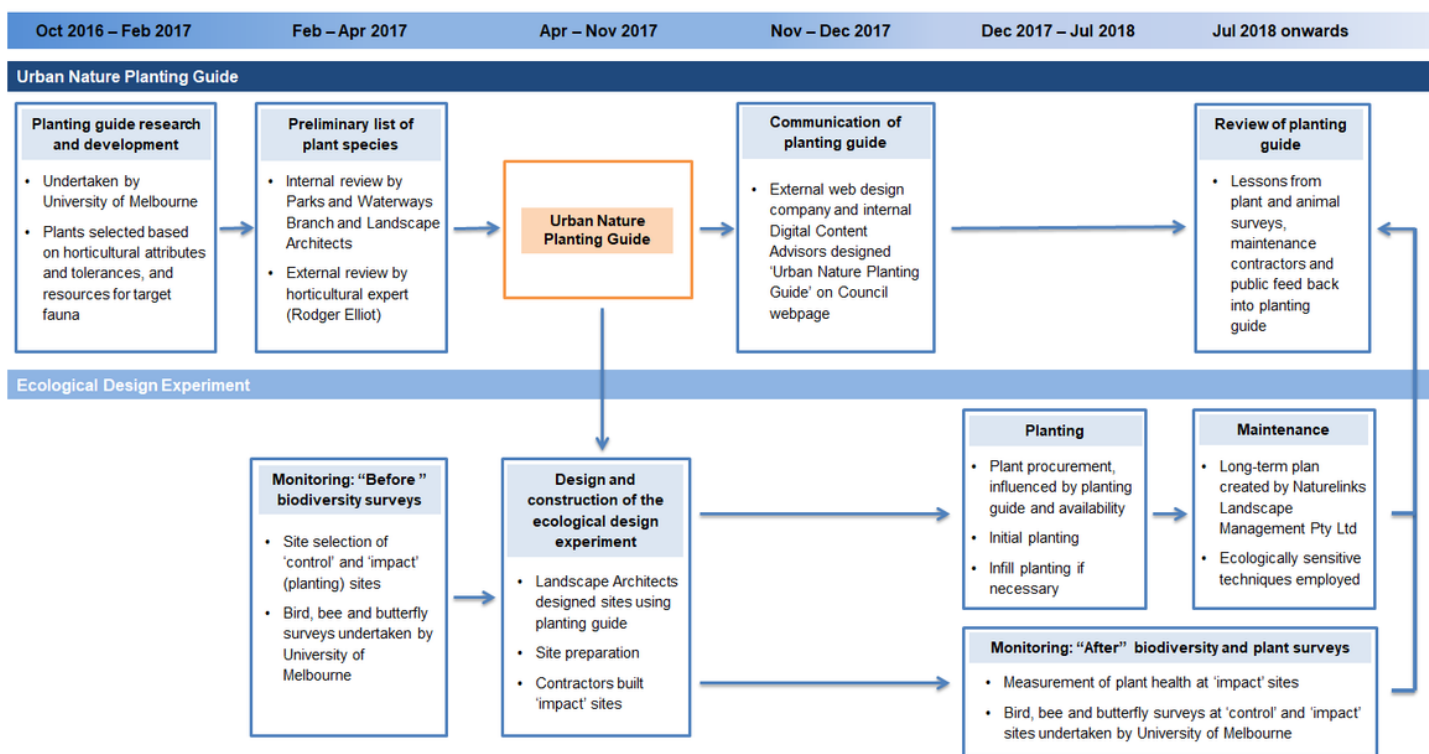
Figures

Figure 1

Diagram summarising the Streetscape Biodiversity Project process framework and timelines
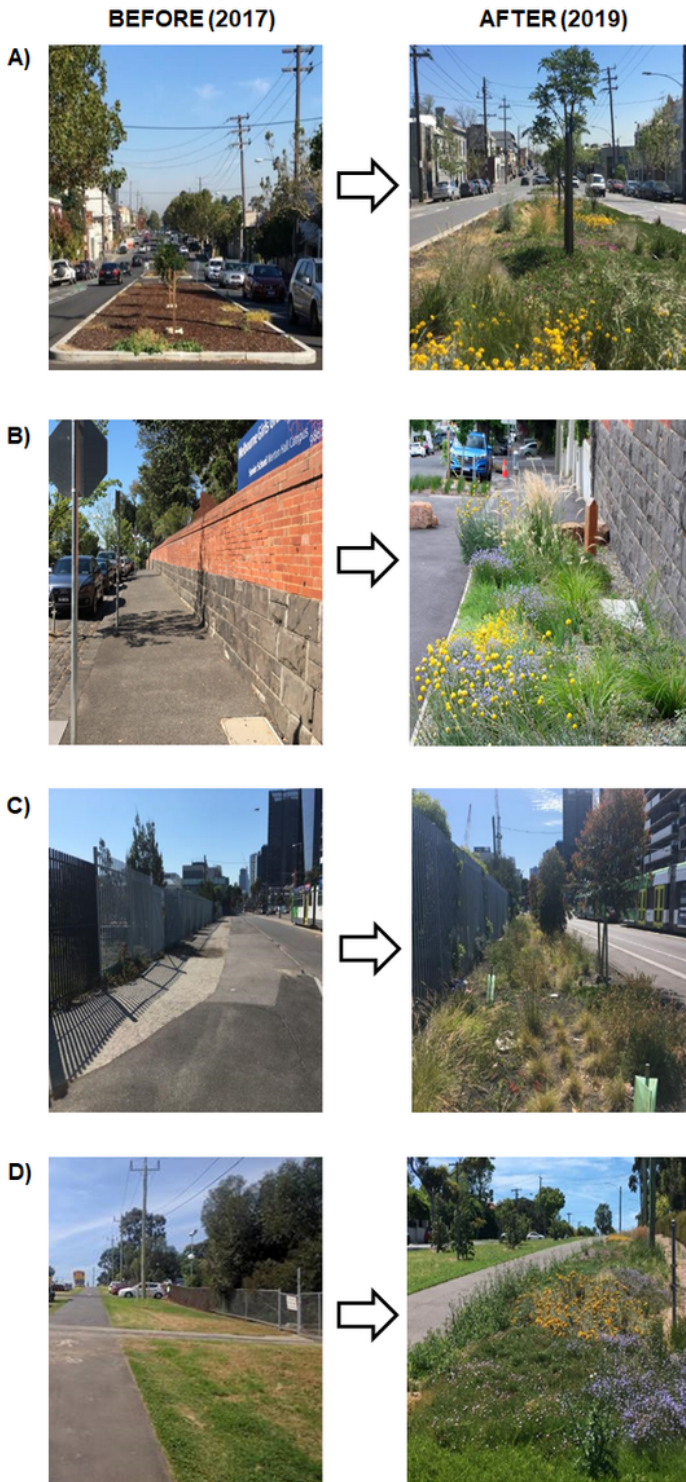
BEFORE (2017)   AFTER (2019)

A)

B)

C)

D)

Figure 2

Before (2017) and after (2019) photographs of the four 'impact' biodiverse streetscape planting sites (initial planting of sites occurred between April – June 2018), located at A) Arden Street, North Melbourne; B) Clowes Street, South Yarra; C) Docklands Drive, Docklands; and D) Park Street, Parkville