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Perspectives on understanding and measuring the social, cultural and biodiversity benefits of urban greening

Discussion paper

Clean Air and Urban Landscapes Hub

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About the Clean Air and Urban Landscapes Hub

The Clean Air and Urban Landscapes (CAUL) Hub is funded by the Australian Government's National Environmental Science Program. The remit of the CAUL Hub is to undertake "Research to support environmental quality in our urban areas". This includes research on air quality, urban greening, liveability and biodiversity, with a focus on practical implementation of research findings, public engagement and participation by Indigenous Australians. The CAUL Hub is a consortium of four universities: The University of Melbourne, RMIT University, the University of Western Australia and the University of Wollongong.

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Acknowledgement of Country

We would like to acknowledge that this paper, and the research it reports conducted as part of the Clean Air and Urban Landscapes Hub, has taken place on Country belonging to the Woi wurrung and Boon wurrung peoples of the eastern Kulin Nation in Naarm or Birrarung-ga (Melbourne), and the and the Whadjuk Noongar people of the Noongar Nation in Whadjuk Boodja (country), metropolitan region of Perth.

We respectfully acknowledge the sovereignty of all of Australia's first peoples, their Ancestors, and Elders, past, present and emerging and that their lands and waters of Australia have never been ceded.

Foreword

This publication has arisen from Project 6, one of the seven projects conducted within the Clean Air and Urban Landscapes Hub, that aimed to establish a network of urban greening study sites across Australian urban centres to understand and measure the multiple benefits of urban greening, focussing on outcomes for biodiversity, culture and human health and wellbeing. An important output from this project is to share the methods and approaches that can be adapted by researchers and practitioners for future use at urban greening projects at a range of different sites and scales. The use of a network of study sites has provided opportunities to study the process of how urban greening initiatives are implemented, how to study them from a socio-ecological perspective, and how or why they are successful. This knowledge can inform future urban greening projects and research designed to understand the benefits and outcomes. In doing so it will provide an evidence base and methodology for measuring and understanding social, cultural and biodiversity benefits of urban greening initiatives according to landscape context, and scale.

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Introduction

Urban greening is defined as enhancing the quantity and quality of urban areas through planting trees, shrubs and other vegetation to bring nature back to cities and to create more greenspace for people (Cooke, Landau-Ward and Rickards 2019, Coffey et al. 2020). Urban greening projects are diverse in scope and scale, encompassing everything from single-household efforts to establish a home garden, to community-led planting efforts to restore degraded habitat, through to developer-led initiatives to incorporate planting in new developments, and agency-led strategies to increase tree cover and revegetate wetlands (the latter can be seen as increasing bluespace. Urban greenspace and bluespace contribute to the sustainability and liveability of cities in many ways. Most often the benefits are described as improving or conserving biodiversity, mitigating urban heat island effects, enhancing people's physical and mental wellbeing and improving quality of life. Urban greening is therefore undertaken for its potential to generate both positive ecological and social outcomes (van den Berg et al. 2015).

Reflecting the international interest in urban greening, there has been substantial investment by Australian governments and non-government agencies in greening Australian cities. For example, the Australian Government has invested $37 million to plant 20 million trees by 2020 and Horticulture Innovation Australia (HIA) aims to make urban areas 20% greener by 2020 (the '202020 Vision'). While in Victoria, 'Greening the West' aims to increase green space by 25% in 2030 and double the urban-tree canopy by 2050. In Western Australia, the Department of Planning, Lands and Heritage (DPLH) has partnered with the Western Australian Local Government Association to develop a comprehensive guide to assist local governments manage their urban forests and enhance urban tree canopy , recognising a decline in tree canopy cover that has occurred in many local government areas in the city (Amati et al. 2017).

Although urban greening encompasses any attempt to increase greenspace and the amount of vegetation in cities, a particular subset of initiatives specifically focus on increasing biodiversity through habitat improvement or habitat creation, while also supporting improved human use and access. This often includes planting native vegetation with varying vegetation structures and removing weed species in existing greenspaces, and renaturalising forms of urban infrastructure including drainage channels, roads and street verges (Farahani and Maller 2019). These sorts of urban greening projects seek to maximise the amount of greenspace and habitat in cities by occurring in either 'leftover' or 'informal' areas such as urban drainage corridors or 'green lanes', or in more formal urbanised spaces such as former industrial sites or street verges that are not typically considered as greenspace. Because such projects occur in close proximity to relatively densely populated residential areas their design intentions are to benefit both people and nature by improving the amount and connectivity of greenspace, and habitat, across cities.

Projects that aim to achieve both social and ecological benefits from urban greening differ from those that traditionally aim to benefit one or the other. For example, many urban parks have been primarily designed around human uses and activities while deprioritising biodiversity outcomes. Conversely, urban habitat or conservation projects are usually designed to support native plants and animals, while deprioritising human activities or limiting human access. This somewhat unhelpful traditional dichotomy is now shifting towards the creation of urban greenspaces that can achieve multiple socio-ecological outcomes. Projects aiming to achieve socio-ecological outcomes not only seek to have a positive impact for people and for nature, but also aim to create or improve human-nature connections in urban areas. A key part of socio-ecological urban greening is therefore understanding the complex relationships between the social and ecological dimensions and how these relationships can enhance or hinder outcomes.

Interdisciplinary research is necessary to understand the intended multifaceted benefits and impacts of urban greening initiatives, and how social and ecological benefits might interact. Despite widespread recognition of the value of interdisciplinary approaches for applied

research, the integration of knowledge across and between disciplines is challenging to achieve and is therefore not standard practice. For example, most of the reported research on urban greening focuses either on presenting the findings from either social or biological data with few examples from the Australian urban context that account for the complex relationships between societies and the environment. Part of the problem is a lack of available methods that cross disciplinary boundaries to integrate socio-ecological knowledge in a comprehensive fashion, and a dearth of researchers and scientists equipped to use them. Other elements to consider include the diversity of urban greening projects with varying temporal and spatial scales, the unique character, histories, land uses, tenure and ownership of sites, the possibility of encountering waste and contamination, engaging with diverse communities, engaging with Indigenous communities and knowledges, and working with multi-agency partnerships that often drive urban greening projects. All of these factors provide a particular framework for considering the collection of meaningful social and ecological data at appropriate temporal and spatial scales.

From a project delivery perspective, landscape and environmental managers must make critical decisions about the plant types, biodiversity, integration of wetland and water features, complexity and amenity features of public open space with very limited resources and budget. Urban planners must make strategic and statutory decisions about the size and proximity of both public and private areas, which influences access to greenspace. In each of these cases, decision makers must act on the basis of limited guidance on how different attributes, quality or types of urban greening impact on communities for whom they plan across different urban environments.

To address these gaps, this report provides new perspectives on how to conduct integrated, interdisciplinary research on the social, cultural and ecological benefits of urban greening in Australian cities, drawing on case study research carried out in the suburbs of Melbourne and Perth between 2016 - 2020. The case studies aimed to integrate both social and ecological methods and techniques to develop a practical, socio-ecological approach to evaluating urban greening projects designed to achieve outcomes for humans and biodiversity, while also encouraging positive interactions between them. The paper includes perspectives on current **research gaps**, **insights into approaches** to pursuing socio-ecological research, and **practical guidelines** on developing future integrated studies at a range of scales from individual households to urban parks and catchments. We aim to provide an overview of the current state of knowledge about understanding the socio-ecological impacts of urban greening, and how best to understand the impacts by integrating social, cultural and ecological knowledge through approaches useful for researchers, practitioners and policymakers. Specifically, the approach developed is designed to enable researchers working in a range of academic and government settings, as well as practitioners who work with researchers in these settings, to design and conduct socio-ecological studies of urban greening projects. We also provide an evidence base and methodology for measuring and understanding the social, cultural and biodiversity benefits of urban greening initiatives at a range of scales.

The following section of this paper reviews the benefits of urban greening, with subsections focusing on the reported benefits for social and cultural dimensions, followed by the benefits for ecology and biodiversity. The final subsection discusses work to date on the integration of benefits across social, cultural and ecological dimensions, highlighting key knowledge and practice gaps. To explain the development of the socio-ecological approach, two case studies of integrated social and ecological research on urban greening initiatives are presented. The case studies form part of a wider body of research on the socio-ecological benefits and impacts of improving urban habitat and bringing nature back into cities. The focus of the work presented here is on new initiatives in urban greening and restoration, where the aim of the initiative is, broadly speaking, to increase the diversity of native plants and animals while improving the amount of and access to urban greenspace for people. The final section of the paper discusses the opportunities, challenges and lessons learned from the case studies.

The Benefits of Urban Greening

The sections that follow provide an overview of a range of benefits of urban greening reported in the literature, with the first two sections covering the social and cultural benefits, and the ecological and biodiversity benefits. In summarising what is currently known, remaining gaps are highlighted, focusing on the Australian context. The final section turns to the task of developing an understanding of how to integrate these benefits into a socio-ecological framework, and how it can be used to design interdisciplinary research seeking to measure the multifaceted impacts of urban greening projects for people and nature.

The social and cultural benefits of urban greening

There are many benefits for people attributed to urban greening. While much research has focused on determining the benefits directly associated with human health and wellbeing, in this paper we adopt a broader perspective, expressed as the 'social and cultural benefits'. This phrasing is used to encompass benefits that may or may not have direct impacts on health and wellbeing but are otherwise beneficial for residents and communities, socially and culturally. For example, this includes community wide benefits such as improved social cohesion, community identity, and a sense of belonging, as well as supporting cultural practices including connection to nature and / or connection to Country. As Chan and colleagues (2016) point out, human relationships with nature underpin the foundations of social wellbeing and cultures of peoples across the globe. Although they are considered overlapping, the social and cultural benefits are distinguished here to acknowledge that the responses to urban greening, everyday practices and perceptions of nature vary widely amongst Australia's diverse multicultural communities, including diverse Indigenous communities.

In terms of the benefits for health and wellbeing, urban greening research often draws on the broader health benefits of contact with nature. Contact with nature has been shown to improve a wide range of physical health benefits, including improved immune function, increased physical activity, reduced cardiovascular morbidity, and improved pregnancy outcomes (Egorov et al. 2016, Aerts, Honnay and Van Nieuwenhuyse 2018). There is further evidence that contact with nature provides opportunities for social connection, improved emotional health (Coley, Kuo and Sullivan 1997, Maller 2009, Townsend 2006, Soulsbury and White 2016) and higher life satisfaction (Honold et al. 2016). Similarly, greenspaces have been shown to be important for health and wellbeing, as they promote physical activity, mental health, and reduce blood pressure and stress levels (Frumkin 2003, Hartig et al. 2014). Urban greenspaces also improve the environmental conditions in cities through pollution removal, noise reduction, and temperature (Hofmann et al. 2012). Consequently, the importance of greenspace provision has received much attention in the built environment and public health fields (Paquet et al. 2013, Sugiyama et al. 2008).

Recent research has begun showing that higher biodiversity levels in cities are associated with better psychological health for humans (Fuller et al. 2007), and there is increasing interest in the connection between human microbiomes and urban biodiversity levels, particularly microbes—what is now referred to as the 'environmental microbiome' (Flies et al. 2017, Mills et al. 2017). Higher biodiversity levels may be associated with higher diversity in the microorganisms living in human digestive systems, known to be beneficial to health (Yong 2016) and potentially regulate immune function (Flies et al. 2017). Other studies indicate a positive relation between self-reported wellbeing and higher levels of neighbourhood biodiversity (Botzat, Fischer and Kowarik 2016, Luck et al. 2011). The effects are likely to vary with biodiversity scale (for example, ecosystems versus species) and type (for example, trees versus insects), and are often mixed (Botzat et al. 2016).

While proximity and access to urban greenspaces are important in generating benefits, poor access has been associated with negative health outcomes (Wolch, Byrne and Newell 2014). This has prompted a critical discussion on equity and environmental justice in urban greening to highlight how the benefits of greening are distributed across different populations and socioeconomic groups (Gould and Lewis 2017, Rutt and Gulsrud 2016, Porter, Hurst and Grandinetti 2020). In fact, greening activities in cities have been shown to be unevenly distributed with wealthier parts of cities often the greenest (Heynen, Kaika and Swyngedouw 2006). Left unchecked, the potential for 'green gentrification' will exacerbate inequities and compromise any contribution that greening can make to health and wellbeing, as well as the potential social and cultural benefits.

It is important to acknowledge that to date the urban greening literature is largely silent on Indigenous peoples and their connection to urban places (Porter and Arabena 2018, Porter et al. 2020). This is a key knowledge and practice gap that requires further attention that we aim to begin to redress in this paper and throughout the work of the CAUL Hub. One key place to start is to work towards actioning an Indigenous-led urban research agenda, including for urban greening (see Box 1). Part of engaging Indigenous perspectives into urban greening discussions, research and policy making involves centering the issue of sovereignty (Porter et al. 2020). Porter and colleagues suggest that 'sovereignty is not an aspiration, but a starting point', noting that in comparison to Westernised notions of states and dominion, for Indigenous peoples 'sovereignties are relational, embodied and emplaced' (Porter et al. 2020, p.3). This is pertinent to urban greening initiatives that are often focused on particular sites, or places, that for Indigenous people, remain recognised and cared for as Country, historically and but also currently in the present time.

Regardless of when or where it is located, urban greening occurs within complex social, environmental and political contexts, and this will be a determining factor of the kinds of social and cultural benefits and impacts that arise from any greening actions and policies. Deeper engagement with issues of Indigenous sovereignty and Indigenous peoples' connection to Country is urgently needed so that urban greening initiatives avoid perpetuating the damaging and ongoing impacts of settler-colonialism (Porter et al. 2020, Porter and Arabena 2018). Aside from the urban greening literature's silence on Indigenous peoples and engagement with Indigenous knowledges, a number of other key knowledge gaps about the social, cultural and health benefits of urban greening remain.

First, researchers have highlighted that specific qualities of urban greenspaces including type, proximity, perceptions of safety, and biodiversity can influence the outcomes under investigation (see Lovell et al. 2014 for an overview). Importantly, whether different qualities are relevant for different kinds of wellbeing benefits remains unknown. Very few studies have considered how specific characteristics of urban greening, particularly those relevant to planning and management decisions, influence the range of social, physical, and mental wellbeing benefits. Beyond parks, there is also a lack of understanding about how residents use and respond to various types and scales of other greenspaces in their neighbourhood, including both more formal and informal greenspaces such as street verges, vegetated corridors along railway lines, and urban drainage channels, a form of bluespace.

Second, despite recent interest in the links between biodiversity and health, how and in what ways these benefits manifest is not entirely clear (Flies et al. 2017, Mills et al. 2017, Pett et al. 2016). It is consequently unknown how various levels, scales and which aspects of biodiversity in cities might be culturally and socially beneficial, and what the specific mechanisms are behind the indicative positive impacts on physical and mental health, including immunity, digestive health and psychological wellbeing.

Third, while research is now emerging from a wide range of national contexts, there is limited understanding of how social and cultural factors shape the complex relationships between people and nature in urban settings. By increasing greenspace and levels of urban biodiversity, it is likely that residents will encounter new and diverse species that they may not be familiar with. For example, baseline data from the Melbourne Case Study (page 24) shows that residents have complex relationships with local native animals. While on one hand they described the positive emotional responses from encounters with native species, for example, blue-tongue lizards, they also reported negative emotional responses that arose from encounters with introduced species. But importantly for future greening programs that aim to increase habitat for native species, not all native animals were viewed positively; for instance, there were fears about how snakes returning to the creek might negatively impact health and wellbeing through bites and fear of going outdoors (Maller and Farahani 2018). There is a need to better understand how residents with different demographic and other characteristics perceive and experience urban biodiversity and these perceptions and experiences affect health, wellbeing and social outcomes.

In summary, very few studies have been able to consider how specific characteristics of urban greening, particularly those relevant to planning and management decisions, influence a range of social, cultural, physical, and mental wellbeing benefits.

Box 1: Working towards an Indigenous-led research and practice agenda and protocols

The work of the Clean Air and Urban Landscapes Hub is guided by an Indigenous Engagement and Partnership Strategy and an Indigenous Advisory Group (IAG). During the early stages of the Hub, there was recognition that while Indigenous engagement and participation were welcome, there was a need to go further. This led to the realisation that there was an opportunity to "flip the table" on the common practice of non-Indigenous people designing research and then (sometimes) going and seeking Indigenous input about pre-determined frameworks and questions. In other words, there was a need to determine how to encourage and support Indigenous-led research within the work of CAUL and more broadly.

A subproject on this topic produced the report, 'Flipping the Table - Toward an Indigenous-led urban research agenda', by Libby Porter and Lauren Arabena (Porter and Arabena 2018), with Lauren employed in the project as an Indigenous Research Officer in Urban Sustainability. The idea was to begin to think about the relationship between the research of the Hub and Indigenous ways of knowing the city, and how that could support transformative Indigenous engagement and participation rather than the standard consultative model where non-Indigenous researchers are considered the knowledge-holders and experts.

Some key messages from the report most relevant to urban greening research and practice are:

- Prior to urbanisation, the sites that became Australia's cities were resource-rich landscapes vital for first peoples offering an abundance of food, shelter, and water and governed by complex economic, social and cultural systems and practices. These systems practiced Aboriginal knowledge systems that understood, formed and shaped Australia's environment. Aboriginal knowledge systems consist of a deep understanding of place, connection to place and responsibility to place.

- The systematic and forced removal of Aboriginal and Torres Strait Islander peoples that has occurred over the past two centuries has resulted in the fragmentation of valuable knowledge and a decline in environmental quality. Cities are places of deep and ongoing socio-economic marginalisation. In the face of these problems, Aboriginal and Torres Strait Islander knowledge systems have continued and adapted. Cities and towns are vitally important in sustaining Aboriginal and Torres Strait Islander flourishing.

- To reconfigure standard practices of 'Indigenous engagement', non-Indigenous researchers and practitioners can begin to rethink their approach by:

  1. Becoming informed by Indigenous methodologies: Indigenous scholars have distilled, defined and refined central characteristics, contexts and principles of Indigenous theories of knowledge and methodological approaches. Indigenous theory is located in a specific cultural context and emerges from organic community-based processes that are the product of the cultural foundations of an Indigenous worldview. Non-Indigenous people come from a standpoint that is not structured by the same experiences and perspectives as Indigenous people – by definition they cannot 'come from' an Indigenous standpoint but can be informed by Indigenous methodologies. Non-Indigenous researchers could commit to explicit and sustained effort to become informed by Indigenous methodologies and theories.

2. Undoing privilege; the role of non-Indigenous researchers: One practice non-Indigenous researchers can develop is to begin to cultivate an ongoing attitude of critical reflexivity about who we are, where we stand in the research and the ways in which our standing is supported as privilege in our organisations. This entails different and deeper work – potentially harder, more profound and certainly more unsettling – than 'including' or 'engaging' Indigenous people in their research projects. Be prepared to challenge and change organisational cultures. Actively mentor Indigenous scholars and find ways to support the development of Indigenous-led projects and proposals. Perhaps most important is building relationships. It is long, slow and sometimes challenging work to build respectful, humble relationships over a long period of time.

3. **Research Governance:** One of the problems with 'inclusionary' or engagement-based approaches is that control of the research process tends to rest with non-Indigenous researchers and organisations. If the deployment of Aboriginal knowledges is not controlled by the holders of that knowledge, then this is the antithesis of the principle of self-determination. Consequently, researchers and practitioners need to give deep and sustained consideration to research governance. This, too, only comes through relationship and the close negotiation of governance arrangements. The principles of ownership, control, access and possession are central.

4. **Research Purpose and Benefit:** In Indigenous methodologies, the process of research can be more important than the knowledge produced. Research must produce significant benefits to Indigenous communities, practices, and knowledge holders. These benefits might be about capacity, healing, knowledge, skills and employment or finances. They might be both intangible and tangible. Defining benefits, who should receive them, and how they might be perceived is a matter of self-determining control. Indigenous partners get to say how benefit will be defined and where benefits will flow.

5. **From procedural ethics to relational ethics:** Non-Indigenous researchers need to engage with Indigenous communities and knowledge holders. Many Indigenous organisations and communities have ethical expectations and requirements of researchers. Some of these are formally instituted through organisational and representative bodies. Others are negotiated through relationships. It is incumbent on researchers themselves to be aware of and informed about Indigenous cultural and intellectual property.

Source: Porter, L. and Arabena, L. (2018). Flipping the Table: Toward an Indigenous-led urban research agenda, The Clean Air and Urban Landscapes Hub, Melbourne, Australia.

The ecological and biodiversity benefits of urban greening

Greenspaces within cities can contribute to broader scale conservation goals and provide important habitat for a range of species. Many global 'biodiversity hotspots' envelop urban areas (Cincotta, Wisnewski and Engelman 2000, Mittermeier et al. 2011), and cities themselves may be 'hotspots' for threatened species (Ives et al. 2016). Australian cities constitute a particularly interesting place for examining the impact of urban greening on biodiversity, given that Australian cities typically contain native ecosystems both within and surrounding the suburban footprint (Shanahan et al. 2015), that 30% of threatened Australian species are found within urban areas (Ives et al. 2016), and that Australian cities have developed around major watercourses and wetlands. The large metropolises of Perth, Brisbane and Sydney are established within two global biodiversity hotspots (Mittermeier et al. 2011), distinguished by having at least 1,500 species of endemic plant species, and having lost more than 70% of native vegetation cover.

The fragmentation of remnant habitats and altered availability of food for wildlife within cities means that while some species adapt and even benefit from urbanisation (Fischer et al. 2015), many species will be negatively impacted (McKinney 2008). Studies on urban biodiversity have tended to focus on species that are threatened and may even be restricted to urban remnant vegetation (Soanes and Lentini 2019, Ives et al. 2016), or on taxonomic groups (i.e., groups of similar species) that are abundant in urban areas, easily observed, and/or hold particular social, cultural or environmental significance. Birds and flowering plants are among the most studied taxa. Bats and other small mammals, reptiles, amphibians, fish and a wide range of insects, spiders and other invertebrates are also found in urban habitats, but have generally received less attention (Threlfall et al. 2017, Lowe et al. 2018, McKinney 2008). To thrive in urban habitats, species must be able to move between fragmented habitat patches (including wetlands and terrestrial habitats), or have access to a sufficiently-sized patch of habitat that will allow them to meet their life history and feeding ecology needs.

Urban vegetation often occurs in small, fragmented and isolated patches (Goddard, Dougill and Benton 2010a). Multiple studies covering different taxonomic groups have highlighted that larger habitat patches can support larger and more diverse populations of animals and plants (Aronson et al. 2014, Goddard, Dougill and Benton 2010b). Larger vegetation patches may be able to better withstand the long-term effects of fragmentation such as declining species richness and weed invasion (Ramalho et al. 2014). However, it is not just the size of the habitat patch that is important – the quality and connectivity of the habitat also influences biodiversity outcomes (Lepczyk et al. 2017, Beninde, Veith and Hochkirch 2015). Animals with smaller habitat size requirements (such as insects) may benefit from even modest urban greening initiatives (Hall et al. 2017). Even temporary, 'pop-up parks' can increase the species richness of functional and taxonomic groups of insects and spiders (Mata et al. 2019). Because of the fragmented nature of urban vegetation, connectivity between patches assumes even greater importance for sustaining diversity, populations and ecological processes (Strohbach, Lerman and Warren 2013, Lepczyk et al. 2017, Shanahan et al. 2011). This means that urban greening initiatives that connect habitats (for example, along watercourses), or contribute to the development of corridors for wildlife, can enhance ecological value above and beyond the total area of greening.

Overall, while cities were perhaps once conceived as 'concrete jungles' with limited ecological value, a large volume of recent research indicates that urban habitats can support diverse populations of a wide range of taxonomic groups. Increasing understory vegetation cover and native plantings can enhance habitat value for birds, insects and bats, among other taxa (Threlfall et al. 2017). Approaches have been put forward to demonstrate how biodiversity can be actively considered within urban planning frameworks, to ensure that the multiple environmental, social, health and economic benefits can be promoted (Parris et al. 2018, Mata et al. 2020, Bekessy et al. 2012).

Integrating knowledge of social, cultural and biodiversity benefits of urban greening

Urban living is said to lead to the 'extinction of experience' through losing regular contact with nature (Soga and Gaston 2016, Gaston and Soga 2020). However, cities are also complex 'social-ecological systems' (Berkes, Colding and Folke 2003), where the daily lives of residents are entwined with the cultural and natural landscapes on which urban settlements are situated (Cook, Hall and Larson 2012). Indigenous conceptions of Country undo the notion that nature is non-urban because Country is considered to be everywhere (Kelly 2019). While cities may indeed be thought of as 'social-ecological' in nature and as Country, much of the existing research on urban greening has centred on measuring *either* social *or* ecological qualities, rather than taking an integrated (social-ecological) or relational (Country) approach incorporating analysis of social, cultural and ecological values to understand how people and nature interact (Hunter and Luck 2015, Johnson et al. 2019). For instance, a recent semi-systematic review of the peer-reviewed literature found just 50 published studies taking an integrated approach to social and ecological studies of urban greenspaces in developed country contexts, with several drawn from Australia (Hunter and Luck, 2015). There are several contributing factors to the dearth of integrated social and ecological research in urban landscapes, including the challenges associated with researchers crossing disciplinary boundaries, applying different concepts of scale, and dealing with different ways of making knowledge and building evidence (Cook et al. 2012). A variety of approaches have been adopted to integrate social and ecological sciences in urban settings; several of these are detailed below.

The concept of 'ecosystem services', defined by Costanza et al. (1997), elaborated in the Millennium Ecosystem Assessment (MEA - 2005) and updated more recently by The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Díaz et al. 2015), has been commonly used to identify the goods, services and intangible benefits that people derive from natural environments and processes. The use of an 'economic' language and framework was used by the MEA and linked initiatives such as The Economics of Ecosystems and Biodiversity (TEEB - 2010) in order to make explicitly clear to decision-makers that nature contributes to local and national economies in diverse ways. There are four broad categories of ecosystem services: provisioning services, regulating services, habitat or supporting services, and cultural services. Of the four categories, cities are most commonly associated with cultural services, within which lies recreation and health, tourism, aesthetic appreciation and inspiration, and spiritual experience and sense of place (See Figure 1).

While urban areas typically consume more ecosystem services then they provide (Andersson et al. 2014), the 'blue and green infrastructure' (such as waterways and vegetation corridors) within urban areas also provide a wide range of ecosystem services including enhancing human health, providing food, providing wildlife habitat, reducing air and water pollution, and increasing water infiltration (Gómez-Baggethun et al. 2005, Bolund and Hunhammar 1999, Tzoulas et al. 2007). Using an 'ecosystem service' approach to developing socio-ecological research can be valuable for working with government and non-government agencies for whom the concept may be widely accepted and embedded within guidelines, protocols, and management approaches. However, the concept may be less well understood by members of the general public.

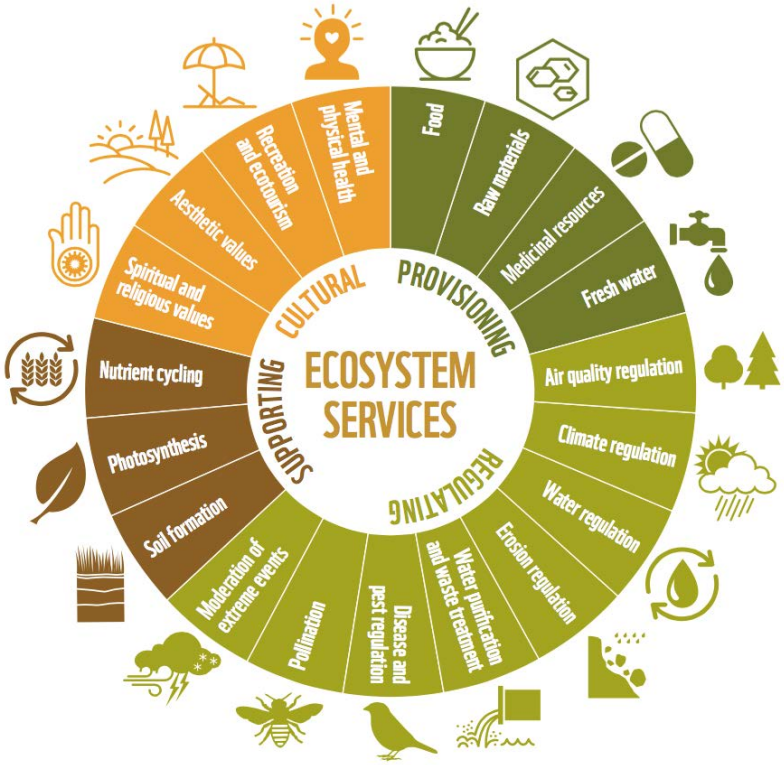


Figure 1: Illustration of categories of ecosystem services. Reproduced from the Living Planet Report, WWF (2016) © WWF 2016. All rights reserved

Plant pollination by animals is one of the key ecosystem services where an integrated social and ecological approach to research has been applied. Animal pollination is often undertaken by highly visible, charismatic or interesting species (such as birds, bees and wasps) during daylight hours in settings that are easily witnessed and often managed by people (such as gardens, parks and nature reserves). In settings where animal pollination leads to production of edible produce for people, there is an added benefit to people which may in turn encourage actions to cultivate flowering plants. In St Louis, Missouri, Burr et al. (2016) sampled wild bees in urban farms, community gardens and prairie pockets throughout the city, and interviewed decision-makers on the social dynamics influencing the management of sampled sites. Their results highlighted perceptions of the ecological roles of bees as well as the actions taken by citizens to actively attract bees into the city. Using a similar approach based on observing birds and sampling bumble bees in green spaces in Stockholm alongside interviews, Andersson et al. (2007) reported that residents and local land managers held strong emotional bonds with the animals they observed, and planted bee-attracting species and made food available for birds. Allotment gardens tended to have a higher coverage of flowering species, and therefore attracted a higher abundance of bumblebees than city parks and cemeteries. Indeed, urban landscapes can provide augmented habitat for native bees compared with surrounding rural lands, due to the active management of biodiversity in urban greenspaces, and because of the relatively small functional requirements of insect pollinators (Hall et al. 2017).

Examples of urban residents deliberately creating habitat for wildlife fall within the realm of ‘civic ecology’ practices, where community members take actions that simultaneously enhance green and blue infrastructure and human well-being (Krasny and Tidball 2012). Examples of civic ecology include community tree planting following natural disasters, community gardening, and community-led ecological restoration projects (Krasny et al. 2014). However, civic ecology projects have often found it difficult to monitor the impact on ecosystem service provision over the longer term, often due to a lack of access to specialised equipment or knowledge needed to undertake such monitoring (Krasny et al. 2014). The use of participatory techniques to engage citizens in co-designing research and in collecting and analysing data on civic ecology practices,

and even in participatory management of urban greenspaces, is an active field of enquiry within integrated socio-ecological research (Dennis and James 2016, Krasny et al. 2014, Rupprecht et al. 2015).

Beyond pollination, perception and values associated with biodiversity in urban green spaces is another focal area for integrated socio-ecological research. Some researchers have asked members of the public to assess plant biodiversity in public spaces and have compared their views with botanical data (Muratet et al. 2015, Lindemann-Matthies, Junge and Matthies 2010) while others have assessed self-reported measures of well-being and restorative properties of green spaces with varying levels of diversity (Carrus et al. 2015), and reported increased levels of volunteer activity at sights with higher biodiversity (Dennis and James 2016). Several studies have reported public support for higher levels of biodiversity in grassland vegetation and lawns (Ramer et al. 2019, Lindemann-Matthies et al. 2010). Urban 'wild spaces' can provide a broad range of ecological and social benefits (Threlfall and Kendal 2018), although these are often not documented in detail for the same location.

Finally, a suite of studies have taken a higher-level approach to linking the social and ecological values of urban greening, often through using geospatial techniques (such as remote sensing and the application of Geographic Information Systems) and/or comparing ecological data with large datasets on social, demographic, health and economic data of urban residents. These approaches tend to rely on detecting correlations and other patterns in data related to socio-economic and biophysical metrics. Examples include an inverse association between street tree density and anti-depressant use in the boroughs of London (Taylor et al. 2015), a positive correlation between plant biodiversity and household income, known as the 'luxury effect' in many cities worldwide (Hope et al. 2003, Leong, Dunn and Trautwein 2018), increased property values attributed to mature street trees (Pandit et al. 2013) and a positive association between landscape biodiversity and better respiratory health across continental Australia (Liddicoat et al. 2018). Such broad-scale studies focus on outlining trends and associations that can be used to inform policy and planning, as well as inform future research on the specific drivers and causal relationships behind these trends (Sandifer, Sutton-Grier and Ward 2015).

In summary, the field of integrated research that includes consideration of social and ecological elements is still relatively small. Research on urban greening has relied upon western rather than Indigenous knowledge or theories and has tended to focus on *either* social *or* ecological benefits considered discretely, rather than holistically. Integrated research that has been undertaken has employed several methods, often using a mix of qualitative and quantitative research techniques to elicit information from participants. Plant pollination by animals, and the links between human well-being and health and biodiversity, are two of the key areas that have been investigated by socio-ecological researchers in urban areas, yet there remain many more to research, measure and understand.

Developing a Socio-Ecological Approach

In this section, we detail some of the broad considerations that were kept in mind when designing the case studies, in order to foster and facilitate replication and the establishment of an integrated dataset on both the social and ecological outcomes of urban greening transformations. At the outset, designing socio-ecological studies to evaluate urban greening projects requires strong collaborative planning with research and project partners, including local stakeholders and Indigenous communities, to understand the actors, drivers, successes and barriers of different urban greening initiatives.

The issues and techniques presented here are applicable to future or other studies, but for practical reasons may not be able to be implemented or addressed in every scenario. We provide this guidance here as part of our intention to present best practice socio-ecological approaches to evaluation of urban greening and to support building a shared evidence base across sites around Australia.

Using these approaches, research conducted across a number of sites in the CAUL Hub aimed to:

- Establish a network of integrated study sites, including urban greening projects and control sites (where feasible) to assess the multiple, socio-ecological benefits of urban greening, while developing research protocols to form part of a 'Handbook' of socio-ecological approaches to measuring the benefits of urban greening transformations;
- Develop a meta-data catalogue of urban greening study sites with relevant partner and research information to encourage collaboration across projects. See the CAUL Network of Integrated Sites website for further information.

To assist those designing and involved in conducting similar socio-ecological research, we use a 'Question and Answer' format below to address the main considerations in developing a socio-ecological approach to urban greening.

What types of urban greening can be included?

Any urban greening project that seeks to achieve social and ecological outcomes can be included. There is no set type of greening action or project of interest, or any minimum number of sites to be 'greened'. Ideally, however there will be both social and ecological or biodiversity research questions, interests and/or outcomes to be achieved. Sites will have different histories, land uses, and social and cultural contexts which should be acknowledged and accommodated in the design of the research as much as possible. Indigenous sovereignty should be acknowledged as central, while also recognising the importance of Indigenous history, ongoing culture and significance associated with any location.

What spatial scale is required?

Any site from those involving individual action to community-scale/catchment scales can be studied. There is no set site typology, hence no site is too small or too large. The approach has the ability to accommodate multiple spatial scales. However, physical or cultural boundaries may not overlap neatly so some flexibility and sensitivity is needed.

What temporal scale is required?

Ideally, a pre/post (or before/after) design is the best way to measure the change and/or impacts of urban greening in both social and ecological domains. This means data are collected both before the greening or any site work has taken place, and after the works are completed and the plantings, wetlands and other ecological features have had time to become established.

A mid-way point of data collection may be useful in some cases, especially if the greening works take months or years to complete.

Alternatively, a 'chronosequence' approach can be taken to elucidate the effect of time since urban greening was undertaken. In a chronosequence approach, a set of distinct sites are chosen where a particular greening initiative has been underway for varying lengths of time, as a proxy for measuring the same site repeatedly over several years. For example, if there was an interest in identifying the potential impact of adding native plants to local parks over a decadal timespan, researchers could compare parks that were planted 10 years ago, 5 years ago, 2 years ago, and newly established plantings, rather than having to monitor the new plantings for 10 years. Both before/after and chronosequence approaches have advantages and disadvantages that need to be considered according to the project needs, feasibility and budget.

Seasonal and climatic effects should be measured and/or accounted for, with data collected over multiple annual seasons if possible. The activity, detectability, audibility, visibility and abundance of different plant, animal and other taxa often vary throughout the year (and even throughout the day). It is best to check the optimum times for sampling to ensure that data reflect the biodiversity of the taxa of interest at the project location. Social and wellbeing outcomes also demonstrate seasonal patterns, with physical activity levels in particular associated with warmer rather than cooler months.

What kinds of methods are used and what kinds of data are collected?

Both social and ecological/biodiversity data are collected using a suite of methods. Data collection should occur in both social and ecological domains at one or more sites and will ideally follow the full research approach and sets of methods suggested here, including working towards an Indigenous-led research and practice agenda (Box 1). Social and ecological components can be studied independently or individually if it is not possible to do both. For **biodiversity**, plant and animal surveys are undertaken. For plants and insects, an inventory of native and non-native species should be documented pre- and post-greening, preferably at multiple/seasonal time points. For vertebrate animals, we recommend they are surveyed in classes (e.g. birds, reptiles, mammals), focusing on taxa most relevant or culturally important to the site/s. As interactions between plants and animals are a measure of success in understanding post-greening impacts, plant-insect pollinator interactions as well as direct observation of plant-bird behavioural interactions should also be recorded (for example, see Figure 2).

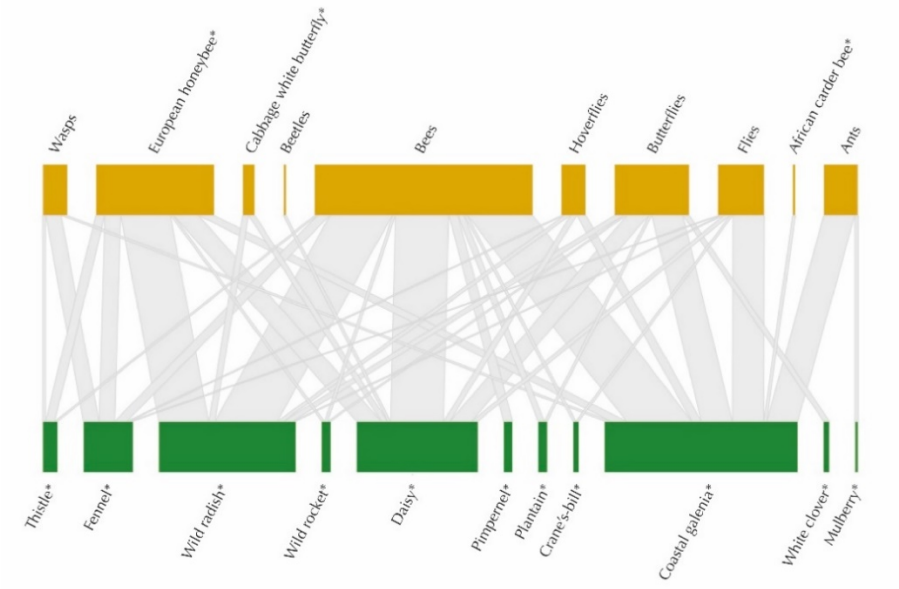


*Figure 2: An example of insect pollinator-plant interactions from Upper Stony Creek. * Indicates introduced species (Source: Luis Mata)*

For **social** data, mixed methods using both qualitative and quantitative techniques will provide the richest insights into the impacts of the greening on local communities, including Indigenous communities. For example, interviews with residents living in close proximity to greening sites can be conducted to for in-depth understanding of their perceptions and uses of the site pre and post greening and how their health and wellbeing may have changed. Interviews with key stakeholders (for example, Indigenous owners, community groups, local government, and industry) can help provide context and understand guiding policies and future plans. A survey of the broader local population at the geography of 'Statistical Area Level 2' (SA2) (used by the Australian Bureau of Statistics) can detect broader population level patterns of use, perceptions and health and wellbeing.

Opportunities to integrate social and ecological methods and data can be found in the design of social science instruments. For example, questions can be asked in interviews and surveys about particular animal classes or species observed or known to be at the site/s. These questions can be informed by the biodiversity surveys conducted pre- and post-greening. Observations of human use of and visitation to the site can round out other forms of data collection by providing insights into diurnal patterns as well as social and ecological interactions as people interact with plants, animals and each other.

Some specific techniques tested in the case studies that are explained in more detail in the following section included:

- Collection and analysis of baseline ecological and social data before the greening project. Identification of points of intersection between the social and ecological research designs and data collection techniques.
- Post-greening social and ecological data collection and analysis identifying the benefits associated with the improvements and an understanding of how humans and other species use the sites.
- Integrated analysis of data from the social and ecological data sets post-greening, based on the points of intersection identified earlier.

What kind of comparisons are important?

Best practice research usually involves one or more types of comparison. Usually, the comparison is structured around a key variable that is considered to be the major driver of difference (for example, the presence of increased diversity of native plants). There are a number of ways comparison can be achieved that fit the approach described here. The use of 'control' study sites is one technique that can clearly identify the gains or differences between greened and non-greened areas. Control sites (where no new greening action has been undertaken) need to be comparable across either or both social and ecological variables, such as socioeconomic classification, housing composition, vegetation structure, hydrology (if relevant), and historical land uses.

Similarly, it can be important to monitor comparative green spaces, grey spaces and public open space that do not undergo urban greening initiatives, so as to assess the impact of inter-annual variability and increased community awareness of the greening initiatives. Socio-ecological temporal comparisons are possible through a pre/post sampling design or chronosequence design, as well as across seasons if seasonal data can be collected.

It is acknowledged that comparisons with 'control' sites are not always possible due to a variety of reasons. These include the timing of greening transformations being out of synch with research scheduling, the lack of comparable control sites available, budgeting or other feasibility

limitations, or extensive variation between pre- and post- greened sites (for example, a carpark with no vegetation compared to a transformation of a street verge into a native garden).

Who is involved in data acquisition and knowledge translation?

The research approach advocated here is governed by principles of inclusiveness and co-design and is therefore designed to include a range of different stakeholders, from researchers, decision makers, Indigenous owners, project funders, communities, and citizen scientists in the entire research process.

Project designers, funders and other partners often have objectives or key outcomes or objectives they wish to achieve that can be worked into the specificities of the ecological and social data collection methods. For example, this could be through additional questions added to interview schedules or survey instruments. Practitioners or researchers trained in the use of the social and ecological techniques may be based in these organisations, or can be based in non-governmental organisations, government agencies, universities or other research bodies.

To work with local communities, the CAUL Hub has trialled and developed a number of citizen science opportunities, from apps to collecting data via pollinator observatories that study plant-insect interactions, including collecting data on bell frogs, flying foxes and beneficial insects with the CAUL Hub Urban Wildlife App.

Indigenous owners of the sites should be engaged from the outset of any greening project to determine how the project and associated research can benefit First Nations communities and care for Country. The Three-Category Approach and Workbook has been created by Indigenous researchers, communicators and designers to help classify projects regarding their involvement of Indigenous communities. This valuable resource aims to guide non-Indigenous researchers and practitioners in their work, helping support Indigenous led projects and make space for co-design. The methodology of the Three-Category Approach was incorporated into the research of the CAUL Hub.

Case Studies: Socio-Ecological Research on Urban Greening

In this section of the report, we present two case studies on integrated approaches to socio-ecological research in urban Australian settings. We have chosen these two case studies to demonstrate how an integrated socio-ecological approach can be applied to a range of different urban greening initiatives, from small- to large-scale, and from citizen-led to agency-led. The first case study examines a citizen-led approach to urban greening, through the voluntary transformation of nature strips (also referred to as street verges) into native gardens in two local government areas in Perth (example shown in Figure 3). The second case study explores the transformation of an urban waterway in western Melbourne from a concrete drainage channel to a linear urban park and wetlands, thereby increasing both greenspace and bluespace. Our focus in presenting these case studies is to detail the approach and overall design of the research, rather than describe the results and outcomes. By focusing on the 'why' and 'how', we hope that these case studies will provide some practical guidelines for managers, planners and researchers to design and implement their own monitoring and evaluation projects on the social and ecological benefits of urban greening.

The two case studies form part of a broader portfolio of socio-ecological research projects that have been undertaken as part of the Clean Air and Urban Landscape Hub, and are informed by an interdisciplinary approach to the multiple values and meanings of 'bringing nature back' into cities (Mata et al. 2020). The socio-ecological approach has also been used to identify the benefits of urban greening in settings such as urban parks, where park managers have increased the planting density of native species in greenspaces that are commonly used for recreation. Many of these examples are illustrated detailed on the CAUL Network of Integrated Sites website.

Figure 3: An example of a diverse nature strip garden in suburban Perth. Image credit: R. McDowell

Transforming residential nature strips to native gardens: a citizen-led approach to urban greening (Perth)

Project title	From footpaths to ecosystem: understanding the role of the verge in delivering urban ecosystem services
CAUL 'Three Category Approach' classification	Category 2[1]
Country	Whadjuk Noongar Boodja (Country)
Sites	22 residential nature strips in the local government areas of City of Stirling and City of Subiaco, metropolitan region of Perth
Timeframe	**2018-2020**

Background

In this research project, we set out to understand the socio-ecological benefits and challenges of planting native gardens on nature strips in Perth suburbs. Nature strip gardening is a form of citizen-led urban greening, involving residents planting and caring for understorey vegetation (and even trees) along the road verge (Marshall, Grose and Williams 2019a). Perth presents a particularly interesting case study for this type of research, due to its location in a biodiversity hotspot, and public policy initiatives to lower water consumption as a consequence of long-term declines in precipitation observed since the 1970s, which have placed pressure on water supply.

The 'nature strip' or 'street verge'[2] is the area of land between the roadway and the front property boundary. These strips of land serve a largely utilitarian purpose, providing space for services such as electricity, gas, water and telecommunications, and facilities such as footpaths and bus stops. Nature strips can be seen as 'liminal' or boundary spaces that intersect public and private space (Rupprecht and Byrne 2014). Nature strips are typically considered 'Crown' land and are vested with local government areas (LGAs). In Perth, while LGAs generally assume responsibility for the planting and maintenance of street trees, maintenance of ground-covers and low-growing vegetation are generally the responsibility of the householder of the property adjacent to the verge. The traditional view of street verges as under-utilised spaces occupied by grasses, weeds, sand or gravel is being challenged by more novel approaches that include greater plant structural and species diversity. In Perth, an increasing number of LGAs are allowing residents to plant low-growing, waterwise gardens on the nature strip in front of their property, with a number of popular subsidy, rebate and incentive programmes in place.

Trees and vegetation on nature strips are increasingly important to maintain the 'urban forest' as vegetation on private land disappears (Bolleter 2016, Hall 2010, Pandit, Polyakov and Sadler 2014, Pandit et al. 2013). The contribution of nature strips to informal urban green space can be significant – recent research in Melbourne found that around one-third of public open space can be found in the nature strip (Marshall, Grose and Williams 2019b). Nature strips can play a key role in providing greenspace and ecosystem services through shading and reducing heat, allowing for water infiltration and reducing run-off (for example, through rain gardens), giving habitat for wildlife, providing an amenity for residents including food production and connection with nature. Reflecting this growing importance, there is a rapidly expanding body of work on the uses, values, distribution, management, and typology of street verges (Marshall, Grose and

[1] A project that explores opportunities for two-way transfer of skills and knowledge sharing through Indigenous employment and research opportunities. Category 2 projects often take place on Country, for example research that has a field work component.

[2] The phrases 'street verge' and 'verge gardens' are more commonly used in Perth than the term 'nature strip', which is more prevalent in other parts of Australia and understood globally. 'Road easements' and 'easement gardens' are equivalent terms, most commonly encountered in the US.

Williams 2020, Marshall et al. 2019a, Uren, Dzidic and Bishop 2015, Meenach-Sunderam and Thomspon 2007, O'Sullivan et al. 2017, Hunter and Brown 2012), as well as explicit discussion of street verges within urban planning and greening strategies. However, there has still been limited integrated research on the social and ecological values of native gardening on street verges. Ecologically, there is limited understanding of the significance of small patches of native plants as habitat for a range of species living in fragmented urban environments.

Research and methods: Socio-ecological chronosequence research with resident and stakeholder interviews

This research project (which is still underway, as of June 2020) takes an interdisciplinary approach to studying the social and ecological dimensions of nature strip gardening with native plants. The project was designed by a multidisciplinary team from the CAUL Hub, and discussed with representatives from four local government areas (LGAs) in Perth to ascertain the key areas of interest and policy challenges. LGAs formed an important unit of analysis for this project, as in Perth, LGAs are responsible for developing and implementing guidelines on nature strip management, and each LGA tends to have its own unique set of guidelines that govern what residents can, and cannot, do with the nature strip in front of their residence.

As nature strip gardening occurs throughout suburban areas, the project utilised two geographic scales: individual nature strip gardens within two local government areas (City of Subiaco and City of Stirling), and city-wide through an online survey with LGA representatives, and interviews with key stakeholders and 'champions of change' across government, industry and community. In both cases, the selection of LGAs and stakeholders was guided by a policy document review, to ensure representative inclusion of a range of viewpoints. The City of Subiaco is an inner-city LGA with a long history (more than a decade) of supporting and providing incentives for verge gardening. The City of Stirling is a large, diverse LGA in the middle-ring of suburban Perth, which has offered a variety of initiatives over the years to residents interested in verge gardening.

We used a 'chronosequence' approach to this research, whereby we interviewed residents who had been undertaking verge gardening for different lengths of time, rather than a before/after comparison. There were several reasons for taking this approach. First, nature strip transformations tend to occur in only one short period per year in Perth, timed to occur with the onset of the first winter rains (late April and throughout May). Second, ecological surveys in the Perth region are typically undertaken in the period from late August to mid-October coincident with peak flowering, and for bees in particular, activity is highest from October to March[3]. In order to do an appropriate before/after comparison and sample at the best time of year, it would have been necessary to identify sites six to nine months *before* transformation works were to begin, and in many cases, residents decide to undertake these transformations with less lead-in time, or may change their mind. Further, in the first few months after planting, there are unlikely to be many flowers to attract pollinators, due to the small size (tubestock) of most plants used in verge gardens, so that major changes would most likely be observed in the second or later flowering season. Because of the limited timeframe for this project, it was impractical to implement a before/after design for this research in a way that would detect meaningful biodiversity outcomes. Instead, we sampled a range of gardens from newly established to more than ten years of establishment.

In addition to background research and policy review, the major research activities include:

- Interviews with residents who have transformed their nature strips to native gardens.
- Biological surveys of resident's nature strip gardens, focusing on plants, birds and insects.
- Discussions with key stakeholders across government, industry and community on the drivers and trends in verge gardening, incorporating interviews, surveys and social networks.

[3] Kit Prendergast, PhD researcher at Curtin University and native bee scientist, personal communication 2018.

These components will be elaborated in the following sections. Note that because this project investigated a 'civic ecology' or citizen-led urban greening initiative and followed a 'chronosequence' rather than before/after approach to understanding urban greening impacts, it was necessary to develop the social dimensions of the research *prior* to the ecological dimensions.

Social dimensions of the research: residents and key stakeholders

A major component of the research centred around interviewing residents engaged in verge gardening. In order to recruit potential participants, local government partners in the research circulated an electronic flyer and link to an online 'expression of interest' portal, where those interested in the research could read the participant information forms, consent forms, and register their interest to participate in the social and ecological elements of the research (Figure 4). Initially, the team were unsure of the level of potential interest in participation, and so had kept the option open for people to register for *either* the interviews *or* the ecological surveys. As the level of interest was far higher than anticipated, the team decided to select from interested participants who wanted to participate in both studies, encompassing a range of socio-demographic characteristics to ensure a diverse sample. Although verge gardens are technically situated on public land and no permission to access these areas is 'officially' required, it is certainly best practice to treat these areas as if they were private property, and seek permission of both the landholder (i.e., the local government area), and the resident to conduct any kind of survey on a nature strip.

Figure 4: Recruitment flyer used to advertise the research. Image credits: Natasha Pauli (left) and Luis Mata (all others)

Semi-structured interviews with residents were centred on the drivers, challenges and opportunities encountered during verge gardening. The initial part of the interview covered the practical process of transformation, while the remainder of the interview questions were derived from themes that have emerged from the literature. In terms of residents' motivation for verge transformation, three overlapping sets of reasons have been put forward: 1) logistical and practical considerations that make growing native plants easier or less resource-intensive than alternative verge 'treatments' such as grass (Uren et al. 2015); 2) a connection with emotions such as a sense of moral responsibility to non-humans and to the environment, or to personal enjoyment, or a sense of wellbeing (Goddard, Dougill and Benton 2013, Weber,

Kowarik and Säumel 2014); or 3) social norms and societal values (Hunter and Brown 2012). With regard to the impacts of the transformation, the interviews encompassed: 1) whether the transformation altered the way they use resources such as water, nutrients, time and energy?; 2) Whether the transformation has altered the way non-humans use the environment?; and 3) whether the transformation has influenced the way the resident interacts with the local community? Finally, respondents were asked about the future – whether they would change anything in their verge garden, and what their ideal streetscape would look like.

A second major component of the project was eliciting stakeholder knowledge, experiences and preferences in relation to verge values and management issues. The objectives of this part of the research were to: 1) Understand the range of stakeholder (non-residential) perspectives and preferences regarding the provision of ecosystem services through the transformation of informal urban greenspace (IUG) using native species; 2) Capture a snapshot (2019) of Local Government Areas engagement with verge/streetscape transformation with native species, as the primary stakeholder managing this land area; and 3) Understand the network of interactions between stakeholders in terms of resource sharing, particularly information flow, and identify factors acting as barriers or enhancers of positive resource sharing. Semi-directed interviews were undertaken with representatives of i) State Government agencies; ii) Local Government Areas; iii) Utilities and services; iv) NGOs, advocacy groups, public influencers, and consultants; v) Industry (including horticulture, irrigation and developers); and vi) Peak bodies.

An interview guide was used to maintain common thematic lines of inquiry across all stakeholder subsets, as well as including questions tailored to elicit specific information from individual interviewees. Interview themes covered: i) Local policy or regulations influencing verge engagement; ii) governance structures influencing verge management and stakeholder engagement; iii) stakeholder interactions and awareness; iv) ecosystem services provided by verges; v) process of transforming verge/streetscapes (using native vegetation); vi) outcomes of transformation; vii) community feedback regarding stakeholder verge management practices; and viii) future preferences for managing and provisioning of verge/nature strips. Interviews were audio recorded for later transcription and coding. The interview process also included a mapping exercise to investigate the social networks stakeholders in the verge management space were engaging with. Stakeholder network maps were hand drawn throughout the interview and the maps were filmed during the interview to capture the verbal explanations provided during the map making.

Local Government Areas are the key decision making entities in relation to street verge management. As there are 31 LGAs in the Perth region, interviewing representatives of all LGAs was beyond the scope of the research project. An online questionnaire was developed to determine the range of values Perth metropolitan LGAs held regarding the role of the verge in delivering ecosystem services. The questionnaire also sought to understand the use of incentive programs existing across the Perth Metropolitan Area in supporting residents to undertake native verge gardening the uptake of these and any perceived barriers to these activities. The Qualtrics survey software platform was used to design, issue and retrieve the responses.

Ecological dimensions of the research: plants, insect pollinators and birds

For each of the residential verges in the study area, the plants occurring on the verge were mapped, with note made of species and the approximate extent of coverage. As the verges were effectively gardens, there were a combination of locally-occurring native species, native species from elsewhere in Western Australia, horticultural varieties where the original native species may be drawn from other parts of Australia, introduced garden species, and weeds. In some cases, the residents had kept the plant tags denoting the species name, created their own maps of which species had been planted (Figure 5), or had detailed knowledge of all plants on their verge and provided this information to the surveyors. In other cases, there was limited to no

information on the plant species present, so that the surveyors had to identify the species present as closely as possible; in some cases this was limited to genus or even family level.

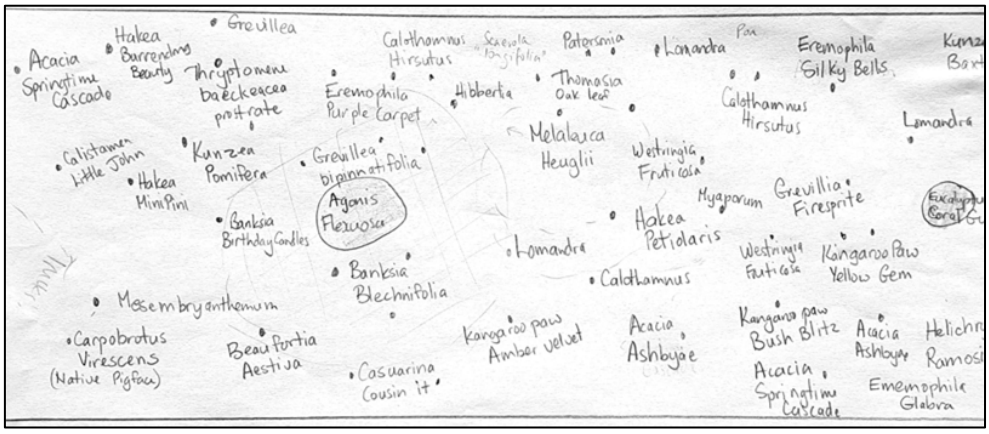


Figure 5: Example of a hand-drawn map compiled by a research participant

The initial plant species map was prepared at the time of the interview with the resident. As the verges were visited multiple times for bird and insect surveys, the plants present on the verge were checked each time to update identifications were needed or note new or dead plants. The smallest and least diverse verges could be mapped easily in 15 minutes or less, while large and/or diversely planted verges required 30-45 minutes to map. Schematic diagrams were drawn for display purposes (Figure 6) and plant species lists compiled.

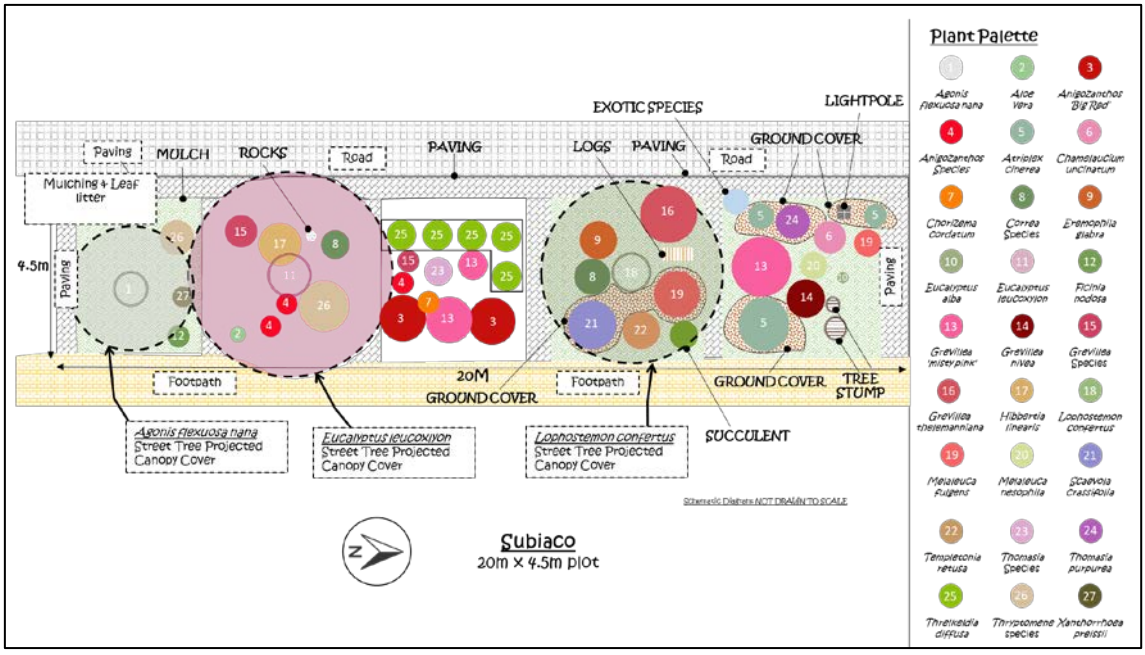


Figure 6: Example of a schematic illustration of a nature strip garden. Credit: Elisha Chu

All verge gardens were visited three times in the period between October 2019 and March 2020 (representing the first field season following completion of all interviews). Native bee activity is greatest between these months[3], and repeated sampling is required to gather information on plant-pollinator links for a variety of species, and allow for imperfect detection during each visit. Verge gardens were surveyed for bird-habitat and bird-flower interactions, as well as visits by insect pollinators (chiefly bees, hoverflies, wasps, butterflies and moths) to flowering plants in the understorey. Species of plants that were flowering during each survey were noted. Insect surveys were undertaken on sunny, calm days between the hours of 9am-4pm (peak activity period) to allow for maximum possibility of detection (Pille Arnold et al. 2019). Evidence of native bees nesting in verge gardens, or visiting flowering street trees, was recorded. Due to

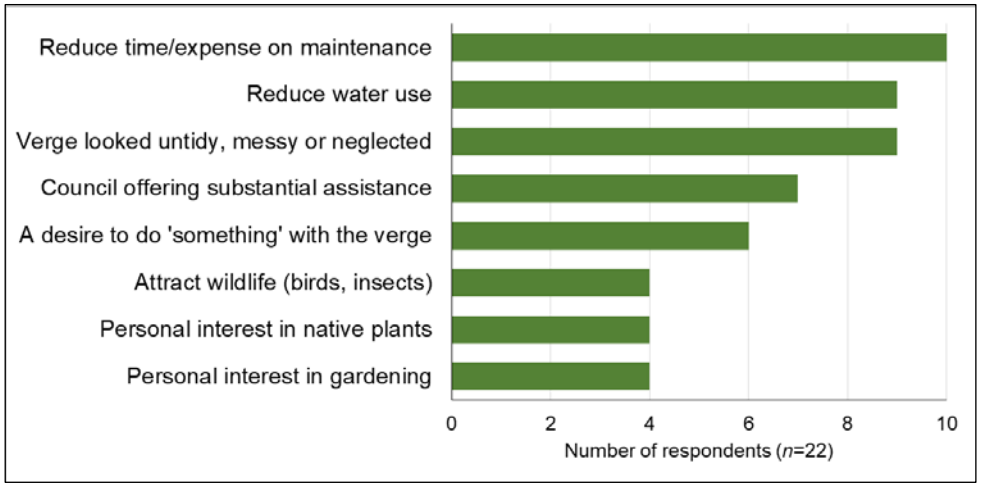
personnel limitations, bird observations were noted during the same time period; ideally, birds would be observed early in the day, or late in the afternoon during their peak activity period.

The bird and insect survey protocols were very similar to those used in the Upper Stony Creek survey (see following case study) and on the CAUL Network of Integrated Sites website, with a couple of notable exceptions. First, rather than using a transect walk in four directions, all plants in flower on each verge were observed for a set period of time to detect insect pollinator visits, to a maximum of two plants from the same species[4]. Second, sweep nets were not used to sample herbivorous insects. Trial sampling undertaken in May 2018 demonstrated that residents were often very protective of the plants growing in their verge, and many would likely not react well to the sight of sweep nets being vigorously applied to clumps of plants.

Social and ecological findings (preliminary results)

The analysis of the social and ecological findings of this research project is underway and ongoing until late 2020, particularly with regard to the stakeholder perspective of native verge gardening Some preliminary findings on the motivations and experiences of residents, priorities of Local Government Areas, and nature strip biodiversity can be shared here.

In terms of initial motivations for undertaking verge transformations, the most common reasons reflected practical motivations to reduce time, expense, water use and maintenance on the nature strip (Figure 7). While some respondents had an initial interest in native plants, most people had limited initial knowledge, and learnt more about native species and ecology through the process of verge gardening. Around half of the participants had received some form of assistance from their LGA; this was a 'tipping point' in terms of motivation for many of these respondents. In terms of inspiration and ideas, observing other nature strip gardens in the neighbourhood was the most important source of inspiration. Many respondents also reported that their conversion inspired other neighbours to undertake a verge transformation. A number of respondents reported increased social interaction with neighbours through verge gardening; in some cases, their physical presence on the verge in a public space was enough to 'break the ice' and initiate conversations with neighbours with whom they had never spoken before. It is important to note that our surveys with residents encompassed 22 households, most of whom had English as their first language. In recruiting potential households, an effort was made to incorporate representation of rental and owner-occupied properties, and different age ranges and household sizes, based on preliminary information supplied by interested residents.



[4] For spreading ground covers and clumping species, it was not always possible to distinguish individual plants. In these cases, two discrete patches of ground cover at different locations on the verge were observed.

Figure 7: Categorised responses to the query of 'Why did you decide to transform your verge to a native garden'? (Some responses reflect more than one category above).

An initial attempt at classifying verge gardeners into three major non-exclusive groups is represented in Figure 8. One group represents the 'early adopters', many of whom have been managing verge gardens for more than a decade, and enjoy sharing their knowledge and experience with others. This group is likely to undertake verge gardening of their own accord, without incentives, and appreciates recognition through awards, and could act as exemplars for others to follow. A second group were influenced largely by decisions about resource use and efficiency, and incentives, subsidies and rebates often acted as catalysis for action. The final group tended to undertake verge gardening at particular milestone moments, such as retirement, building, moving house or renovating. For this group, incentive packages might be valuable.

Figure 8: Preliminary typology of verge gardeners for policy makers

The number of native, low-growing plant species on the mapped verges ranged from three to more than 60. Some verges were deliberately designed and managed to resemble *kwongan* species assemblages and landscapes (Figure 3), while at the other extreme, some gardeners selected species purely for aesthetic and 'easy-care' purposes. Most gardeners had avoided planting invasive exotic species that could create biosecurity issues, although this risk certainly exists for verge gardening more generally. The birds noted visiting nature strip gardens encompassed common species for Perth; in most cases, birds were associated with street trees rather than directly interacting with verge gardens. Over the course of three visits between October to March, native pollinating insects were noted on almost all verges. Even gardens that were small in extent, with low plant species diversity, were seen to attract native bees. Having summer-flowering species within verge gardens was associated with native pollinator presence (Figure 9). Further analysis is required to determine plant-pollinator species associations, and the extent to which nearby patches of remnant vegetation or other native gardens are associated with the presence or absence of native pollinators.

Figure 9: Summer-flowering species such as this berry saltbush (Chenopodium baccatum) *attracted a range of native pollinators (depicted here, two native bee species and a hoverfly)*

Icons (Figure 8) by Icons8. Links: Gardening plants, water, calendar

Transforming an urban waterway and informal greenspace: an agency-led initiative of urban greening (Melbourne)

Project title	The Upper Stony Creek Transformation Project
CAUL 'Three Category Approach' classification	Category 2[5]
Country	Woi Wurrung land, Wurundjeri Tribe Council, Kulin Nation
Sites	1.23 kilometre stretch of Upper Stony Creek, Sunshine North, Melbourne
Timeframe	2016 – 2019 (Phase 1, pre-greening)

Background

Informal greenspaces are diverse in form, prominence, size and aesthetic appeal, and can range from vacant residential and industrial lots, to railway line sidings, utility easements, street verges and parkland. The tenure arrangements that underpin them also change drastically and there is no singular form of tenure or material feature that adequately accounts for the variability of informal greenspaces. Likewise, the uses of informal greenspaces are highly contextual, in some spaces supporting unique ecosystems (Kremer, Hamstead and McPhearson 2013), where non-human species take refuge, and serve as a place where human inhabitants reap socio-psychological benefits (Gandy 2013). Yet, they are also sometimes characterised as 'ambivalent landscapes' (Jorgensen and Tylecote 2007), and as such, responsibility for their care, maintenance and renewal is often difficult to place. This section presents a multi-stakeholder urban greening transformation of an informal greenspace in Melbourne's western suburbs. Portions of the site are owned by the local government council and a regional state-owned water utility company, and responsibility for the creek that dissects the site rests with the state water authority.

The Upper Stony Creek Transformation Project was led by a partnership of government and non-government agencies, including Brimbank City Council, City West Water, Melbourne Water, Development Victoria, the Victorian Government Department of Environment, Land, Water and Planning (DELWP), and Greenfleet Australia. The project secured AU$11.35 million in initial funding, including AU$4.76 million from the Australian Federal Government's Building Our Future Fund, $2.04 million from a state government department, AU$4.027 million from state statutory authorities, and AU$100k from local government. Additional funding was contributed by the Victorian state government to complete the project after half of the initial budget was absorbed by remediation cost.

The project aimed to transform a section of Upper Stony Creek, an urban drainage channel running through Melbourne's western growth corridor in Sunshine North (Figure 10), into an urban wetland and usable greenspace for residents, while still maintaining storm water management functionality. The transformation will create a new stormwater harvesting wetland and irrigation system to support the revitalised greenspace. The outcomes sought were to improve residents' health and wellbeing through better greenspace provision and increase local biodiversity over time.

The case study area was bounded by Gilmour Road, Furlong Road and Stony Creek (Figure 10). Before the project commenced, the only formal greenspace in the area was Lloyd Reserve (Figure 10). Lloyd Reserve is located to the south of the local primary school, is approximately

[5] A project that explores opportunities for two-way transfer of skills and knowledge sharing through Indigenous employment and research opportunities. Category 2 projects often take place on Country, for example research that has a field work component.

18,000 square metres with a sports field in the middle, has a few trees on the boundary, and a small playground. It has no benches or sitting spaces.

Figure 10: The case study area of Upper Stony Creek, Sunshine North (Source: Nearmap)

Before the transformation, the Upper Stony Creek site included a linear informal greenspace culminating in a larger triangular area accessible off Gilmour road (Figure 10). The creek flowed through a large concrete drainage channel (Figure 11).

Figure 11: Upper Stony Creek pre-greening (Source: Leila Farahani)

Research and methods: Socio-ecological longitudinal research with control site comparisons

A multidisciplinary team of CAUL Hub researchers and project partners designed a longitudinal, social and ecological study for the site and its transformation. The research was collaboratively designed over approximately twelve months and tailored to the research/evaluation needs of project partners. Overall, the research aimed to determine the impact of the transformation on

residents, with a focus on psychological, social and physical health outcomes, as well as to understand and measure the biodiversity changes over time. Another key aim was to understand and document the interactions between people and nature at the sites, and how these changed over time with the greening transformation.

It is important to recognise that this project missed a key opportunity to include and collaborate with local Indigenous communities, and it is a key limitation of the work presented here. Opportunities will be identified for building future relationships with Indigenous stakeholders, including in future research collaborations, co-authorship on publications, Indigenous employment, and other capacity building associated with this project. There were also limitations inherent to the project findings given that the participant group was not representative of the wider demographic characteristics in the area. The interview participant group consisted of 23 people, all of whom were of European ancestry and spoke English at home. In 2016, over 40% of the Sunshine North population had Vietnamese or Chinese ancestry compared to the Victorian average of just over 6%; over 72% of people did not speak English at home in Sunshine North, compared to the Victorian average of just over 27% (Australian Bureau of Statistics 2016).

The research was phased using a pre- and post-greening design, drawing on ecological and social research techniques. Collecting pre-greening or baseline data is essential to monitoring any changes in social, wellbeing and biodiversity outcomes associated with the Upper Stony Creek Transformation project. The social and ecological dimensions of the research were integrated through the design and analysis of resident interviews and surveys. The qualitative and quantitative social research incorporated both general and specific questions about residents' neighbourhoods, their health and wellbeing, connection to nature, and their use of the site as well as their observations and experiences with local plant and animal diversity.

Control sites were established to compare the findings with natural experiment provided by the Upper Stony Creek site and to measure the impact of the transformation. Different controls were needed for the ecological and social dimensions, but the sites were in close proximity to the Upper Stony Creek site. To detect ecological impacts, the control site was Jones Creek, a waterway with similar ecological and environmental characteristics located to the west of Upper Stony Creek in Ardeer. At each site, a transect of approximately 1000m was surveyed. To quantitatively detect social impacts, St Albans South was used as the comparison site based on comparable socio-demographic characteristics identified from the Australian Bureau of Statistics Census data at the 'Statistical Area Level 2' (SA2) geographical scale. St Albans South residents also lived within close proximity of Jones Creek which was unnaturalised and concreted. Residents living within 5 kilometres of Upper Stony Creek or Jones Creek were geographically identified using the Geocoded National Address File and invited to participate in the survey.

An unexpected finding: Asbestos

The transformation works at the Upper Stony Creek site commenced in early 2018, with the completed date expected to be approximately 12 months later. However, by July 2019 works had to cease due to the discovery of significant asbestos contamination in the informal greenspace and concrete drainage channel. Unfortunately, a large portion of the project budget was consumed by the costs of remediation, and the ability to complete the original site design was in doubt. After a delay of more than six months, the Victorian Government provided additional funds to complete the works with a rescoped, simplified design, and with a revised completion date of October 2020. Unfortunately, the concrete drainage channel that contained the Creek is not able to be removed, although other parts of the site will be naturalised to create a more functional greenspace. The delays in the progression of the works due to the asbestos contamination have delayed the collection of the post-greening data to beyond 2020.

Ecological dimensions of the research: plants, pollinators, bats and frogs

The ecological component of the research focuses on the changes in the diversity of pollinator species (insects and birds) and plant-pollinator interactions at the site, as well as changes in the diversity of microbat and frog species. The pre-greening ecological research commenced in November, 2016, with the post-greening data collection postponed due to the asbestos contamination. Each of the ecological surveys are briefly described below.

The plant-pollinator interactions were guided by these research questions:

1. What is the change in insect and bird species richness and composition after the greening actions take place?
2. How many new plant-pollinator and plant-herbivore interactions occur after the greening actions take place?
3. Does the new structure of the plant-pollinator and plant-herbivore interactions networks contribute to increased ecosystem health?

A first key step was to conduct an inventory of the plant species occurring at the control and comparison sites before the greening took place. The following three surveys were then implemented at each site: (i) direct observation of plant-insect pollinator interactions, (ii) direct observation of plant-bird behavioural interactions, and (iii) sweep-netting of insect species on above-ground vegetation. Surveys are temporally replicated at least three times during each year of the study, to allow the generation of the necessary replication data to account for the imperfect detection of species/ interactions.

To detect bat species present at Upper Stony Creek and Jones Creek, both active and passive surveys were undertaken from 6th to the 23rd March, 2017. Passive surveys were carried out using bat detectors placed in trees from dusk to dawn. Active surveys involved researchers walking the transect at each site with hand-held detectors after dusk on the 6th and 23rd March, 2017. Collected data were analysed to determine which species were present at the site and to document the number of vocalisations. Data were also analysed to provide an inventory of bat species detected at both sites.

To detect frog species at Upper Stony Creek and Jones Creek, nocturnal surveys were conducted of the concreted channels of each creek. The surveys took place on the 17th November and 8th December in 2016, and on the 17th October in 2017. Data were analysed to provide an inventory of frog species detected at both sites.

Social dimensions of the research: interviews, observations and a survey

The social research was designed to understand the impacts and use of Stony Creek as an informal greenspace pre-greening, and then post-greening to understand how the new, more formal greenspace impacts use, enhances connection with place or to nature, and the impacts on liveability, health and wellbeing. Pre-greening data were collected from October 2016 until July 2017. The timing of the post-greening data collection was expected to be one to two years after the site was completed but, as stated this phase of the research was postponed. The social dimensions of the research involved using mixed-methods comprised of qualitative interviews and observations of site users at Upper Stony Creek and a survey of residents in Sunshine North (SA2 area) and St Albans South (SA2 area). Each of these methods are briefly described below.

Twenty to fifty in-person interviews were planned with residents living in close proximity to Upper Stony Creek site, primarily living on the eastern side of the Western Ring Road, closest to the creek. Observations were conducted of people using the informal greenspace shown in Figure 3. The interviews and observations aimed to:

- Understand residents' perceptions, preferences, uses and values of neighbourhood greenspaces and vegetation (trees, shrubs, plant species).
- Understand residents' perceptions and expectations of the Upper Stony Creek Transformation project.
- Document residents' experiences with and perceptions about local wildlife and biodiversity and understand their connection to nature.
- Collect subjective health and wellbeing data about residents' general health, physical activity and mental health.
- Collect baseline pre-greening qualitative and observational data on residents' current use of Upper Stony Creek and public and greenspaces to assist in the survey design.
- Develop longitudinal qualitative and observational methods to assist with the design of other measures, including research that will occur post-greening.

The interviews were mainly conducted in residents' homes using a semi-structured format to allow for a more informal, conversational tone. Twenty interviews with 23 participants were conducted from October 2016 to March 2017. At the beginning of the interview participants were asked to complete a brief demographic questionnaire and were asked if they agree to be interviewed again in a follow-up interview post-greening. Interview data were transcribed and transferred to qualitative analysis software for analysis based on the aims stated above.

Observations of the use of Upper Stony Creek were undertaken to understand how residents were using greenspaces around their houses, both pre- and post-greening. An unobtrusive observation method that did not involve interaction with individuals or manipulation of the environment was developed. Observations occurred systematically from 8:00 am to 8:00 pm on four days (two weekdays and two weekends). The informal greenspace site at Upper Stony Creek was divided to six identifiable sections to ensure the entire site was covered. Each section was video recorded for two minutes, every two hours to provide the pattern of use over a day. Researchers repeated the observations over four seasons to explore the seasonal pattern of site use over a year. The four rounds of observation occurred in October (spring), Jan (summer), April (autumn) and July (winter). This component of the research captured data about site use (e.g. headcounts and type of user over specified periods of time) with counts linked to behavioural mapping. Behavioural mapping is a technique used in environmental psychology and related fields for recording and registering behaviours and activities systematically as they take place in particular settings (Ng 2016).

The aim of a quantitative survey is to identify and measure the social, physical and mental health benefits that urban greening transformations and improvements in an area could provide local residents. Where there is scope, it is recommended that surveys are conducted with a relevant and comparative control sample of residents and residents residing within 5 kilometres of the redevelopment site (the closest experimental exposure) should be identified and approached to complete surveys asking questions about:

1. Residents satisfaction with their local neighbourhood and use of local recreational areas;
2. Physical health and physical activity;
3. Mental health and wellbeing;
4. Connection to nature; and
5. A range of socio-demographic factors.

The survey questionnaire design for Upper Stony Creek and St Albans South focused on collecting base line information on: multiple site use (and other outdoor spaces including residents' backyards); other public open spaces used in the area; the local neighbourhood environment; physical activity; depression, stress and anxiety; subjective well-being; connections with nature; and, demographic questions. Questions asked in the interviews were

used to inform the survey questions. The survey was also designed to provide scope for recontact of participants over several years post-greening to measure changes over time and allow comparisons across and between sites.

A survey was conducted at Upper Stony Creek and St Albans South between March and May 2017. Approximately 1000 residents over 18 years of age were sent the survey using a postal survey and online survey platform, with the survey available in multiple languages to match the cultural profiles of the SA2 areas. Participants were selected and recruited from the City of Brimbank Local Government Area using the Geocoded National Address File (GNAF) to target residents living within a 5 kilometre radius of the Stony Creek as well as residents in the St Albans South comparison site in the neighbouring suburb. Data were geocoded for residence, allowing analysis of benefits relative to proximity to the transformation site and further analysis of existing factors in the built environment that might influence health outcomes. The response rate for the survey was 8% but after usable (completed) questionnaires were consolidated, the final sample comprised 300 respondents (150 in each location). Respondents were representative of the socio-demographic characteristics of the selected areas. All participants were asked to provide contact details to receive an invitation to participate in a follow-up survey in approximately 2 years' time to assess changes to their health and wellbeing after the urban greening has been completed.

Social and ecological findings (pre-greening)

Pre-greening baseline data collection at Upper Stony Creek and control sites at Jones Creek, Ardeer and St Albans South was undertaken to assess the impact of this greening and waterway restoration on residents' health and wellbeing, and plant and animal biodiversity.

The ecological surveys found seven native and three non-native insect pollinators at Upper Stony Creek, and nine native insect pollinators at Jones Creek. Insect pollinators interacted mostly with non-native herbaceous weeds (Figure 12). The most common were native bees, followed by non-native European honeybees. Seventeen native bird species along with two non-native bird species were identified at Upper Stony Creek, while sixteen bird species were identified at Jones Creek. The birds interacted with six native plants and six non-native plants, as well as with lawns, bare ground, wire fences and the concrete channel. At both the control and transformation site, eight species of insect-eating microbat were detected out of the fourteen species found across Greater Melbourne. A large number of calls, more than 7000, were recorded passively over the study period, with similar numbers of calls from bat species detected at the control and transformation site. However, this result has not been statistically tested. The active bat surveys only detected the Southern Free-tailed bat and Gould's Wattled bat. Only the Southern Free-tailed bat was detected at Upper Stony Creek during the first survey, although both species were detected at both sites during the second active survey. The most common species identified were Gould's Wattled Bat and the Southern Free-tailed Bat across both bat survey types. Several frog species were found at the Stony Creek transformation site, including the Pobblebonk, Striped Marsh Frog, and Spotted Marsh Frog. Frog species found more widely in the neighbourhood included the Common Eastern Froglet. Frogs were often heard calling from the concrete channel, particularly where plants grew through cracks in the concrete. In Jones Creek, only the Common Eastern Froglet was detected, indicating a higher level of amphibian baseline biodiversity was present at Upper Stony Creek.

Figure 12: Native bee on non-native dandelion (Source: Luis Mata)

The interview and observational data at Upper Stony Creek showed that the informal greenspace is underused, and the interviews revealed that one of the reasons is that residents had concerns about safety and maintenance of the site, and lack of paths. In general, the site was unloved, underutilised and perceived as unmaintained. Despite these concerns, some residents walked their dogs along the creek, in the informal greenspace, or used the site as a short cut through the neighbourhood. It was not surprising that most residents interviewed were excited about the transformation and believed it would impact their health and wellbeing positively. The interview data showed that residents are observant of local biodiversity and the changes in the numbers and types of species they had witnessed in their neighbourhood over time as native gardens became more popular. Overall, residents perceived native species more favourably than non-native species, and preferred more native species in the area. Residents spoke mainly about birds and some reptiles, including snakes and lizards. There was little mention of mammals or insects. Some residents held concerns about snakes as they reported there were high numbers of these animals before the creek was concreted. Nevertheless, they were prepared to accept that snakes may return to the area once the site is transformed as part of overall changes to local biodiversity.

The survey data showed that 65% of survey respondents said the area is a good place to live. However, only 35% of respondents felt they have many opportunities to be physically active. Early results suggest that fewer people reported their health to be excellent or very good in Sunshine North and St Albans South when compared to the Victorian state average. The 2015 Victorian Population Health Survey found that 47% of Victorians reported their health to be excellent or very good while much smaller proportions are noted in both the greening location (29%) and the comparison site (34%) in St Albans South. Consistent with this finding, Subjective Wellbeing results for the two populations are also lower than expected. The Australian average for Subjective Wellbeing measured using the Australian Unity Subjective Wellbeing Index is consistently found to be around 75-76 out of a total possible score of 100 (Capic et al. 2016) making the results overall for both Sunshine North and St Albans considerably lower than national and Victorian averages, albeit with considerable variation amongst respondents (mean 66.3, standard deviation 20).

Only 44% of Sunshine North residents were satisfied with their local parks. A slightly higher proportion of St Albans South residents were satisfied with the overall quality of their local parks

(57%) which could also be reflective of better availability to public open space and parks in St Albans South: 25% of St Albans South Respondents reported being within a 5 minute walk of their most visited local park, compared with 14% of Sunshine North residents. A greater proportion of respondents in St Albans South reported that their local neighbourhood parks were used by many people (58%), compared with those of Sunshine North (48%). Consistent with the interview data, the Upper Stony Creek site was reported as their most visited park by less than 2% of residents (none of whom were from St Albans South). This makes sense in terms of proximity, in that 13.5% of Sunshine North respondents reported a walk of 10 minutes or less to the site, compared with 1.8% from St Albans South

Ambiguities in the definition of 'park' in comparison to 'green space' also produced differences and may reflect some of the difficulties in defining areas of open space that are commonly used by residents. The Upper Stony Creek site was commonly referred to as 'the drain' during interviews with residents and a coded map of open space used to identify parks and green space areas. By adding green spaces and parks into the question, higher proportions of residents indicated that they had used the areas in the last 3 months. In Sunshine North, park use alone in the last 3 months was approximately 67% but increased to 87% when park usage and green space were combined in the one question and a similar increase is visible in the St Albans South area. A number of residents were also unsure of the name of the local park or green space they used or didn't provide an answer to this question (48%).

Opportunities, challenges and lessons learned

As Australian cities grow and densify, further pressure will be placed on the health and survival of all species found in urban environments, including humans. In recognition of this, urban greening and restoration projects are becoming more prevalent with increasing evidence that despite their urbanised and built form, cities are on Country, provide crucial habitat for biodiversity and are also the sites where most people live. Although there is a significant evidence base there is still much to learn about how to achieve the most effective social and ecological outcomes in urban greening, including how greening projects can generate benefits across multiple social, cultural and biodiversity domains, and the pathways and mechanisms that lead to beneficial outcomes. Alongside these gaps in knowledge, there is a shortage of integrated socio-ecological approaches and techniques that can be used to systematically study and measure the impacts of urban greening, and accommodate projects at a variety of temporal and spatial scales, and in different landscapes and complex social and cultural contexts.

Doing urban greening to achieve both social and ecological outcomes is not easy. It requires support from multiple partners and agencies, long-term investment, interdisciplinary research teams, and sustained community inclusion and engagement. Urban greening projects make substantial material and cultural changes to the fabric of cities that can produce unintended or unexpected impacts. For example, although beneficial in the long-term to cities as a whole, in the short-term, many urban greening projects can result in gentrification resulting in the exclusion of residents in the very spaces designed for them. Understanding sites and residents' lived experiences of them, as well as any issues and concerns more completely through in-depth consultation is important in order to ensure that future greening projects meet community needs and expectations.

This discussion paper by the Clean Air and Urban Landscapes has provided an overview of the latest knowledge about the social and ecological benefits of urban greening, identified where key gaps remain, and introduced new integrated socio-ecological methods for use in measuring and understanding social, cultural and biodiversity benefits in a wide range of urban research settings. The approach outlined here will not only help to provide empirical data on the success of urban greening transformations at various scales, but it will provide an opportunity for benchmarking and comparison with other sites around Australia and globally, and help with effective planning, policy, and funding targeted towards urban greening. These outcomes are crucial for planning liveable and sustainable cities of the future.

The integrated socio-ecological approach and methods developed by the CAUL Hub were illustrated in this paper through the presentation of two urban greening case studies, one in Melbourne and one in Perth. Further examples will be available on the CAUL Network of Integrated Sites website. The repeated application of these methods at a range of current and future sites will further contribute to a growing network of integrated study sites across Australia. These methods can be adapted by researchers and practitioners in a wide range of roles and at different sites and scales, continuing to systematically build the evidence base for the socio-ecological impacts of urban greening.

The application of these socio-ecological approach and methods over several years, in different cities, and at different settings and scales, has provided key insights into opportunities and challenges this type of research and practice presents, and has revealed some key lessons. We summarise some of the main lessons below. We believe that discussing these challenges and potential solutions is particularly important, as many of these difficulties are rarely discussed at length in the published and peer-reviewed literature, and some issues may be well-known amongst ecological researchers but less so amongst social science researchers, and *vice versa*.

Practical socio-ecological challenges of urban greening research – and some solutions

The ethics and practicalities of working on and with Country

Urban sites have complex histories of land ownership and use, primarily including the fact that in Australia Indigenous sovereignty was never ceded. Any urban greening project and associated research will be taking place on Country, on Aboriginal land and it is important that this be recognised from the outset. CAUL's Three Category approach can be used to classify urban greening projects according to their level of Indigenous participation and engagement and assist in inclusive ways forward towards an Indigenous-led research and practice agenda. Any opportunities to support the development of Indigenous-led projects and proposals, and Indigenous determination of benefits, should be prioritised. Non-Indigenous practitioners and researchers should seek opportunities to reconsider standard models of research governance to empower Indigenous communities and knowledge-holders.

Knowing on whose Country an urban greening project is taking place is a key first step. A detailed map of Indigenous language or nation groups is available from the Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS). For projects classified as Category 1 and 2 using The Three Category Approach, AIATSIS has developed Guidelines for Ethical Research in Australian Indigenous Studies (GERAIS) to ensure that research with and about Aboriginal and Torres Strait Islander peoples follows a process of meaningful engagement and reciprocity between the researcher and the individuals and/or communities involved in the research. It is important to recognise that Indigenous language groups and/or nations may have their own, additional ethical expectations, practices and requirements of researchers.

For non-Indigenous practitioners and researchers, there are several other steps that can be taken prior to engaging with Indigenous owners and communities. For example, some local government areas and universities have reconciliation action plans in place, and these should be consulted and enacted where relevant or appropriate. If it is not already known, check for sites of past and current cultural significance where this knowledge has been made public, and ensure these places of significance will not be negatively affected by the project. Other key steps to working on Country involve looking for opportunities to employ and mentor Indigenous scholars, researchers, and practitioners as part of urban greening projects and research, co-authoring research papers, reports and other outputs with Indigenous colleagues and communities, and communicating outcomes to Indigenous communities and knowledge-holders. Ideally, all projects will have significant benefits for Indigenous communities. These benefits may be tangible, such as employment, or intangible, such as healing or capacity building.

All of the above should be framed around building long-term relationships with Indigenous communities and knowledge-holders on whose land urban greening is taking place. Time and effort to support such relationship building should be built into the design of any urban greening and associated research project.

Other logistics of ethical research design

In integrated socio-ecological research, it is necessary to understand and implement both human and animal ethics protocols, and to factor in these considerations from the very beginning of the research. Compliance with ethical requirements is standard practice in research, however, the challenging element in integrated socio-ecological research is to ensure that both social and biological ethical protocols are properly understood and applied, as well as understanding the variable timeframes involved in receiving ethics approval. For 'simple' observational studies of non-threatened animals, permits may be granted within a few days. However, for more complex research projects requiring human ethics approval and/or research

on endangered species, lengthy approvals processes of several months need to be factored in to research planning.

Whenever people are the participants in or 'subjects' of research activities, researchers must carefully design research activities to ensure that they comply with key guidelines the National Statement on Ethical Conduct in Human Research and Ethical Conduct in Research with Aboriginal and Torres Strait Islander Peoples and Communities. Typically, this will occur through the development and application of a detailed human ethics protocol, administered through a partner organisation such as a university. A complete ethics application, which includes all details and methods of proposed research activities, must be approved *prior* to the start of recruiting participants and commencing research activities. The inclusion of social scientists within the project team (either as researchers or in a consultative capacity) is essential to ensure that an ethically appropriate research project is developed. CAUL's Three Category Workbook is a valuable resource for guidance on Indigenous co-design, collaboration and communication on urban greening projects.

Research involving all vertebrate animals (i.e., mammals, birds, reptiles, amphibians and fish) and cephalopods[6] must comply with the Australian code for the care and use of animals for scientific purposes. In an urban situation, this would typically involve ensuring that any capture, tracking or even observation of vertebrates complies with ethical standards[7]. The inclusion of ecologists or zoologists within the project team is essential to ensure that field techniques comply with the code. Again, animal ethics approvals are typically administered through a university or other appropriate institution, and approval must be granted *prior* to the start of any proposed research activities. If any threatened invertebrates are targeted as part of the research scope, or if invertebrates are to be collected from conservation reserves, then an application to the state government department administering conservation reserves is likely to be required.

Historic industrial land uses

Urban greening sites are usually being improved from an impoverished or degraded state, and many suffer from contamination due to former land uses. For example, in metropolitan Melbourne, there were 11 asbestos manufacturing sites in operation at one time (Millar and Schneiders 2016)[8], along with many other manufacturing and processing industries over Melbourne's history, including the production of agricultural chemicals, leather and tanning, munition production and other industries generating toxic waste. As cities have expanded geographically, landfill and sewage operations have been relocated to accommodate new residential areas. As a result, urban greening projects can commonly be located on sites that have had many layers of previous land uses, some of which are likely to have left toxic traces.

In most cases, remediation efforts will have resolved any harmful residues of toxicity. However, despite best attempts to identify, remediate and resolve land contamination issues, they can still resurface unexpectedly causing project delays and expensive clean-ups. To prepare for these types of interruptions and offset their impact, pre-greening site research is fundamental to any urban greening project, as well as building in contingency planning and additional funding into project budgets where available. The Upper Stony Creek Transformation project, despite being

[6] Cephalopods are unlikely to be encountered in urban greening research as they comprises a particular group of intelligent, marine molluscs including octopus, squids and nautilus.

[7] For example, in the research conducted on urban nature strips in Perth, a permit to observe vertebrate animals – birds – was required prior to the start of fieldwork, under the requirements of the University of Western Australia's protocols in ethical animal research.

[8] The Upper Stony Creek Transformation project in Melbourne was located near one of these former asbestos manufacturing sites, the Wunderlich Factory.

interrupted by unexpected asbestos contamination was ultimately able to continue because of dedicated partner support that enabled a reconfiguration of the original greening plans.

Study design considerations

There are several other challenges involved in designing socio-ecological studies. First, the integration of social and ecological data is dependent on project scales and budgets. If the goal of producing integrated data and findings is identified in the planning and design phases of projects, opportunities to cross-reference and integrate social and ecological components are usually readily found, as long as there is an intent within the project team and partners, and the necessary interdisciplinary expertise is able to be included, or acquired. As part of seeking to integrate traditionally separate disciplines, non-Indigenous researchers may find it helpful to be informed by Indigenous methodologies and theories. There is a growing body of literature by Indigenous scholars that is highly relevant to socio-ecological research because it concerns reciprocal relations between people and nature. Such research is becoming prominent in disciplines such as planning, health, geography and ecology and sustainability fields. For example, the work of Vanessa Cavanagh and Tyson Yunkaporta. If projects are working with Indigenous scholars, communities and knowledge-holders as recommended above, further opportunities to synthesise social and ecological approaches are likely to emerge and become embedded in the project design.

Another challenge in designing socio-ecological studies is that there may not be sufficient funds or support for the entire approach and methods described here, or there may not be a balanced emphasis on both social and ecological dimensions. There is considerable flexibility built into the socio-ecological methods presented above to accommodate varying project budgets, including that pre-existing or pre-established methods used to evaluate urban greening projects can be adapted where needed, and comparisons across sites made where appropriate. Relatedly, the location of appropriate control sites for social and ecological dimensions are likely to vary because of the different sorts of variables under study, often requiring each dimension to have a different control site. If multiple control sites can be accommodated within the same local government or statistical area (e.g. SA2), this will reduce the amount of geographic variation. There can be particular challenges associated with using a geocoded methodology for social survey distribution when datasets are new or untested. For example, the Geocoded National Address File (GNAF) used in the Melbourne case study was new at the time, and its reliability had not been extensively tested. Inconsistencies in the address data may have produced a lower than expected response rate[9].

The timing of ecological and social surveys may also need to differ according to different opportunities and the availability of participants and sites, as for the case studies in Perth and Melbourne presented above. These variations can be unproblematic as long as there are opportunities to collect longitudinal data on both social and ecological domains, and these data can be integrated as much as possible.

Obtaining pre-greening (baseline) data and post-greening data can require a sustained engagement of research at the site/s involved requiring long-term funding and researcher and partner commitment. This engagement can be exacerbated by the expansion of project completion timelines and other unavoidable logistical delays[10]. The flexible approach built into the methods here means that adjustments to the methods can be accommodated if needed. If

[9] Later research using the GNAF conducted by a PhD student in spatial science identified errors where although land parcels may have been identified on a map, not all of the houses physically existed. For example, a subdivision might have been created producing new addresses for two townhouses but at the time of the survey, only a single house existed. The use of GNAF might have therefore inadvertently resulted in surveys being sent to addresses that did not yet physically exist.

[10] For example, the asbestos contamination in the Upper Stony Creek Transformation case study in Melbourne.

pre-greening data cannot be obtained as for the pre/post design, the changes and impacts of the greening activities can still be measured and compared over time, for example between the early and more established phases of the project, or using alternative temporal measures such as chronosequence.

Finding and communicating with research participants

Much social science research, as well as citizen science activities, relies on 'recruiting' participants from diverse communities to take part in the research. Participants may be recruited directly or indirectly. Direct recruitment is where researchers make direct contact with the potential participants. This may be appropriate where the participant is a 'stakeholder' and is contacted in their professional capacity rather than in their personal capacity. Indirect recruitment is where potential participants are contacted via a 'third party', for example through a newsletter, mailing list, social media post or flyer, and are asked to 'opt in' to the research based on information provided to them, thereby retaining privacy of information and contact details. Indirect recruitment is appropriate when participants are residents of an area where greening is taking place, are the general public, or are participating in the research in a personal capacity.

Different kinds of research (for example, qualitative or quantitative) will have varying requirements for the number and representativeness of participants. When there is an open-ended call for participation in a research study[11], the final number of participants might be smaller than anticipated, or there may be an overwhelming amount of interest that cannot be easily accommodated with participation opportunities in the research. In both cases, a flexible approach and developing a decision tree of what to do in case the research project is under- or over-subscribed will be valuable. For example, in the case of over-subscription, it is helpful to be prepared with a standard, polite response that acknowledges people's interest in the research, and notes that it is not possible for everyone interested to participate. Using a variety of both social and ecological methods provides opportunities for sample sizes to grow and provides a variety of ways residents can be involved in the research. Searching social media sites is also helpful in understanding the scale of potential interest in the research project by public participants[12].

The variability in the final sample size that is often part of social science research is perhaps different to ecological research, where the design of field activities is typically fixed in advance (in terms of the comparison sites chosen for sampling, the timing and frequency of sampling activities, and the taxonomic groups that will be sampled). Social scientists and ecological scientists will need to bear this variability in mind when designing research activities, and acknowledge that 'perfect' sampling design in both social and ecological terms may not be possible. A good case in point is for activities that request participants in household garden or nature strip research, to pursue both ecological and social research. An ecologically 'ideal' design might focus on sampling gardens along a particular gradient in size, plant diversity, or proximity to remnant vegetation, but this may not be possible if the residents of the 'ideal' case study locations are not interested in participating in the research. Again, a flexible and collaborative approach to the study design, including social and ecological scientists, will be valuable in determining the study objectives, and perhaps developing 'decision trees' in the case that the 'ideal' study design does not eventuate.

[11] For example, by asking people visiting a park to answer a brief questionnaire 'on the spot', or inviting residents of an area to answer an online or paper-based questionnaire through letter-drops, or soliciting research participants through an online expression of interest disseminated via electronic means.

[12] For example, in the case of nature strip research there are several active Facebook groups where native verge gardeners post images and comments on their activities, as well as community conferences where the main contributors are members of the public and advocates from within community groups. Similarly, there are active groups on Australian insects, birds and plants, as well as 'Friends' groups for particular bushland or wetland reserves.

It is important to acknowledge and respect that researchers and participants may hold differing views and knowledge and are likely to speak different languages. For example, in the case of citizen science projects, research participants may need specifically designed training programmes to enable them to observe and record plant-pollinator interactions (for example, to identify invertebrates, birds or plants). When interviewing research participants, they may conceive of invasive or naturalised species as keystone ecological species (for example, residents may plant flowers to 'support the bees' but conceive of naturalised European honeybees as the species that should be 'saved', rather than prioritising the conservation of native Australian bees); depending on the goals of the study, it can be important to distinguish to which species respondents are referring when using common names. Equally, with training, citizen science participants could identify emergent biosecurity risks by reporting occurrences of plants and animals that threaten ecological and social values in gardens and public open spaces.

Residents living near or around urban greening sites can have different ideas to project partners and practitioners about what species they are comfortable living with in their neighbourhood. For example, in Upper Stony Creek in Melbourne, residents were concerned about the return of snakes and mosquitos, but were content to live with blue-tongue lizards and native birds nearby. How residents perceive wildlife in urban areas is also likely to be place-dependent, and involve entangled histories and past experiences, as the data from the Melbourne case study demonstrates. This means that adequate consultation to understand resident experiences and perceptions of local wildlife and vegetation is important prior to any urban greening project taking place.

Conclusions

This report has sought to present perspectives on integrated social, cultural and ecological research on urban greening initiatives, through reflection on the experiences of an interdisciplinary team of researchers working on Country, in Australian cities under the aegis of the Clean Air and Urban Landscapes Hub of the National Environmental Science Programme. A vast body of literature has been written extolling the potential social and ecological benefits of urban greening, with increasing recent attention to the inclusion of Indigenous cultural perspectives and values. The goal of this discussion paper was to highlight how CAUL's research approach has drawn from the literature, and from a wide range of perspectives, to develop new, practical approaches to measuring and understanding the multiple benefits (and challenges) of urban greening. Often, the practical side of 'how to' is left out of final, published reports, and we hope that the inclusion of pitfalls, missteps, and omissions alongside the innovation and success stories presents a more rounded picture of how to move forward with inclusive, thoughtful and well-designed integrated socio-ecological research projects, which can demonstrate tangible outcomes for the community and environment at large.

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