



Clean Air and
Urban Landscapes
Hub

National Environmental Science Programme



Cities for People and Nature



Partners:



About the Clean Air and Urban Landscapes Hub

The Clean Air and Urban Landscapes (CAUL) Hub has been funded by Australian Government's National Environmental Science Program. The remit of the CAUL Hub has been 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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About the artist

Dixon Patten is a proud Yorta Yorta and Gunnai man who was born and raised in Melbourne. He has over 10 years' experience in the arts and design space as an artist, curator and graphic designer who draws his influence from his connection to his culture and family. He is passionate about storytelling in all its forms and loves the information, wisdoms, knowledge and energy exchange that unites us and bridges the gap between people(s).

About the art

Community, environment and caring for Country are central to Aboriginal cultural principles. The artwork tells the story of those values and practices. It acknowledges that everything is connected and that one thing influences another. Caring for land, water and sky is important and our duty is to design spaces that allow for urban areas to evolve and grow with great consideration and respect for existing ecosystems.

Circles meaning:

The circles represent a community coming together to share, learn and care for each other.

Acknowledgement of Country

All Australian cities are located on unceded Indigenous land. We acknowledge the Traditional Owners of the lands and waters where this research took place, all around Australia, and pay our respects to Elders past, present and emerging. In particular we acknowledge and pay our respects to the many different peoples on whose lands our four universities are situated.

"Country is ever present. Regardless of the built environment, regardless of the bitumen and asphalt, that beneath the concrete, Country always is and always will be. And Country is not just the physical landscape. It absolutely is the natural environment. It is the birds, the bees, the animals, the reptiles, the life in the sea, but it's also the relationships between people and the relationships between people in their place. It's the culture of the people and their place. It's the story and the continuity of that story of a place and its peoples, of its way of being. And it's the interrelationship of all these things," – Jade Kennedy, Indigenous Advisory Group

A note on terminology

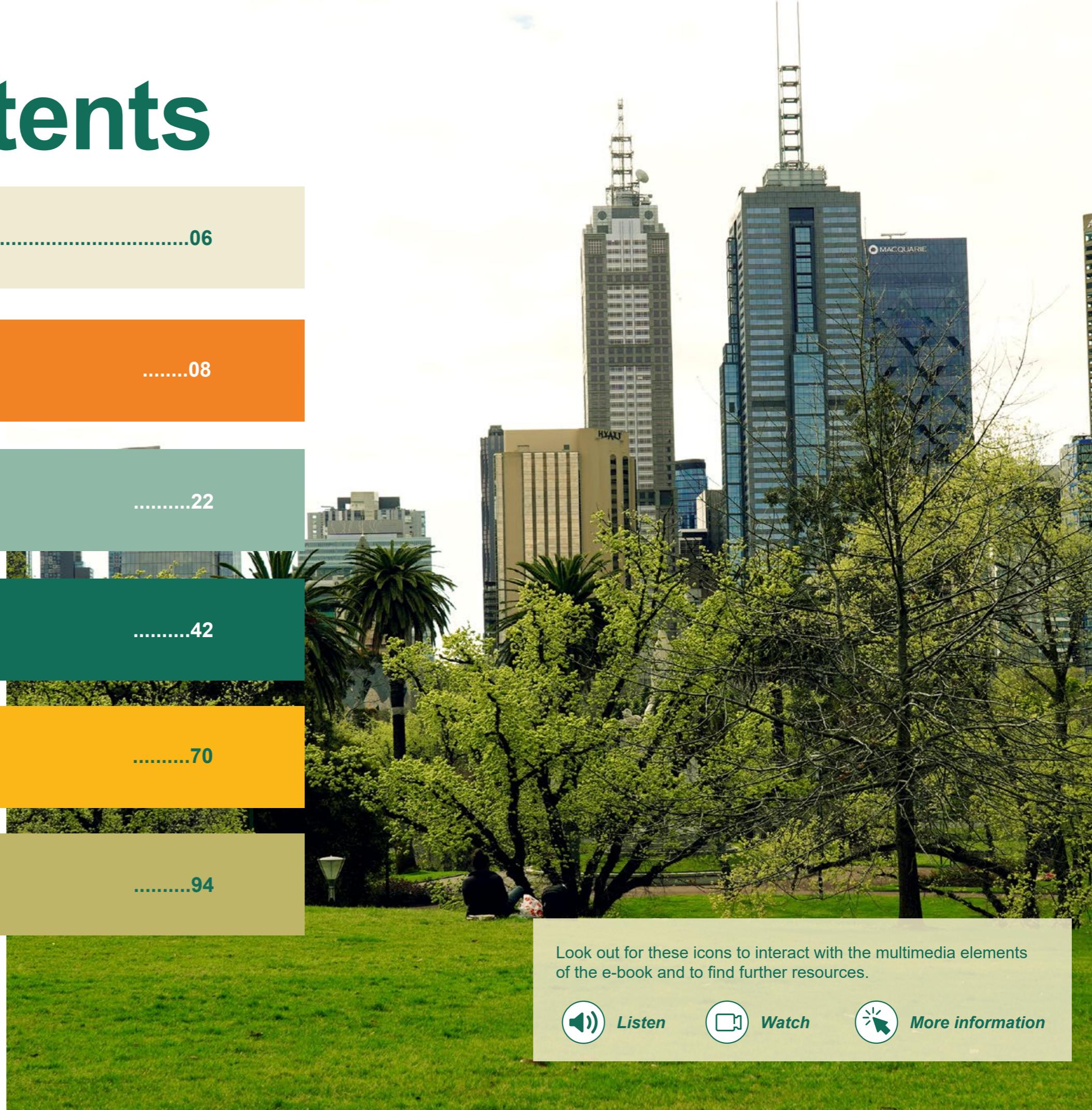
For the purposes of this document, use of the term 'Aboriginal' is inclusive of Torres Strait Islander peoples. The term 'Indigenous' is also respectfully used interchangeably with the term Aboriginal and Torres Strait Islander.



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*Urban park near Melbourne's CBD.
— Photo by Briena Barrett*



Look out for these icons to interact with the multimedia elements of the e-book and to find further resources.



Listen



Watch



More information

Introduction

Urban environments are among the most important environments in Australia. More than 90% of the Australian population – or around 22.6 million people – lives in cities. This is where we experience the environment on a daily basis, from the air that we breathe to the park where we walk, the frogs we hear calling or the green roof we may see from our office window.

The Clean Air and Urban Landscapes (CAUL) Hub began in 2015 as a new research consortium with a focus on practical research to improve urban environments in Australia. It brought together researchers from four universities and a wide diversity of fields including atmospheric chemistry, civil engineering, urban planning, urban ecology, urban greening, geospatial data, conservation biology, social environmental science and population health.

Our mission was twofold: to undertake multi-disciplinary research for practical outcomes, and to highlight Indigenous perspectives in urban environments. Our approach was collaborative, and our philosophy recognised the value of working across boundaries to create something bigger than each individual field could achieve on its own. It also recognised the value of providing early- and mid-career researchers with opportunities to pursue cutting-edge science while also taking on formal leadership roles within the hub. Our aim was to undertake a body of work, engagement and outreach activities that would change the way people think about cities in Australia, and open new possibilities to make them better places for people and nature.

The opportunity to highlight cities as Indigenous places, to make space for Indigenous voices and perspectives in cities, and to promote Indigenous-led research is one we have taken seriously. We have pursued this through our research but also through outreach activities including

The Living Pavilion, Indigenous Science Conversations at Questacon, events at the MPavilion and Melbourne Design Week, annual NAIDOC-week editions of the hub's newsletter *Urban Beat*, and development of the Three-Category Approach toolkit to facilitate cross-cultural work between Indigenous and non-Indigenous Australians. Indigenous voices can also be heard through this e-book, in both written and video formats.

While the hub was funded by the Australian Government's National Environmental Science Program (NESP), the stakeholders of our hub comprised a much broader group including all levels of government, urban practitioners, community groups and the general urban-dwelling public of Australia. We created partnerships with many different agencies and organisations to pursue applied research that has already contributed to making our air cleaner and our cities greener, more biodiverse and more liveable.

It has been an honour to work with the CAUL Executive Team, including former Hub Leader Peter Rayner and Deputy Hub Leader Joe Hurley, to lead such a committed group of researchers over the last six years. It has also been an honour to work with the broader family of CAUL's many collaborators and supporters, including our Indigenous Advisory Group (IAG) and Steering Committee. Every member of the IAG and Steering Committee has provided wisdom and advice to help us steer our course, with both generosity and enthusiasm. For this we are very grateful.

I am excited to present to you this e-book as a showcase of our work to make cities better places for people and nature. I hope you find it engaging, thought-provoking and inspiring, as we all prepare to tackle the many environmental and social challenges that cities will face in coming decades.

Our mission was twofold: to undertake multi-disciplinary research for practical outcomes, and to highlight Indigenous perspectives in urban environments.



Royal Park, Melbourne.
— Photo by Luis Mata



Cities are Indigenous Places



Birrarung Marr, Melbourne.
'Birrarung Wilam' – meaning river camp – is an environmental art project made up of several interrelated elements that celebrate the physical and spiritual connections between Indigenous people and place. Pictured are the five shields.
— Photo by Helaine Stanley



Cities are Indigenous places

Indigenous knowledge systems and Indigenous science, developed over thousands of generations, are key to living sustainably in Australia's urban environments. Partnerships with Indigenous Australians have formed an important component of CAUL's urban research and practice. Under the guidance of its Indigenous Advisory Group (IAG) members, Stan Lui, Jason Barrow and Maddison Miller (Chairs), Timmah Ball, Jade Kennedy, Kirstine Wallis, Luke Briscoe and Lauren Arabena, and a network of Indigenous contributors, CAUL has sought to highlight Indigenous perspectives in cities.

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From our Indigenous Advisory Group

We acknowledge that every place in Australia – cities, towns and regional centres – are also Aboriginal and Torres Strait Islander Country. Here, we asked several of our IAG members to reflect on CAUL's work and how we can better recognise urban areas as Indigenous places.

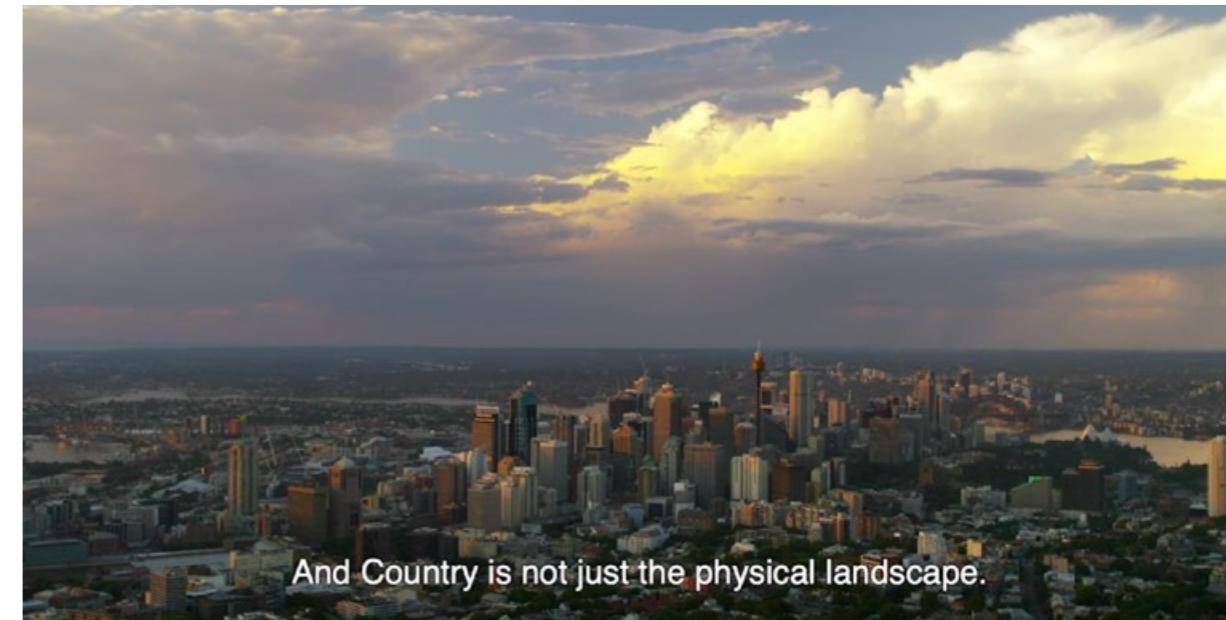
Jason Barrow. Jason is a Noongar man. He is the co-chair of CAUL's Indigenous Advisory Group and an advisor to a range of other groups and committees across the government and education sectors. Jason has supported policy-makers, key personnel and researchers to find ways to engage with their respective Aboriginal communities.

Maddison Miller. Maddison is a Darug woman. She is an archaeologist at Heritage Victoria and the co-chair of the Indigenous Advisory Group.

Jade Kennedy. Jade is a Yuin man. Jade is an academic developer and lecturer in Indigenous Knowledges at the University of Wollongong and is leading and facilitating the internationally acclaimed educational development grants program, Jindaola. He is also the Chair of the Illawarra Local Aboriginal Lands Council.

Kirstine Wallis. Kirstine has connections to Yorta Yorta Country, along with pre-colonial Irish/Scottish/Canadian, and ancestry way back to Palawa milaythina. She also has colonial links to England and Captain Cook's family. This cultural dichotomy fuels Kirstine's research and practice as a landscape architect and artist, and her perspective serves as a bridge between cultures.

Luke Briscoe. Luke is a Kuku-Yalanji man. He is the founder and CEO of INDIGI LAB, an Indigenous owned and operated business that creates innovative projects for social and environmental change through digital culture.



And Country is not just the physical landscape.



Members of our Indigenous Advisory Group share insights on how we can better recognise urban areas as Indigenous places.



Q: How can we recognise cities as Indigenous places?

Jason: For me the answer lies in the question, we should seek to celebrate and learn about the place we find ourselves, rather than seeking to transplant a notion of somewhere else to wherever we, as humans, travel. When we do this, we'll have a better connection to and understanding of what has always been and always will be special and unique about a place or 'Country'.

Kirstine: We can recognise cities as Indigenous places by better acknowledgment of First Nations people as the Traditional Owners, custodians of the land, waters and ecologies. Amongst all the concrete and asphalt, the glass, the steel of our cities, we can create better distinction of character in our placemaking, highlighting the identity representing our unique Indigenous cultures, and outwardly present a better connection to Country and authenticity of place.

Maddison: Cities, although they may not appear it, contain the archaeological remains of the past and as an archaeologist that's something that I work with. Through the careful excavation of these places we can see the layers of time beneath our feet and that continues to today with thriving and wonderful Aboriginal communities who call these places home.

Jade: And Country is not just the physical landscape. It absolutely is the natural environment. It is the birds, the bees, the animals, the reptiles, the life in the sea, but it's also the relationships between people and the relationships between people in their place. It's the culture of the people and their place. It's the story and the continuity of that story of a place and its peoples, of its way of being. And it's the interrelationship of all these things. And when we become cognisant of these aspects or concepts or understandings, that cities are part of the ecology that describes and is understood from an Aboriginal perspective as Country, then we start to give entity, we start to give recognition, we start to give respect and we start to behave with reciprocity, what we call napagi napagi.

Luke: When we look at recognising Indigenous places in the city, I think it's vital for any conversations about places in Sydney or Melbourne or wherever, that the first conversation that needs to be had is with Indigenous people. And also that those place names and languages used for those names, you know, Eora, Garigal, it's important to note that they have been around for thousands of years and there is important connection between the land and language that you can't separate.

'Amongst all the concrete and asphalt, the glass, the steel of our cities, we can create better distinction of character in our placemaking, highlighting the identity representing our unique Indigenous cultures, and outwardly present a better connection to Country and authenticity of place.'

—Kirstine Wallis

Q: How can Indigenous peoples' knowledges and practices help shape better cities?

JK: We know our Country, we know how it breathes. We know how it moves and we know how to engage. It comes down to sometimes just really simple things like that's not a good place to put a road or that's not a good place to put a building. We have an understanding through our dreaming and through our stories as to why things are where they are. See for us, everything is where it's meant to be.

M: In the past, our ancestors did not live in a way that damaged the Earth. Our ethos was to sustain and to nurture her and so Indigenous knowledges in creating cities, in creating sustainable futures, is integral to understanding this land and its unique properties.

JB: Just as we seek to recognise cities as Indigenous places, we could, and should, use the points of difference to create opportunities for special and unique ways of working with the local environment, rather than continually engineering solutions to man-made problems.

L: That question always stumps me because it's not the fact that non-Indigenous people or governments don't see that Indigenous knowledge is valuable. It's just the fact that they don't respect it enough to reciprocate and give its full kind of rightful attributions for use of that knowledge.

'We know our Country, we know how it breathes. We know how it moves and we know how to engage.'

—Jade Kennedy



The Dights Falls area in Melbourne is culturally significant for the Wurundjeri people.
— Photo by Briena Barrett



Q: How can cities give back to Indigenous peoples?

M: Cities can give back to Indigenous peoples in a number of different ways. The way in which we plan our cities and the way in which we consider our cities can reflect Aboriginal thought and Aboriginal knowledge and Aboriginal principles for caring for Country. If we consider all of the parts of Country, and all of the parts that are important to Aboriginal peoples, we can create better communities. Ones that consider waterways and animal pathways, ones that consider our sacred sites, ones that consider the way in which resources are used and protected and nourish back to the Earth.

JB: For too long, Aboriginal people were excluded and then secluded on the margins before being engulfed as cities grew without them ever being involved in the decision-making processes. To address this past, first an acknowledgement of it needs to be told and heard, not just listened to. Secondly, an opportunity for meaningful places with the processes and mechanisms of development need to be not only created, but fulfilled; this will take some time. These couple of steps will result in better outcomes for everyone, not just Aboriginal peoples.

'If we consider all of the parts of Country, and all of the parts that are important to Aboriginal peoples, we can create better communities.'

—Maddison Miller

K: The main thing is meaningful reciprocity for Indigenous participation and knowledge sharing. What is appreciated is increased broad community awareness and understanding of culture, historical to contemporary Indigenous perspectives, truth and belonging, but also not imposing expectations on Indigenous communities but asking how First Nations people want to design and consult, how they want the place to feel, look, function and be protected and what they would like in payment or compensation for that knowledge that feeds back to benefit their communities.

JK: Aboriginal peoples, Torres Strait Islanders, need to be present in all levels of decision-making. Aboriginal people need to be given those significant roles, not just stakeholdership, but decision-making power and thereafter, the self-determination to operate and function through the initiatives and projects that they understand are required for the health and wellbeing of our cities. Aboriginal people carry this Country's dreaming and in that dreaming are the answers of the ways in which we are to behave within our particular places and spaces.

Three-Category Approach toolkit



Failure to recognise Indigenous knowledge systems in urban research and practice means lost opportunities to improve cities for people and biodiversity. The Three-Category Approach was developed by Torres Strait Islander researcher, scientist and consultant Stan Lui, together with members of the Indigenous Advisory Committee of the Commonwealth Department of Agriculture, Water and the Environment, to build this cultural awareness and walk urban researchers and practitioners through processes for collaboration with Aboriginal and Torres Strait Islander peoples and organisations. It guides non-Indigenous professionals through three categories: communicate, collaborate and co-design (Figure 1).

In 2018, Jirra Lulla Harvey of Kalinya Communications set out to produce a workbook based on the approach, following discussions with Stan. We have since hosted a series of Indigenous-led workshops to show how communication, collaboration and co-design with Indigenous people can create new and unexpected insights, enabling practitioners to identify opportunities to reframe their future professional work. The framework can be applied to a wide range of areas, including Reconciliation Action Plans, academic research, policy and practice.

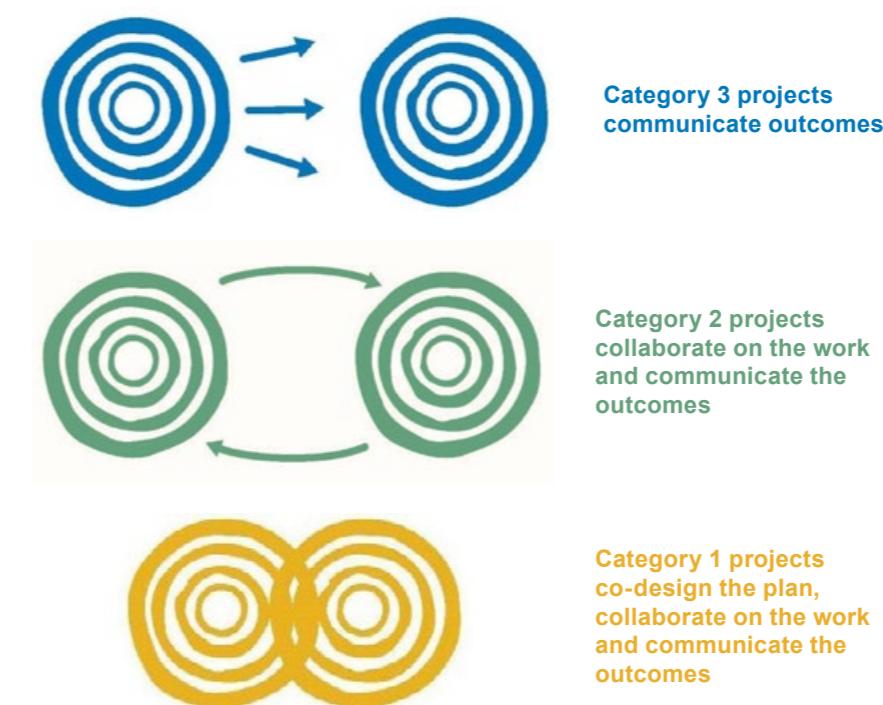


Figure 1. The Three-Category Approach



Q: How can we meaningfully engage with Aboriginal and Torres Strait Islander peoples to improve urban policies and practices?

K: The Three-Category Approach is a great toolkit for researchers and practitioners who want to work with First Nations people and organisations. Meaningful engagement starts with better understanding of the strengths and customs of traditional to contemporary First Nations culture; better communication of methods; better collaborations by being patient and building time into a project at its inception to build meaningful and trusting relationships; empowering participatory collaborations with appropriate acknowledgements, ethics and protocols; and by co-authorship and co-design with Traditional Owners.

JB: Through meaningful relationships, not the kind that last Monday to Friday, 9 to 5, or the length of a funding cycle or an election cycle. As Aboriginal people, we don't clock on/off from our responsibilities about looking after Country or advocating for our communities. It's who we are, a way of being. If you look closely at the non-Aboriginal people who've made significant and ongoing positive contributions with Aboriginal people you'll see a depth of relationships formed and nourished over time.

L: There's a big focus on trying to get Indigenous peoples at the forefront of the conversations around [the UN's] Sustainable Development Goals. And one of those conversations is developing cultural indicators. The cultural indicators would set a guideline on when to do business. So then if you're looking at starting some sort of business, it might even be in agriculture or something like that, that you work with the community to learn when best to plant grape seeds or whatever's in the region because it's important.

Q: How can science-communication events like The Living Pavilion work to empower and educate participants about Aboriginal peoples' custodianship and knowledge of Country?

L: [The Living Pavilion] was really a good event to showcase the amazing scientific and cultural insight that the local Victorian Indigenous community have and also help educate the broader community about Indigenous knowledge. Even in the city around some of the plants and fruits that you might find still today on the streets, like lilly pillies and stuff like that, they all grow through the cities, but no one ever really knows what they are until they walk past a group of blackfellas who are standing at the tree eating these lilly pillies. So, it's important when we look at projects like The Living Pavilion that they are not just showcase events, they are actually an opportunity to really engage with the Indigenous community to learn. To learn about what's in your backyard, even though you live in a built-up city.

JB: By having Aboriginal and non-Aboriginal people co-presenting side by side about the unique natural elements that have been covered over, dismissed or replaced for too long, we can help participants become better connected to the land/place they're standing upon. By modelling the joint and collaborative approach of Kurongkurl Katitjin, as it's said in Noongar, or 'coming together to learn', hopefully people will feel more comfortable and confident in embedding this practice for themselves, and more importantly, their children.

The Living Pavilion



The Living Pavilion, held in 2019, was an Indigenous-led, temporary event space, festival and living lab that featured a unique landscape of 40,000 plants native to the Kulin Nation. Situated on the University of Melbourne's Parkville campus, the program featured over 40 events and 39 Indigenous contributors. It attracted thousands of visitors over its 17 days.

A key aim of the event was to evoke a sense of Aboriginal belonging and sovereignty at the University and highlight the importance of Aboriginal perspectives in tackling ecological challenges. Surveys conducted over the course of the event found that 84% of participants agreed, or strongly agreed, that they felt more connected to Indigenous culture by visiting the event¹. The data also revealed a 40% increase in people's perception of the site as an Aboriginal place.

'Traditional ownership unacknowledged and pushed beneath the surface is being brought forward. It has always [been] and always will be an Aboriginal place, it is only now that we non-Aboriginal folk are learning what that means ... even a little bit. With respect'. – Survey participant

Signage at The Living Pavilion. Illustrations by Dixon Patten of Bayila Creative, research and words by Zena Cumpston, design and production by 226 Strategic.

— Photo by Alison Fong



Zena Cumpston leading the plant installation at The Living Pavilion.
— Photo by Alison Fong



The landscape of inclusion

Zena Cumpston, Barkandji woman and Research Fellow

Only recently have the wider Australian population and environmental practitioners started to understand urban areas in terms of Aboriginal perspectives. The ongoing erasures of colonisation have made it difficult for urban places to be properly understood as Country in Aboriginal terms. This lack of proper attribution has enabled systems that do not meaningfully incorporate Aboriginal perspectives, approaches, pedagogies and knowledges. Sadly, whilst things are slowly changing and there is enthusiasm to include our communities within this realm, the inclusion too-often remains overly extractive and heavily weighted towards benefits for non-Indigenous people.

I am deeply saddened and troubled by the lack of understanding I see around me when it comes to people accepting their individual responsibility to educate themselves. My people face challenges across every fora of modern Australia and the burden is almost always on us to educate and share. There is also a heavy burden that First Peoples must carry when 'included' in mainstream systems. We are too often seen as a resource to be plundered, added, sprinkled on top, showcased and used to illustrate, to prove everyone is doing the right thing. This is particularly evident in 'Indigenous-led' projects, which are too-often overtaken by non-Indigenous people, institutions and their objectives, failing to make room for timelines and circumstances that do not rigidly conform to sharp-edged white systems. 'We tried' isn't good enough because it too-often means 'We made room in a way that was comfortable for us'. Leadership for Aboriginal and/or Torres Strait Islander peoples is, in truth, experienced as a burden and not as empowerment when that appointment is (whether overtly or inadvertently) insincere. To make room for us in ways that are empowering and transformative for all

means that people will need to be uncomfortable. We can't be wedged into sharp spaces that do not allow the foundations of our culture to play out, spaces that restrict, dilute and distort by only allowing what can look and feel like familiar non-Indigenous ways of seeing and doing.

I am grateful for the opportunities and learnings that have come from the position I have held with the CAUL Hub. I have deliberately chosen projects that work towards empowering community voices and enhancing the visibility and understandings of our perspectives in the built environment. I hope to see more Aboriginal and/or Torres Strait Islander people working in urban-environmental contexts, especially within the realm of academia and knowledge production. We as Aboriginal people know and understand that Country holds her stories, no matter how violently she is altered, reconfigured or reinscribed. Just as our culture is not stagnant, rigid or relegated to the past, so too has Country survived and adapted to accommodate new circumstances and challenges. Urban areas may be seen as the front line when we consider the challenges we all face with climate change and the work we need to undertake collectively to reconfigure the lack of custodianship and care that has caused such degradation and devastation over a relatively short period of time.

A new dawn is emerging, where the environmental challenges we face collectively call for new alliances to be forged, new ways of producing knowledge, and a reckoning with extractive and insincere processes and structures that must be dismantled. We must enact this new landscape together because, as Wurundjeri Elder Aunty Di Kerr tells us, '*When we look after each other and we look after Country, Country looks after us.*'



Learning on Country with Uncle Badger Bates.
— Photo by Zena Cumpston

To make room for us in ways that are empowering and transformative for all means that people will need to be uncomfortable.



Resources



Looking for more information? These resources cover: the full series of NAIDOC Week Urban Beats, a toolkit guiding cross-cultural work in an urban setting, the research conducted at The Living Pavilion, and more.



Newsletters:

- [First Nations' edition of Urban Beat \(2020\)](#)
- [NAIDOC Week 2019 edition of Urban Beat](#)
- [NAIDOC Week 2018 edition of Urban Beat](#)
- [NAIDOC Week 2017 edition of Urban Beat](#)



Toolkit:

- [Three-Category Approach](#)



Factsheets/Reports:

- [Reshaping settler-colonial urbanism in Australia](#)
- [Caring for Country: An urban application](#)
- [The Living Pavilion research report](#)
- [Flipping the table: Toward an Indigenous-led research agenda](#)
- [Conservation of urban biodiversity: A national summary of local actions. Part II: INDIGI LAB review](#)



Article/Presentation:

- [To address the ecological crisis, Aboriginal peoples must be restored as custodians of Country](#)
- [How Aboriginal perspectives can shape new landscapes](#)



Booklet:

- [Indigenous plant use](#)



The Living Pavilion Signage:

- [Indigenous plants and cultural stories of The Living Pavilion](#)



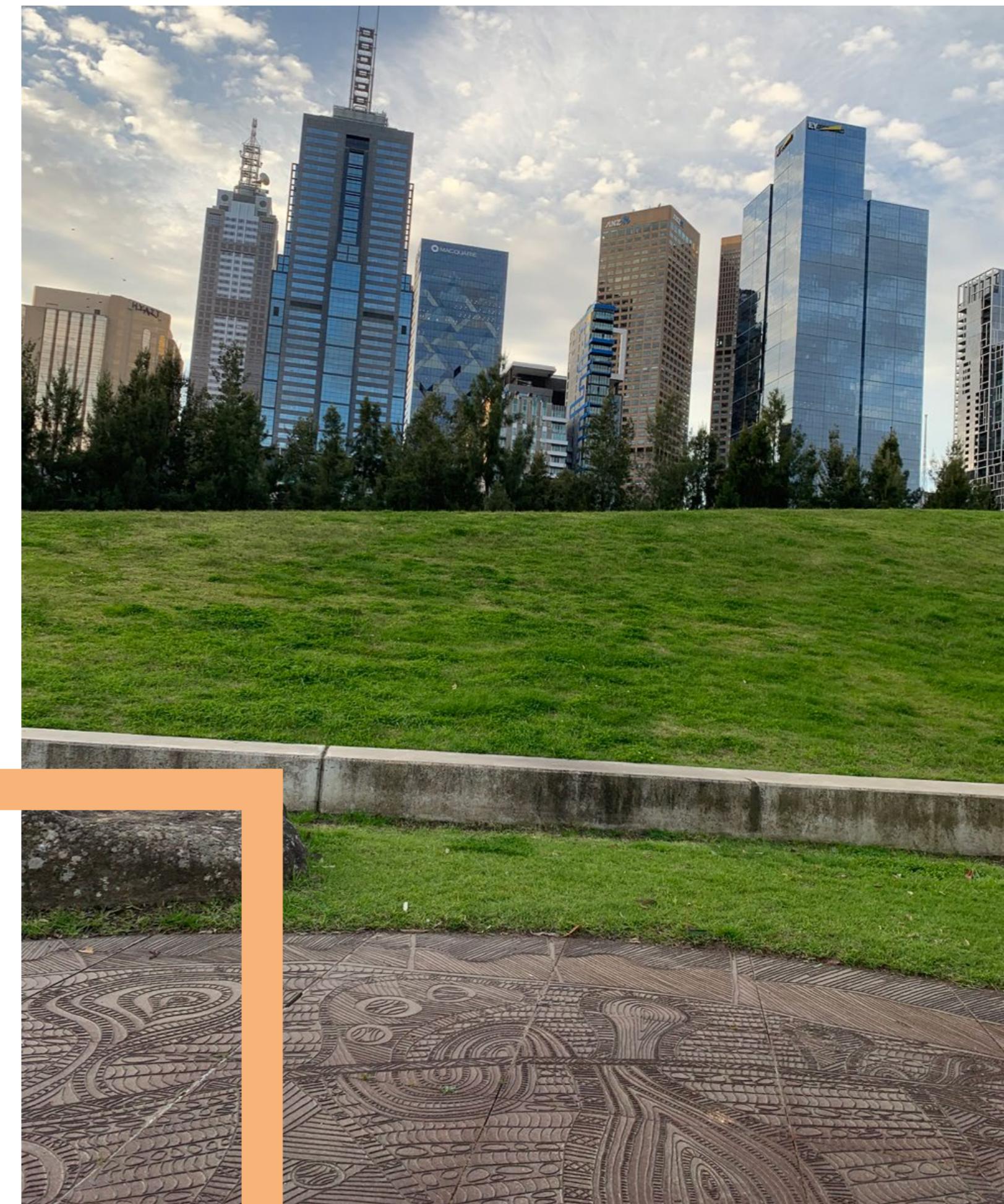
Academic paper:

- [Bringing nature back into cities](#)

Birrarung Marr, Melbourne.

'Birrarung Wilam' – meaning river camp – is an environmental art project made up of several interrelated elements that celebrate the physical and spiritual connections between Indigenous people and place.

— Photo by Helaine Stanley





Air Quality

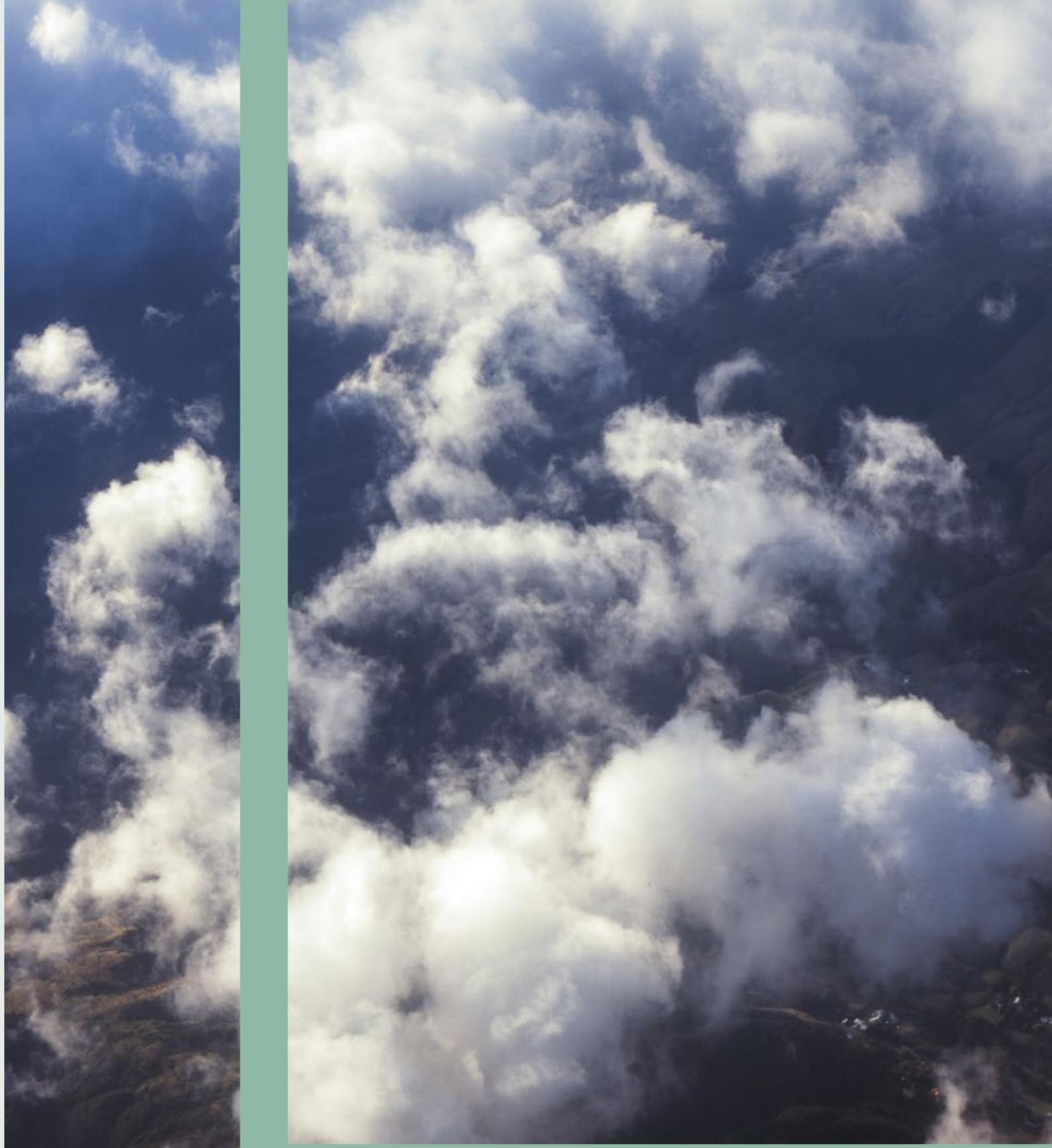


Photo by Wolf Zimmermann (Unsplash)

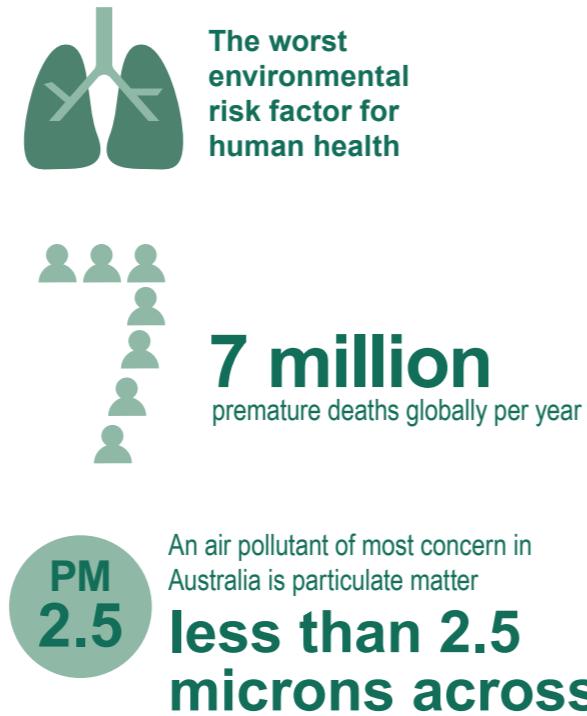


Introduction

Clare Murphy (Paton-Walsh)

There is no more fundamental human need than clean air to breathe, yet increasingly we live in densely populated cities where air pollution is a common problem. The United Nations has identified air pollution as the worst environmental risk factor for human health worldwide. Globally, indoor and outdoor air pollution is estimated to cause seven million premature deaths every year¹. Australian cities typically enjoy cleaner air than other major cities worldwide, but we cannot be complacent: climate change and population growth are both expected to worsen air pollution in Australia.

The air pollutants of most concern in Australia are particles suspended in the air that are less than 2.5 microns across (PM_{2.5}) and ozone. Even at low levels, these have been shown to be bad for human health. The most severe air-pollution episodes in Australian cities are usually caused by events such as bushfires and dust storms. The 2019-20 bushfires exposed millions of people in Sydney, Canberra and Melbourne to hazardous air for weeks on end. The pollution levels were so high that some cities experienced levels similar to those on the fire ground^{2,3}. Outside these episodes, human-made pollution from sources such as traffic, wood-combustion heaters and hazard-reduction burns dominate over natural sources⁴. The air we breathe indoors is also important; exposure to potentially harmful air pollutants occurs in our homes, workplaces, schools and other buildings.



So what can be done to improve urban air quality in the future? CAUL researchers have brought a multi-disciplinary perspective to urban air-quality research. We have sought to better understand the major sources of outdoor air pollution, including from traffic and smoke, and have identified effective ways to detect and manage air pollution in urban areas. Our research on indoor air quality focused on volatile organic compounds (VOCs) from fragranced consumer products such as cleaning supplies and air fresheners. Finally, our work has shed light on the health risks of air pollution in Australian cities.

Here, we reflect on this work and answer questions such as:

- Where and when should you exercise in cities to avoid the worst air pollution?



Air quality captured in Sydney on December 10, 2019 during the bushfire crisis.

- Could the way you choose to heat your home be contributing to air pollution?
- Could the use of fragrance-free products improve indoor air quality and reduce exposures to potentially hazardous pollutants?
- How can we encourage more people to drive electric vehicles?
- Could Indigenous knowledge of weather and seasons help us understand the variability of air quality?

As our climate warms and the population density of our cities grows, we must look to new, cleaner technologies to safeguard the quality of the air that we breathe for future generations.

The most severe air pollution episodes in Australian cities are usually caused by events such as bushfires and dust storms.

Smoke, traffic and trees: air quality in NSW

Clare Murphy (Paton-Walsh), Hugh Forehead and Jack Simmons

For the last five years, we have focused on studying the air quality of Australia's largest city – Sydney¹. Here are some key findings from which every Australian city can learn.

Smoke pollution

A major source of poor air quality in Australian cities is smoke from bushfires, hazard-reduction burns and domestic wood-burning. Bushfires are unavoidable in the Australian landscape. While hazard-reduction burning may be an effective way to reduce fire risk and protect property in some circumstances, there is a trade off with the health risks posed by the smoke they create. Weather conditions that are most suitable for controlled hazard-reduction burns (cool and still) are likely to trap smoke close to the ground, which can result in significant air-pollution problems in nearby towns and cities. Widespread burning is still controversial and there is much to be learned about best practice from Traditional Custodians of the land².

The chemical makeup of smoke is very similar, regardless of whether it comes from bushfires or domestic wood heaters.

A less obvious but equally important source of smoke pollution comes from household wood heaters. We conducted an air-quality measurement study in Auburn, in Sydney's west, over 18 months. The study found that although the highest pollutant concentrations were observed during periods of controlled burns, domestic wood heaters caused greater cumulative exposure to smoke than other sources³. The study also showed that pollution from wood smoke contains chemicals such as formaldehyde and ammonia that are known human toxins. The chemical makeup of smoke is very similar, regardless of whether it comes from bushfires or domestic wood heaters. Tighter regulation of domestic wood heaters and the use of atmospheric models that can predict smoke impacts from hazard-reduction burns before ignition are recommended to reduce air pollution and to increase public safety.

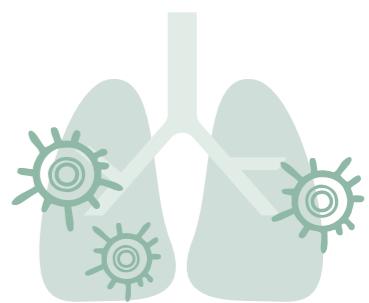


(Left) Hazard-reduction burning.

(Right) Wood-burning heater.

What is particulate matter?

Many Australians became familiar with the term particulate matter during the devastating bushfires of early 2020, which caused poor air quality in many cities and towns. Particulate matter (PM) comprises a mixture of solid and liquid toxic compounds that can be inhaled into the lungs. The particles become trapped in the lining of the lung, where toxins can be efficiently transferred to sensitive tissues and into the blood. The finer the particles, the deeper they can be inhaled into the lungs. Particulate matter smaller than 2.5 micrometres (less than a tenth of a human hair), referred to as PM_{2.5}, is recognised as a serious hazard to health, with effects on the brain, heart, lungs, circulatory system, immune system, endocrine system and during pregnancy⁴.





A reflector array was installed in Auburn, NSW to measure integrated gaseous pollution levels across the centre of town.

Traffic pollution

Traffic emissions are a well-known source of air pollutants in urban areas worldwide. The concentration of air pollutants generated by traffic can vary significantly over a small area. We conducted a roadside study in Randwick in Sydney's east to investigate this.

The research found levels of PM_{2.5} at the roadside were sometimes twice those measured at nearby air quality monitoring stations⁵. PM_{2.5} concentrations were also found to be about 50% higher in the morning peak hour compared to the evening traffic peak. This research could inform public education campaigns about changing levels of air pollution and encourage people to commute and exercise in different locations or at different times to reduce their exposure.

PM_{2.5} is not the only significant air pollutant generated by vehicle exhaust; ammonia is also of concern. Ammonia is a gas that contributes to PM_{2.5} formation and has traditionally been very difficult to measure. During our air-quality measurement campaign in Auburn, we employed a new measurement technique that uses a beam of light to accurately measure ammonia concentrations⁶. This research demonstrated that the main source of ammonia was local traffic, and that the previous inventory of air pollutants had significantly underestimated ammonia emissions in Sydney. Better measurement of air pollutants in Australian cities can assist policy-makers by accurately identifying pollutants and areas of concern.

Levels of PM_{2.5} at the roadside were sometimes twice those measured at nearby air quality monitoring stations.

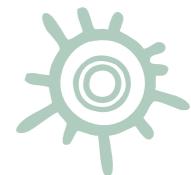
Electric vehicles

Terry Li

Additional uptake of low-emission vehicles in Australia could significantly reduce greenhouse-gas emissions and other air pollutants, with benefits for the environment and human health. As well as strategies to improve the fuel efficiency of the existing vehicle fleet, increasing the uptake of electric vehicles (EVs) can accelerate this change.

Our research explored current patterns of EV adaptation and infrastructure and predicted that there will be up to 85,000 battery-powered vehicles in Australian cities by 2030¹. It found that the speed and scale of EV uptake in Australia is strongly associated with affordability, travel patterns, housing supply and access to supporting infrastructure. It also showed there are further opportunities to stimulate EV uptake, rather than relying solely on the market.

The environmental implications of expanding EV use are significant. It is estimated that in Melbourne alone, there would be more than 500,000 litres of fuel saved per day if 10% of the current private vehicle fleet were replaced by EVs.





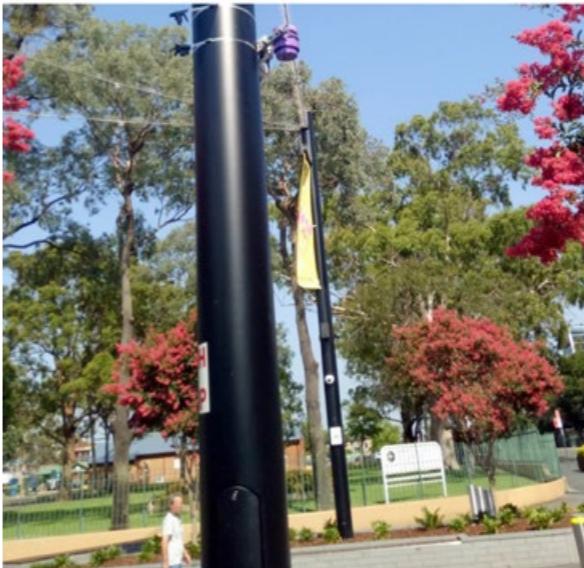
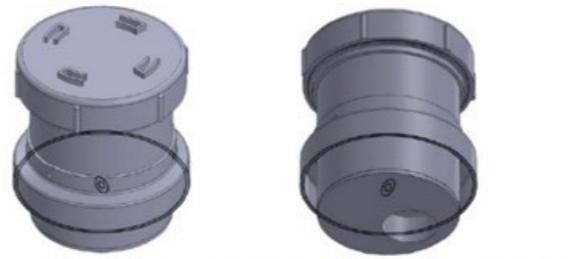
Bryum argenteum (pictured) was one of the moss species found to retain more particulate matter from the atmosphere per gram than the leaves of nearby native trees at a study site.

— Photo by Alison Haynes

Urban greening and air quality

Creating green space in urban areas by planting trees, shrubs and groundcover can have the co-benefit of mitigating air pollution in locations such as busy roadsides. We conducted an experiment in Wollongong, NSW, to compare the effectiveness of mosses and trees at particulate removal. Along roadsides ranging from quiet suburban streets to busy highways, moss was more effective at removing particulate matter from the atmosphere than selected native tree species⁷. As levels of pollution increased, mosses trapped more particulate matter.

A companion study demonstrated that particulate matter trapped by evergreen leaves is absorbed deeper into the leaf structure. In contrast, particles deposited onto the leaves of deciduous trees are washed off after rain, ‘refreshing’ the trees’ ability to remove particles⁸. However, urban greening is complex – some studies have attributed high concentrations of air pollutants measured in urban areas to the ‘trapping’ effect of street-side vegetation. Street trees can create a physical barrier that restricts ventilation of the air beneath. Also, many plants emit volatile organic compounds (VOCs). VOCs are highly reactive and can contribute to formation of particulate matter and ozone in urban environments¹. Further research is needed to determine whether urban-greening projects would have significant benefits for air quality in Australian cities, especially those located in heavily forested regions.



We built our own low-cost air quality monitors using parts from electronics and hardware stores to measure pollution near traffic. Pictured here attached to a light pole in Sydney.

— Photo by Hugh Forehead

Monitoring and modelling air pollution

Continued air-quality monitoring is crucial for understanding changes in air quality. The NSW Department of Planning, Industry and Environment (DPIE) runs an extensive network of 17 air-quality monitoring stations across Sydney. We carried out three case studies to compare measurements at these stations and in typical everyday environments where people may be exposed to air pollution. The first case study demonstrated that air quality at a simulated suburban balcony was similar to that at three nearby monitoring stations⁹. In contrast, two other studies found that roadside concentrations of PM_{2.5} were often greater next to major roads than at nearby monitoring stations, and that hotspots existed next to busy intersections and bus stops^{5,10}.

The best way to apply knowledge gained through site-specific measurements to a wider area is to use atmospheric models. Air-quality models use a combination of meteorological factors, such as temperature and wind speed, and chemical measures, such as emission inventories and chemical reactions, to predict concentrations of pollutants across a geographical region. Model accuracy can be checked against measurements from air-quality monitoring stations.

We undertook comprehensive model testing that compared six different models over Sydney, Wollongong and Newcastle, NSW¹¹. The comparison resulted in improvements to models of air quality over Sydney and demonstrated that these models can meet international standards of performance. One of the models was then used in studies that highlighted the significance of chemical emissions from vegetation, along with domestic and industrial pollution sources, in ozone formation in Sydney¹². A second study confirmed domestic wood burning and traffic as the major sources of PM_{2.5} across the city¹³.

Understanding climate with Indigenous knowledge

Stephanie Beaupark

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Meteorological variables like temperature and wind can strongly influence air quality and it is common to analyse air pollutants within a seasonal framework. However, the European seasons of summer, autumn, winter and spring that have been retrofitted to our country don't represent the reality of local weather patterns. As the hub's Indigenous Student Research Intern, I set out to discover Indigenous perspectives of seasons and weather patterns in Sydney¹.

Through discussions with the Darug community of Sydney, we found that Indigenous knowledge can define a more meaningful set of seasons/weather cycles in western Sydney, demonstrating the complementary nature of Indigenous knowledge and western science. Members of the community shared that this particular knowledge had been lost after European colonisation. We could not find a set of Indigenous seasons for the region that was widely accepted within the community. However, there was a common understanding of changing weather patterns, reflected in the local flora, which signaled availability of food in certain places at different times of year. Current food availability is an indicator of past weather, and current weather is an indicator

of future food availability. We combined these perspectives with decadal-scale records of meteorological measurements to create a set of six 'quasi-seasons' for the western Sydney region. We call these IKALC-seasons (Indigenous Knowledge Applied to Local Climatology).

These IKALC-seasons were found to be helpful in understanding annual variability of air quality in western Sydney, particularly due to better identification of the time of year when cold/still weather conditions cause higher levels of fine particulate pollution, carbon monoxide and nitrogen oxides. The six seasons also differentiate between hot/wet and hot/dry periods (Figure 2).

This method can be applied anywhere worldwide to better understand local climatology. However, the IKALC-seasons are missing interconnected aspects of Indigenous knowledge that would be essential in creating a conclusive Indigenous seasonal calendar, such as land management, local language, food availability, animal behaviour and plant life. This project was the first step in a long process to create an Indigenous seasonal calendar for Sydney.

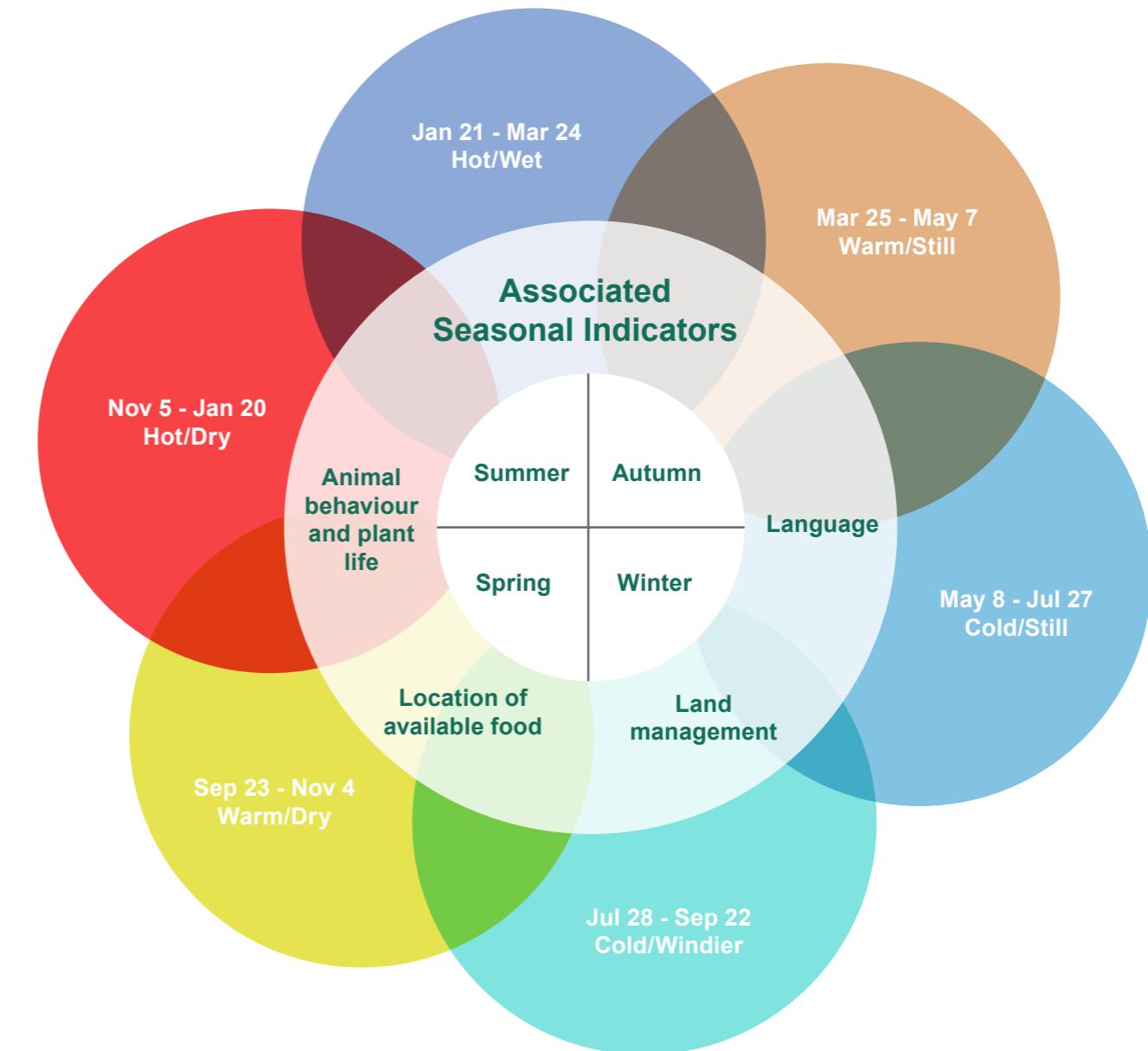


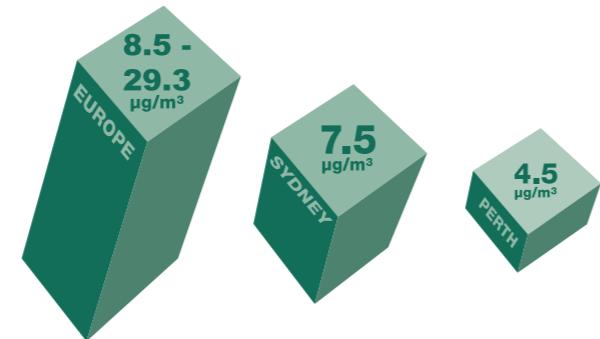
Figure 2. IKALC-seasons of western Sydney, based on weather and time of year.
Credit: Stephanie Beaupark



Does air pollution in Australia impact human health?

Jane Heyworth, Ivan Hanigan, Farhad Salimi, Luke Knibbs and Geoff Morgan

Most data on the adverse health effects of air pollution come from populations exposed to relatively high pollution levels in North American and European cities; we know less about the risk to health at the lower concentrations of pollution that we typically see in Australian cities. Among the outdoor air pollutants of concern are particulate matter less than 2.5 micrometres in diameter ($PM_{2.5}$) and nitrogen dioxide (NO_2), which mainly arise from combustion of fossil fuels through traffic, power generation and domestic wood heaters.



Our research indicates that there is no safe threshold for health effects from air pollution.



Researchers setting up air sampling equipment on Noongar Country as part of the HIMS-Air Quality study.

We worked with researchers from the NHMRC Centre for Air pollution, energy and health Research (CAR), to improve the estimates of individual exposure to pollutants through sophisticated statistical and chemical modelling techniques^{1,2}. Australia's National Environment Protection Measure for $PM_{2.5}$ is a maximum annual concentration of 8 micrograms per cubic metre ($\mu g/m^3$)³. We estimated that the annual average concentration of $PM_{2.5}$ for Sydney and Perth was around 7.5 and 4.5 $\mu g/m^3$ respectively. In comparison, averages in European cities ranged from 8.5 to 29.3 $\mu g/m^3$ ⁴.

We linked data on individual exposure to annual average air pollution in two large cohort studies: the 45 and Up Study in Sydney and the Health in Men Study (HIMS) in Perth. In each cohort, we observed increases in the risk of death:

- In the 45 and Up study, the risk of death increased by 5% per 1 $\mu g/m^3$ increase in $PM_{2.5}$ and by 3% per 5 $\mu g/m^3$ increase in NO_2 ⁵. These increases were not statistically significant.

- In HIMS, the risk of death increased by 6% per 5 $\mu g/m^3$ increase in $PM_{2.5}$ and 12% for an increase in black carbon exposure (as measured by $PM_{2.5}$ absorbance)⁶.
- In the 45 and Up study we did not see an increase in risk of being hospitalised for respiratory illnesses overall, but there may have been an increased risk for asthma hospitalisations associated with $PM_{2.5}$ ⁷.

Given these adverse health effects seen at the lower levels of pollution in two Australian cities, our research indicates that there is no safe threshold for health effects from air pollution. These studies provide valuable data for cities that have lower exposure, which has been a gap in our knowledge of air-pollution impacts on health.

Noise pollution

Jane Heyworth



We live in a noisy world. The constant buzz of traffic, construction and technology has become an unfortunate fact of city life. But chronic exposure to noise can be harmful. It has been linked to sleep disturbance, tinnitus, annoyance, cardiovascular disease and cognitive impairment¹.

We have been developing traffic-noise maps for Perth, Sydney and Melbourne in partnership with the Australian Catholic University and the Centre for Air pollution, energy and health Research. These estimate daily exposure to noise using a model called the Common NOise aSSessment methOdS (CNOSSOS-EU) developed by the European Commission².

This work also complements our broader research on air pollution. Noise and air pollution often go hand in hand and it can be difficult to disentangle the effects of each of these on health and wellbeing. Supporting strategies that reduce both pollutants will help us breathe and hear more easily.

Indoor air quality

Nigel Goodman, Anne Steinemann and Neda Nematollahi



When you think of air pollution, car exhaust pipes and factory smokestacks might come to mind. However, in Australia, more than 90% of our exposure to potentially harmful air pollutants occurs indoors^{1,2}. A common source of indoor air pollutants is fragranced consumer products, such as air fresheners, cleaning supplies, and personal care products³. Fragranced products emit a range of volatile organic compounds (VOCs), including some classified as hazardous⁴. In addition, fragrance chemicals can react with ozone to generate hazardous pollutants, such as formaldehyde.

What are volatile organic compounds (VOCs)?

'VOCs are a group of carbon-based chemicals that easily evaporate at room temperature. Many common household materials and products, such as paints and cleaning products, give off VOCs [...] Different VOCs have different health effects, and range from those that are highly toxic to those with no known health effect [...] VOCs particularly affect indoor air quality⁵'
- Australia State of the Environment (2016)



The health risks of fragranced consumer products

Our nationally representative surveys of the Australian population reveal that fragranced consumer products, such as laundry detergents and air fresheners, are associated with adverse health effects. When exposed to the scent of laundry products from dryer vents, 6% of Australians report health problems, such as migraine headaches, asthma attacks, dizziness and breathing difficulties⁶. When exposed to air fresheners, 16% of Australians report similar health problems⁶. Among asthmatics, the percentages are higher: 34% report health problems from scented laundry products, and 12% report health problems from air fresheners⁷.

Practical approaches to reduce health risks and improve indoor air quality

Our work also examined the concentration and prevalence of indoor VOCs, and the effectiveness of strategies to reduce indoor pollutants. This research found that discontinuing the use of air fresheners can reduce indoor concentrations of potentially hazardous fragrance chemicals by up to 96% within two weeks⁸. In addition, switching from fragranced to fragrance-free laundry products can reduce dryer vent emissions of fragrance chemicals by up to 99%⁹.



(Left) Air quality monitoring equipment used in the study.

(Right) Examples of air fresheners.

How houseplants can improve indoor air quality

Cristina Hernandez-Santin, Marco Amati

Over the past 35 years, researchers around the world have demonstrated that plants (and their associated organisms) can have a positive effect on our indoor air quality; however, this is a complex and variable process. Research shows that indoor plants can improve air quality by absorbing VOCs, but their efficacy depends on their characteristics, especially bacteria in their roots and soil known as gram-negative bacteria^{1,2,3}. The bacteria account for up to 80% of a house plant's ability to remove toxins from the air^{4,5}.

Indoor plants can also filter out particulate matter. In this case, it is the plant (and not its soil-dwelling bacteria) that takes centre stage. The ability of a plant to trap particles on its leaves is linked to the amount of wax leaves produce⁶ and the number of tiny hairs (*trichomes*) and/or the grooves on the leaf surface⁷. For example, various ferns or a wax plant (*Hoya carnosa*) will be more effective than a Monstera (*Monstera deliciosa*) with its smooth leaves.

So, how can you reap the benefits of plants at home? An important consideration is their placement. Ideally, plants should be kept near high-traffic areas such as doors and hallways to capture particles that are stirred up in the air through movement⁸. The total number of plants in a room also matters (Figure 3). A general rule of thumb is that adding one medium-sized plant to a medium-sized room increases air quality up to 25%.

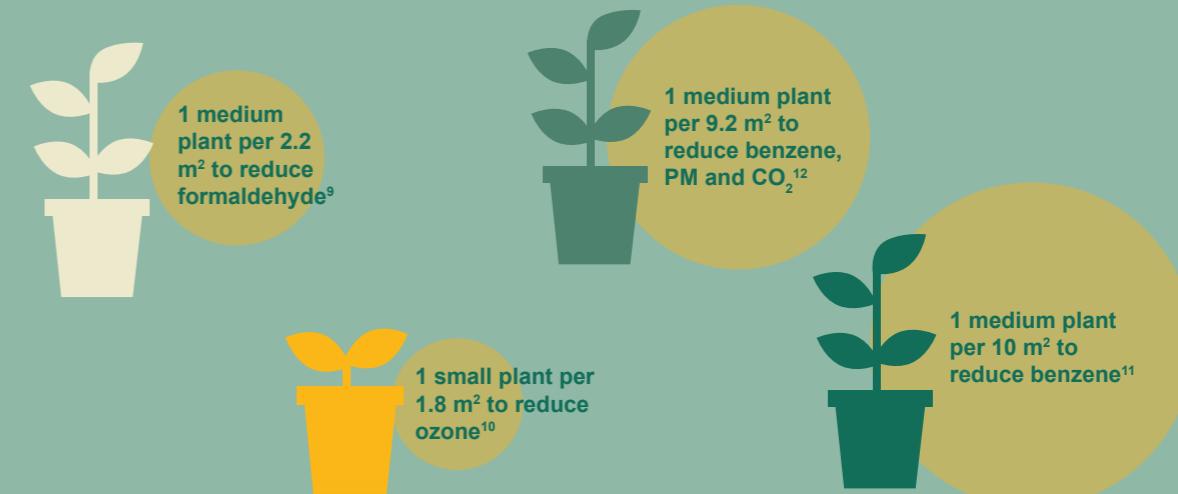


Figure 3. The range of a single plant to remove different household air toxins. For example, you would need 70 plants in a 167-m² house to remove formaldehyde. This figure is based on plants known as 'high-removalists' that support numerous gram-negative bacteria in the soil, and are thus more effective in removing various air toxins.



Indoor plants.
— Photo by Luther.M.E. Bottrill (Unsplash)



Research with impact: Air Quality

Air quality enters the public consciousness when it is visibly poor. But even when we are not in the middle of an extreme event, we shouldn't be complacent. So how can we use CAUL's research to improve the air we breathe? CAUL's air-quality research has led to improved NSW government air-quality modelling and forecasting, and has informed government strategies on climate change, transport and energy in Sydney. But there is always more that can be done to reduce air pollutants in urban areas. From incentives for buying electric vehicles to using fragrance-free products, here's what different stakeholders can do to make a difference.

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Government and policy-makers

CAUL research has provided a variety of case studies on outdoor and indoor air quality that can be used to inform policy change and deliver effective messages to the public. The following opportunities to improve air quality in Australian cities and towns can be considered. Many of these actions are further detailed in *A Clean Air Plan for Sydney*.

Smoke pollution

- Investigating mechanisms to reduce levels of potentially hazardous particulate matter (and other pollutants) in the air caused by domestic wood heaters in cities and some regional areas.
- Highlighting evidence of health effects, even at low levels of air pollution. This will be important for health and environment agencies when reviewing current air-quality standards.

Traffic pollution

- Exploring policies, infrastructure and services that reduce the number of vehicles on the road. These could include improved cycleways (away from traffic hotspots), better public transport, tax deductions for public transport, congestion taxes and safe-cycling maps.
- Identifying policy and regulatory opportunities that will accelerate the move to low-emission vehicles. These could include legislated vehicle fuel-efficiency standards, industry support, financial incentives, dedicated electric vehicle parking and an improved network of charging stations.

Air-quality monitoring, modelling and public alerts

- Improving air-quality monitoring and modelling, and the communication of relevant air-quality information in real time. This will be especially valuable for vulnerable members of the population.
- Embedding Indigenous cultural knowledge as scientific evidence to support a more meaningful way to conduct air-quality analysis. This could be achieved by including a variety of knowledgeable Indigenous co-authors/contributors as part of scientific research and policy development at every step of the process.

- Highlighting evidence of health effects, even at low levels of air pollution. This will be important for health and environment agencies when reviewing current air-quality standards.

Urban planning and development

- Placing buildings such as pre-schools, child-care centres, schools, hospitals and aged-care homes away from traffic hotspots and valleys prone to weather conditions that trap pollution near the ground. This will help protect vulnerable members of the community from air pollution.
- Incentivising planning approaches that ensure high-rise buildings are set in ample green space, with a focus on plant species that can efficiently remove particulate matter from the atmosphere. This would improve air quality where many people live together in high densities.

Indoor air quality

- Implementing fragrance-free policies in public locations, such as workplaces, schools, and care facilities. This could help to reduce public exposure to potentially hazardous air pollutants.

Industry and practitioners

CAUL research can provide information on noise levels for building professionals and has highlighted opportunities for workplaces to help reduce air pollution.

- Use noise maps to inform quieter cities through city planning, noise prevention and management strategies and improved building design. These maps can assist planners to pinpoint where noise management is required or where development should be avoided altogether. This would reduce noise exposure, especially for vulnerable groups such as children.
- Encourage workers to use more sustainable modes of transport by providing workplace facilities that encourage cycling and public transport.

- Provide indoor air-quality improvements in workplaces by implementing fragrance-free policies¹. This could help to reduce workplace exposure to potentially hazardous air pollutants.

Community

There are several steps community members can take to minimise their exposure and contribution to both outdoor and indoor air pollutants.

Outdoors

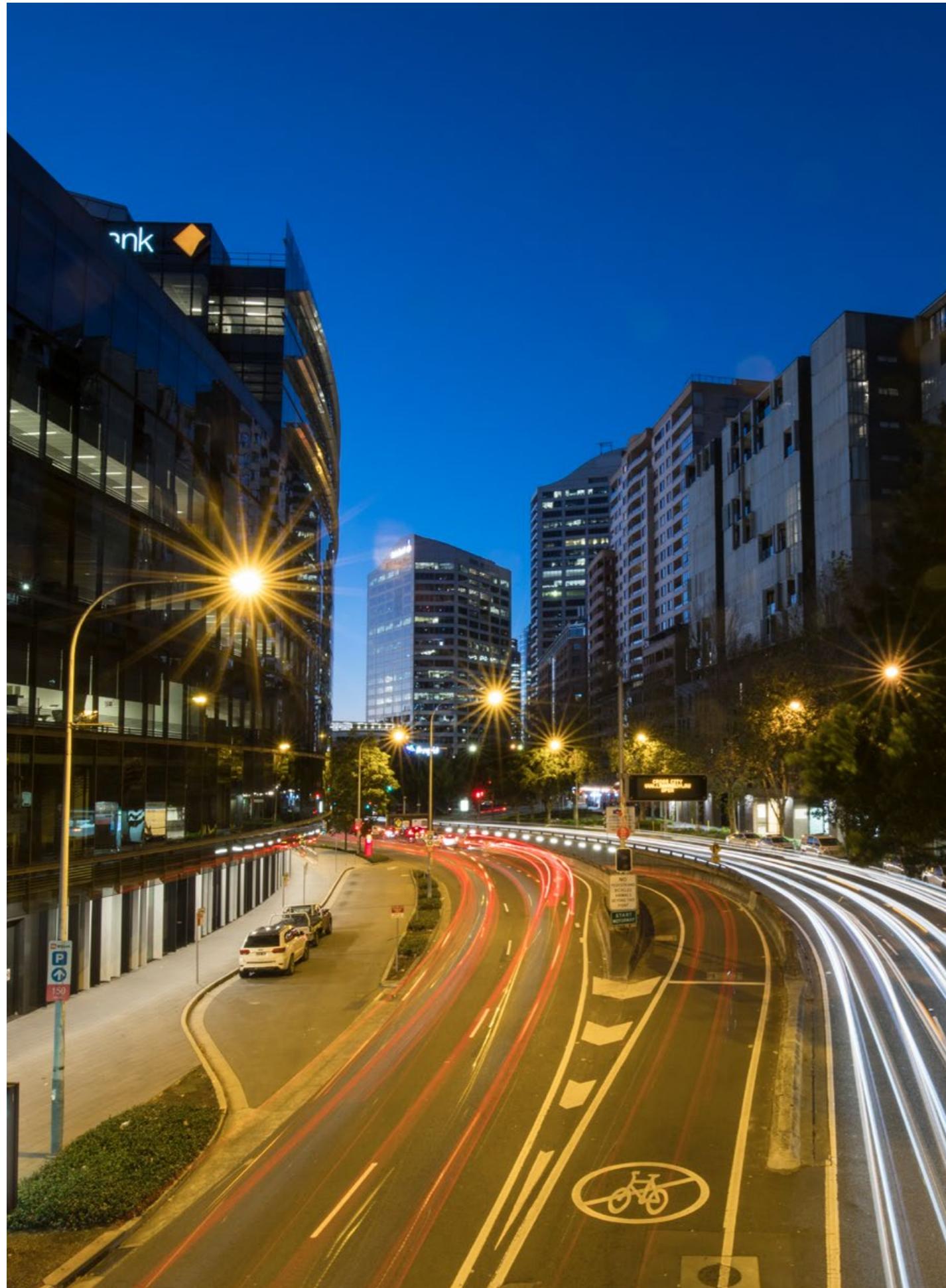
- Look for opportunities to leave the car at home and ride, walk or use public transport instead. If you can afford the higher up-front costs, consider switching to an electric vehicle.
- Exercise and commute along routes where there is less traffic. If you can't avoid main roads, plan your activity to avoid peak traffic times, especially the morning rush hour.

Indoors

- Consider alternatives to wood-fired heaters in your home. If you don't have this option, the [Environment Protection Authority Victoria](#) has information on how to reduce wood smoke and how to choose the best wood to burn.
- Choose fragrance-free instead of fragranced products.
- Use alternatives to air fresheners, such as removing sources of odours or opening a window.
- Purchase or propagate indoor plants. CAUL research was used to create the virtual-greening app 'Plant Life Balance'. The app helps people to select and visualise plants in their home based on their personal style. It also lets them know a plant's contribution to their indoor air quality and wellbeing.



Photo by Department of Agriculture, Water and the Environment



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Resources



Looking for more information? These resources cover: tips to reduce your exposure to unhealthy air, the future of electric vehicle use in Australia, the benefits of indoor plants, and more.



App:

- [Plant Life Balance](#)



Factsheets:

- [Air fresheners and air quality](#)
- [Fragranced laundry products and air quality](#)
- [Future distribution of electric vehicles](#)



Report:

- [Development of complementary tools for a complete framework for road traffic emission modelling](#)
- [Electric light passenger vehicle uptake in Melbourne: Projections and spatial distribution by 2030](#)



Academic papers:

- [A clean air plan for Sydney](#)
- [Atmosphere special issue: Air quality in New South Wales, Australia](#)
- [All-cause mortality and long-term exposure to low level air pollution in the 45 and up study cohort, Sydney, Australia, 2006–2015](#)
- [Ten questions concerning fragrance-free policies and indoor environments](#)



Urban Greening



Native plants offer a magnificent pallet of colours, forms and textures, provide ecological resources to local biodiversity (e.g. birds and insects) and require little water and fertiliser.
— Photo by Cristina E. Ramalho



Introduction

Cristina E. Ramalho

Urban greening has never been so important for liveability and sustainability. Australian cities have expanded rapidly since the 1960s, driving widespread land clearing and habitat loss, and pushing the green belts surrounding metropolitan regions further and further away from city residents. Australian cities have become denser too, with a corresponding loss of backyards, larger semi-rural lots and the trees that used to spread throughout private and public spaces^{1,2}. It is in the context of this extraordinary urban transition and associated environmental change, occurring at a national but also a global scale, that urban greening has become so vital. In many instances, local urban green spaces are the only nature people can access³.

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As well as being aesthetically pleasing, green spaces provide many functions and benefits for people and the other species that call our cities home. Indeed, they cool our cities, treat air and water, provide space for recreation and connection, and support habitat for biodiversity⁴. Trees and other vegetation can mitigate the combined effects of climate change and urban heat islands, and thus a healthy, abundant canopy layer is a critical ingredient in resilient and sustainable cities.

This chapter focuses on CAUL's research on urban greening with attention to four key areas: the benefits of urban greening, including a novel approach used to capture residents' sentiment about their local parks; the potential of informal and underutilised green spaces, such as drainage lines and residential verges, to provide multiple benefits; an overview of urban canopy in Australian cities; and the role of green-space governance and planning.

In many instances, local urban green spaces are the only nature people can access.

Large mature street trees provide various socio-ecological benefits, including shade, aesthetics and sense of place. Wherever possible, existing trees should be retained in urban development projects and even given centre stage in small green spaces and informal seating and/or resting areas (Fremantle, Australia).

— Photo by Cristina E. Ramalho



Well designed medium-density urban precincts can offer exceptional quality of life, while reducing the urban footprint that suburban development demands. Leading examples of urban design worldwide show how sustainability and liveability can be achieved through a combination of green building technology, water sensitive urban design, and greening solutions in private and public spaces (Western Harbour Development, Malmö, Sweden).

— Photo by Cristina E. Ramalho



The benefits of urban nature for wellbeing

Kate Lee and Kathryn Williams

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Urban nature is one component of sustainable, healthy and resilient cities. It is associated with benefits for the environment and for people's health and wellbeing¹. For example, urban nature may provide ecosystem benefits such as habitat provision, biodiversity and stormwater management in cities; physical, mental and social health benefits for people in the community; and economic outcomes through increased real estate value, reduced energy consumption, reduced health costs and productivity improvements². But different forms of urban nature are likely to be designed and experienced differently, and this may influence their potential benefits³. This section will focus on innovations in assessing the benefits of urban nature for wellbeing.

Measuring psychological and wellbeing benefits of urban nature

Urban nature plays an important role in the daily experience of people living and working in cities. To better understand these potential benefits, we combined data from 2.2 million tweets with maps of urban nature in the Melbourne CBD⁴. We analysed the sentiment expressed in tweets and noted people's proximity to urban nature. We assigned an overall sentiment score to each tweet by aggregating across the different emotions expressed. For example, text reflecting positive emotions such as joy and text reflecting negative emotions such as anger were aggregated to reflect the overall sentiment in a tweet. We found that people in parks expressed more positive sentiments and fewer negative sentiments in general than people tweeting from built-up areas⁴. This novel approach provides general insights into the emotional benefits of urban nature such as parks across a broad scale and complements other work that delves into people's nature experiences.

We found that people in parks expressed more positive sentiments and fewer negative sentiments in general than people tweeting from built-up areas.



Green spaces that include interesting aspects, like the demonstration green roof at the University of Melbourne's Burnley campus, may boost creativity.
— Photo by Judy Bush

Urban nature and creativity

The idea that there is a link between nature and creativity is not new, but there is relatively little research in this area. Emerging research suggests that time spent in nature may boost creativity but with little consideration for how this may happen. We extended existing theory about the health and wellbeing benefits of nature by integrating it with broader work explaining the mental processes underlying creativity and mind wandering⁵. We used this to suggest that spending time in urban nature

allows people's attention to drift between the softly fascinating features of the external environment and their internal unguided thoughts, or mind wandering. Taking breaks in nature may provide opportunities for incubation and mind wandering for creative ideas, as well as better concentration to generate and evaluate these ideas. Urban nature that is safe, easy to understand and interesting is likely to be most beneficial in this context⁵.



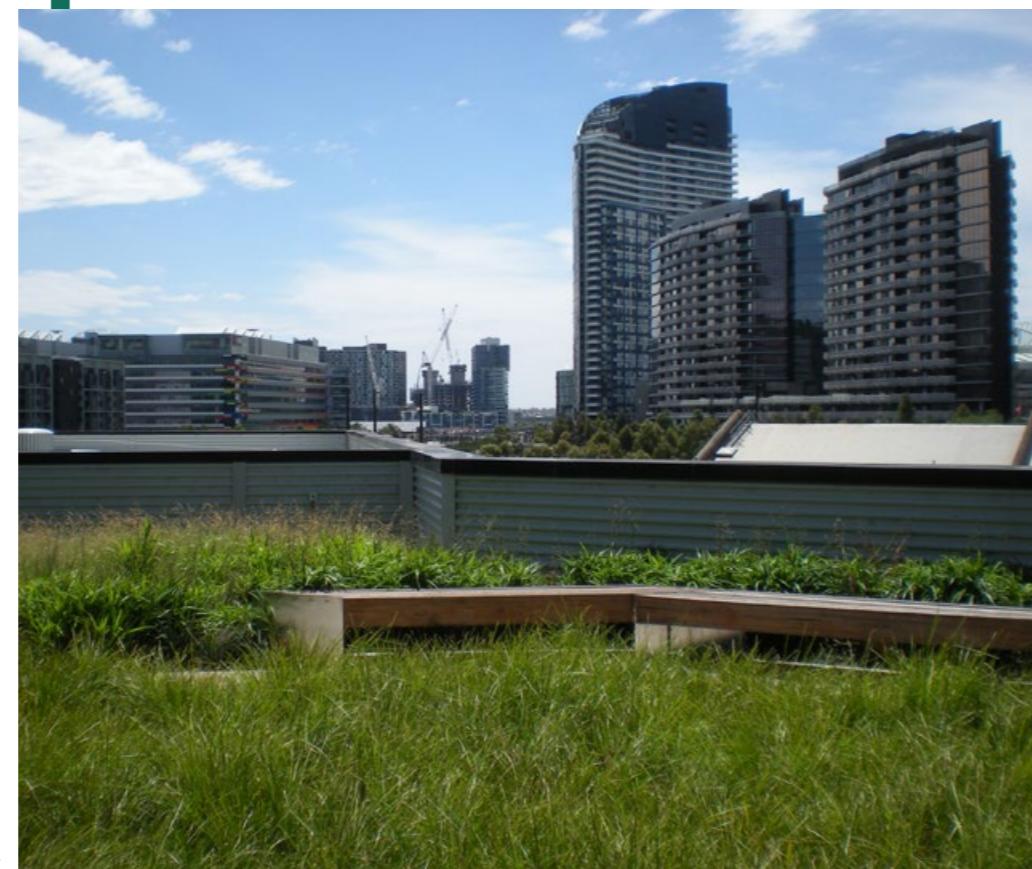
Balancing benefits to people and the environment

Incorporating nature into cities provides benefits for people and the environment. There are, however, challenges to achieving both outcomes. For example, there are differences in how accurately people perceive the ecological quality of nature, as well as differences in aesthetic, emotional and behavioural responses to this. Such differences may be due to psychological factors such as people's individual attitudes and expertise related to the environment, and contextual factors such as ecological complexity, the information provided, and design and management practices⁶. Together this suggests that it is important to manage urban nature in a broad range of ways to better capture differences in people's responses to landscapes, for example by engaging with the community⁶ and using participatory planning processes³.

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New forms of 'nature' may also provide benefits

Research has often focused on traditional forms of urban nature such as parks, but new forms such as engineered green roofs may also provide benefits. To better understand this, we reviewed the existing evidence for the psychological and wellbeing benefits of green roofs, and developed a framework and guidelines that articulate the potential benefits and constraints of these new forms of urban nature, particularly on roofs³. This framework (Figure 4) considers a range of factors such as whether people feel like they can access and use these spaces; how the view, elements and plants create an engaging and comfortable visitor experience; and the suitability and function of the space. All of these may differ from traditional forms of urban nature. This framework might serve as a preliminary guide to support the design of green roofs specifically for psychological benefits.



Green Roof, Kangan Institute, Docklands, Victoria.
— Photo by Nick Williams

Designing green roofs for psychological benefits



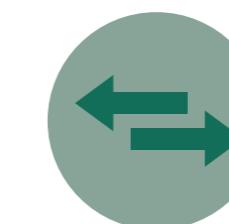
Provide for supporting activities

- Design for activities such as socialisation, physical exercise, gardening and mindful engagement
- Promote organisational norms and practices that enable green roof access



A restorative physical environment includes:

- Living plants
- Taller, flowering and grassy plants (where horticulturally feasible)
- Comfortable temperature and wind strength
- Low noise levels (e.g. from air-conditioning units)
- More complex planting designs (where perceptible)
- Height, variation and facade ornamentation of surrounding buildings
- View points from the roof and scope for psychological distance.



Enable individual adaptation to changing environments

- Designs for high coherence, opportunities for freedom and self-expression, pleasure, and belongingness
- Participatory planning processes to incorporate user needs
- Flexible designs for user adaptation
- Strategies to avoid inequitable impacts of gentrification or property prices



A social climate that enables access and works with social norms for nature in cities

- Provide perceived and actual access to green roof
- Maximise visibility of green roof to nearby occupants
- Fit design with socio-cultural norms for nature in cities
- Provide experiences that support understanding and appreciation of urban nature

Figure 4. Designing green roofs for psychological benefits³.



Transforming urban green spaces into habitat for people and nature

Cecily Maller, Natasha Pauli, David Kelly and Luis Mata

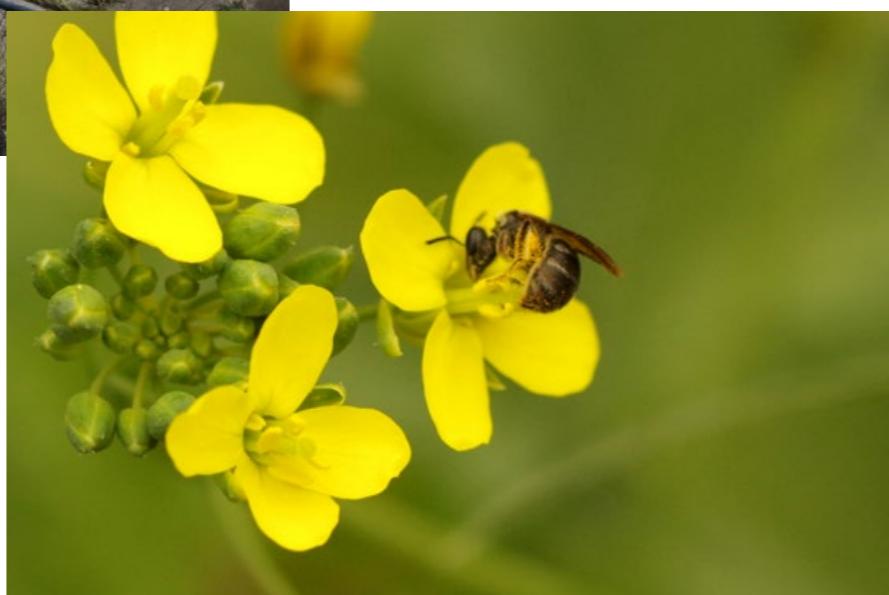
The Indigenous concept of Country refers to places that give and receive life, whether they are in rural or urban areas. As Australian cities grow and densify, the green spaces of urban Country are becoming increasingly important for biodiversity and enhancing human health and wellbeing. Through green spaces and other natural features, cities provide crucial habitat for plants, animals and other living beings, and provide important opportunities for people to experience everyday nature¹.

Although the benefits of urban green spaces are thought to be well-understood, in policy and planning the benefits for biodiversity and people are usually considered separately, and different types of green spaces are often designed or improved to prioritise certain benefits over others². As pressures on natural areas grow, there are opportunities to explore how urban green spaces can be improved to simultaneously benefit both biodiversity and people. This includes improving informal and underutilised green spaces common to cities, such as drainage corridors and street verges.

As pressures on natural areas grow, there are opportunities to explore how urban green spaces can be improved to simultaneously benefit both biodiversity and people.



Upper Stony Creek on Wurundjeri Country.
— Photo by Leila Farahani



The most common pollinators were native bees, followed by non-native European honeybees.
— Photo by Luis Mata

7 native
3 non-native
insect pollinators found



Pollinators interacted mostly with **non-native herbaceous weeds**



Most people were excited about and looking forward to the transformation:

'We're very grateful, and [it] feels like Christmas has come [laughs].'



Stats from [Upper Stony Creek Transformation Project Factsheet 2018](#)

Transforming an urban drainage corridor in Melbourne

The Upper Stony Creek Transformation Project in Sunshine North aimed to transform a section of Upper Stony Creek, an urban drainage channel running through Melbourne's western growth corridor, into a biodiverse urban wetland and green space for residents³. Led by a partnership of government and non-government agencies, the project sought to improve residents' health and wellbeing by providing green space that would increase biodiversity over time. We designed a socio-ecological study to monitor the changes from before to after the greening transformation².

Before the transformation, the site was a concrete drainage channel and an informal green space. Compared with another local waterway, Jones Creek, Upper Stony Creek supported a similar number of native insect, bird and bat species, with birds and insects interacting mostly with non-native plants. Frogs were detected in the concrete channel at Upper Stony Creek, and there were more amphibian species present than at Jones Creek. Residents were unexpectedly observant of local biodiversity and perceived native species favourably, reporting that they had seen an increase in native birds as native gardens became popular⁴.

The area is classified as having a low socio-economic status and there are few green spaces in the neighbourhood available to residents. Despite having poor access to green space, only 2% of research participants reported using the informal green space at the site². Residents held concerns about safety, maintenance and the lack of paths, and reported the site was unloved³. They were excited about the transformation and believed it would improve their health and wellbeing as well as improve local biodiversity. The post-greening transformation research has not yet taken place due to unexpected project delays.



Transforming street verges in Perth

There is a growing trend for Australian suburbanites to plant a colourful palette of low-growing native plants along the nature strip (or street verge) in front of their home. Faced with declining rainfall, increased awareness of water conservation and a desire to promote native plants within a global biodiversity hotspot, many residents and local government authorities in Perth are getting involved in 'verge gardening'. Our researchers set out to uncover the benefits and challenges of these transformations for local residents, key stakeholders and wildlife.

Local residents interviewed for the research explained that their key motivations were around saving water and time on maintenance, and improving the visual appeal of their nature strip². They were inspired to keep going by observing wildlife attracted to their gardening efforts. Our researchers found that native bees visited the majority of verge gardens⁵. Many residents enjoyed increased social interactions, as their verge garden provided a friendly place for conversation and neighbourly interaction.

A key finding from the research was that limited knowledge of biodiversity was not a barrier for residents who were keen to try gardening with native plants. Access to tailored advice on local plants, weeds, wildlife, soils, water and nutrient regimes is valued by residents and can help 'apprentice' native gardeners succeed⁶.

Many residents enjoyed increased social interactions, as their verge garden provided a friendly place for conversation and neighbourly interaction.



This verge garden in inner-city Perth uses a mix of native and non-native plants, adding biodiversity and colour to the streetscape.
— Photo by Natasha Pauli



The wildlife attracted by the verge gardens inspired people to continue their gardening efforts.
— Photo by Natasha Pauli



Urban greening and heat

Joe Hurley, Bryan Boruff, Marco Amati and Dave Kendal

The relationship between urban green space and cooler urban temperatures has been well established, yet trees are disappearing across Australia's cities. So how do we ensure thriving and extensive urban vegetation as our cities develop, consolidate and grow? Benchmarking and monitoring changes in the urban forest across multiple land-uses can help us understand the drivers of change and options for mitigation. CAUL researchers have contributed to this work through a number of state-of-the-art mapping exercises. Here, we explore the results of these assessments, as well as the impact of vegetation loss on heat and the resilience of our urban forests.

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Urban tree canopy is disappearing

Suburbs dominate urban land-use and support the majority of tree canopy in Australia's major metropolitan cities. To measure the extent of vegetation loss within our suburbs we examined changes in urban vegetation using several cutting-edge approaches. Our research showed that 55 of 139 urban local government areas (LGAs) across Australia experienced significant reductions in tree-canopy cover between 2008 and 2016. In total, this amounted to a national loss in canopy equivalent to 1,586 km², or an area larger than the City of Brisbane. This loss can be attributed to a number of factors. For example, LGAs on the urban fringe often form part of national parks and conservation areas. Recent effects of drought and bushfire along the urban-rural interface have taken a toll on these environments, contributing to a significant reduction in canopy over the

study regions. At the same time, a significant proportion of urban LGAs are privately owned land, with local authorities having limited control beyond regulations to prevent the most obvious tree removals and educational campaigns to encourage tree planting.

To better understand the distribution of urban vegetation across land-uses we analysed vegetation structure of the greater metropolitan areas of Perth, Melbourne and Sydney. We found that residential land accounts for almost half the urban tree canopy in these cities (Figure 5)¹. However, much of the current policy and management attention is focused on parks and streetscapes². While these land-uses are critical for supporting an extensive urban forest, it is equally important for governments to influence the retention and expansion of vegetation on private land^{2,3}.

We found that residential land accounts for almost half the urban tree canopy in these cities.

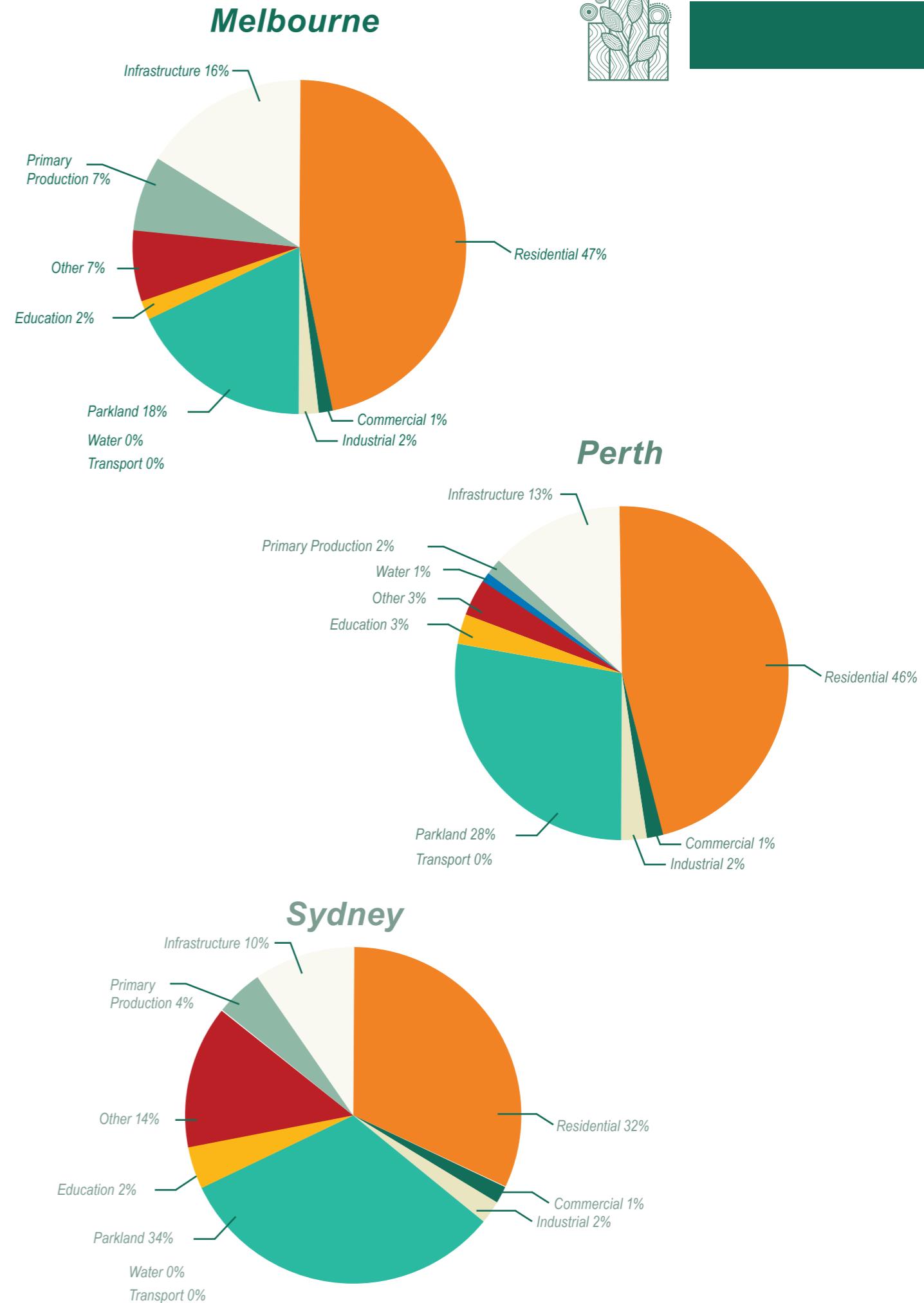


Figure 5. City comparison, land-use contribution to tree canopy cover.



As cities grow and sprawl, pressure for urban consolidation increases. In Australia, consolidation often equates to densification, replacing our traditional ‘house and garden’ suburbs with mixed-dwelling developments and hard surfaces. Further to this, changing landholder preferences have contributed to significant urban tree loss. Land-owners remove trees for a variety of reasons, including landscaping, unlocking views, safety fears and maintenance. In combination, these pressures erode the contribution of private land to urban tree-canopy cover.

Loss of vegetation is often mitigated by gains in the public realm, including parks, streetscapes and publicly managed lands. However, balancing the conflict between development and community aspirations is an ongoing challenge, placing incredible pressure on the public realm to offset tree canopy loss on private lands. For example, between 2014 and 2018, metropolitan Melbourne lost 737 hectares of canopy on residential lands alone⁴ (Figure 6). Parklands also saw a loss over this period of 158 hectares. Notable gains of over 220 hectares of canopy cover were identified along the street network, but these were not sufficient to offset losses across the city. To protect and enhance our urban vegetation, particularly trees, a multi-pronged approach is required. Different land-use types bring different land-owners, managers, governance structures, policy and politics, all of which must be negotiated for the successful retention and expansion of canopy cover in our cities.

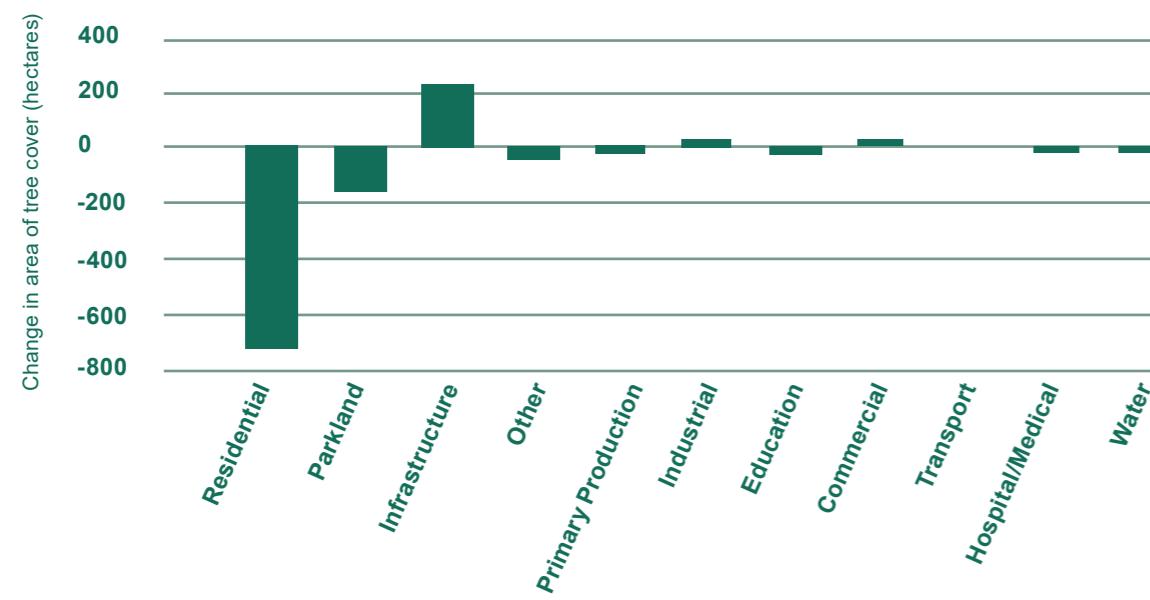


Figure 6. Changes in tree canopy cover by land-use between 2014 and 2018 for metropolitan Melbourne.



September 2013



August 2014



February 2017

An example of vegetation loss during a home rebuild in suburban Perth.

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More trees equal less heat

Understanding how the configuration of urban vegetation influences surface temperatures can help urban planners to effectively increase green spaces and vegetation to reduce the urban heat-island effect (increased temperatures resulting from the absorption and re-emission of heat by urban building materials). Using advanced statistical modelling, detailed mapping of urban vegetation and satellite-derived land surface temperature information, we examined the cooling returns of different configurations of urban vegetation⁵ (Figure 7).

For example, in Perth, on an average summer day, areas with a high percentage of tree-canopy cover (>29.75%) and shrub cover (>7.75%) exhibit surface temperatures of approximately 36°C. In contrast, areas with less than 13% tree-canopy cover, no shrub cover, and between 3% and 6% grass cover experience land surface temperatures above 43°C. Simply put, a mix of trees and shrubs has a much greater cooling effect than grass, and by increasing tree-canopy cover across an area by 1 km², land-surface temperatures can be reduced by 5 °C. As such, these models illustrate the potential to develop locally detailed tools to guide planning of vegetation configuration to optimise cooling at local- and city-scales.

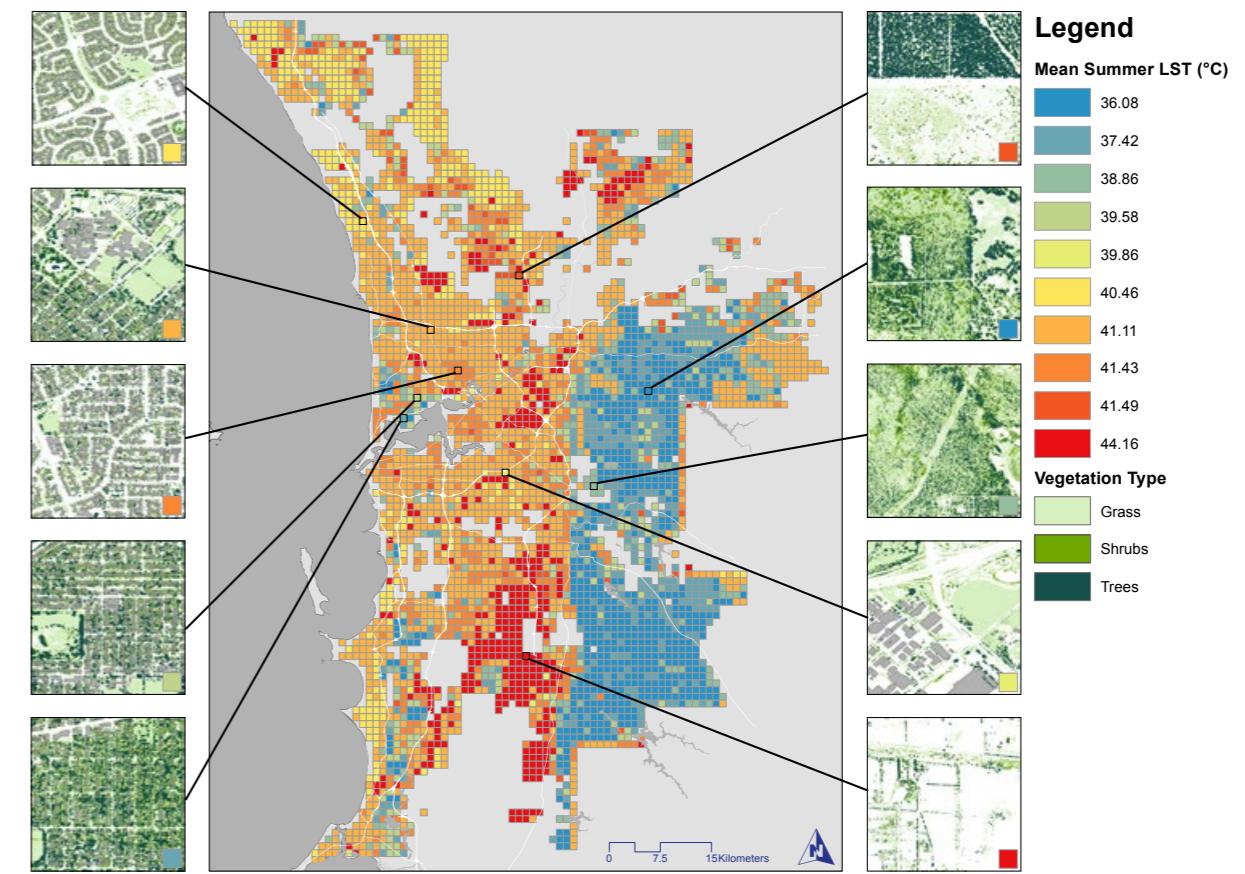
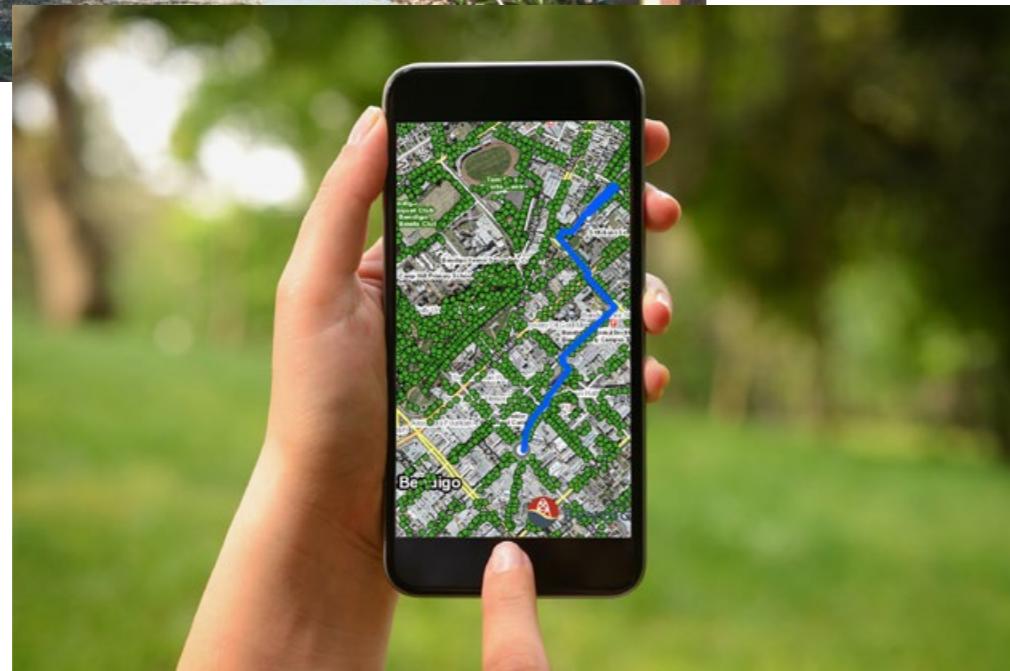


Figure 7. Examples of locations across Perth depicting various vegetation structures and associated land-surface temperatures.



Shadier routes can incentivise physical activity on a warm day.
— Photo by Andrew Butt



Shadeways maps the coolest routes from A to B.
— Image provided by RMIT Centre for Urban Research

Active movement through the city

Urban heat can vary greatly by location: the difference between standing under a tree or in the sun can be as much as 10 °C. Current navigation apps such as Google Maps provide instructions that account for distance, but what about shade? Our Shadeways app was designed for the City of Bendigo, Victoria, to show the coolest routes for walking or cycling. It integrates freely available satellite heat imagery and Google street view images. The outcome has been a better informed and more active public, with the platform used thousands of times since its launch in December 2019⁶.



Click to learn more about the Shadeways app.

Resilient urban forests

We know that trees play an important role in combating the impacts of climate change. However, our urban forests will themselves be vulnerable to rising temperatures. As part of its Urban Forest Strategy, the City of Melbourne commissioned research on the vulnerability to climate change of tree species currently planted in the city⁷. Of 375 tree species, 19% are already vulnerable, including commonly planted trees such as the Dutch elm.

By 2040, under a scenario where average temperatures increase by 0.8 °C, one in three species will be in danger. Two broad groups of tree species were found to be particularly vulnerable: species from colder climates such

as those from northern Europe or the north-eastern United States, and native species with a narrow range of climate tolerances.

This research was later extended to cover 29 councils across Australia⁸. The study found that 24% of all public trees in Australia's cities, or more than one third of tree species, will be at risk from increased temperatures by 2070, in a 'business-as-usual' emissions scenario. So which species should we be planting today to protect our urban forest against future climates? The City of Melbourne study also considered 1,729 new species for Melbourne and identified many that will be well suited to the city's rising temperatures. These include Australian native species such as brush box and the coast banksia.



Climate-ready gum trees in Fitzroy Gardens, Melbourne.
— Photo by Dave Kendal

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Managing green spaces

Judy Bush, Cristina E. Ramalho and Joe Hurley

Urban green (and blue) spaces, such as nature reserves, parks, waterways, private gardens and street trees, are essential elements of resilient and liveable cities. Yet, while an individual tree, park or waterway provides important local benefits, it is the integrated network of green and blue spaces across both public and private land that provides many of the benefits we value¹. Effective planning and management of green spaces requires an understanding of this integrated whole, and not just a piecemeal 'public asset' management approach.

Because green spaces are diverse and multifunctional, effective planning and management requires communication and coordination across numerous policy domains involving multiple government departments and tiers, private sector and community organisations, and the broader community. This requires innovative governance arrangements that address green-space retention, biodiversity protection, and community involvement, engagement and participation.

Green-space governance

Governance is an important element of resilient and healthy urban green spaces. In addition to urban land-use planning, which provides overarching strategic directions for urban development and land use, other relevant policy domains include environmental sustainability, climate change, integrated water management, transport infrastructure, parks and public open space, ecology and conservation (natural resource management)². The policy domains of health and emergency management are also important, addressing both short-term, acute perspectives such as disaster mitigation and long-term issues such as public-health improvements associated with physical activity, mental wellbeing and social cohesion.

Effective management of green spaces is supported by clear, agreed governance processes, a clear division of responsibilities, timely communication and reporting mechanisms. Effective governance structures and processes connect stakeholders (including government, non-government and community), resources and expertise across different jurisdictions, and promote their participation³. Aboriginal and Torres Strait Islander peoples, the Traditional Owners, play a central role as custodians of Country^{4,5}.



Merri Creek, Victoria.
— Photo by Judy Bush

While an individual tree, park or waterway provides important local benefits, it is the integrated network of green and blue spaces across both public and private land that provides many of the benefits we value.



Dr Judy Bush in the field.

Local government and green-space management

Local governments are increasingly focused on greening the public realm through the planting of street trees and the ongoing creation and management of parks, gardens, town squares and other public spaces. In addition, they are developing urban-forest, biodiversity and urban-nature strategies⁶ and engaging local communities through education and initiatives that support community groups to participate in green-space management⁷.

There are opportunities and imperatives for linking policies and actions in the public realm to strategic and statutory land-use planning, as well as integrating minimum requirements for greening new developments into planning-scheme regulations⁶. Further, both regulations and incentives are required to strengthen the protection and retention of trees in the private realm, as research has shown that while tree cover is increasing on public land, tree cover is decreasing across cities due to tree removal from private land⁸.



A community garden is one way people can get involved in urban greening in their local area.
— Photo by Cristina E. Ramalho



The value of monitoring and evaluation

As cities develop and adapt to ongoing environmental and societal change, an adaptive governance approach can underpin a flexible and responsive framework for green-space management⁹. Adaptive governance is supported by effective monitoring, involving ongoing collection of data that can reveal changing site conditions and shifts in ecosystem function, form, composition and use. Identifying and documenting ecosystem changes allows adjustments to be made to management actions, resourcing and governance. Monitoring also underpins ongoing accountability and reporting to stakeholders, governance partners and community.

Methods for measuring and monitoring the distribution and condition of green spaces often focus on measures of land cover, for example tree canopy, or land use, for example access to parks¹⁰. To better understand the quality of green space, including ecosystem condition and benefits provided, we need to monitor a broader range of indicators, such as presence and/or abundance of native birds

Collecting and analysing qualitative data as well as quantitative data can provide additional insights: not only what has changed or been achieved, but also why and how.

and insects, and understorey vegetation cover. Collecting and analysing qualitative data as well as quantitative data can provide additional insights: not only what has changed or been achieved, but also why and how.

Establishing pre-existing or baseline data and identifying and assessing changes in landscapes, both regenerative and degenerative, can provide a powerful evidence-base to support ongoing management decision-making and funding allocations. Data can be in the form of aerial photographs, photographs taken from fixed reference points, surveys of park users, as well as records of flora and fauna species, abundance and so on¹¹.

Selection of indicators and the scale, timing and frequency of monitoring matters. For example, annual monitoring will overlook seasonal differences; city-scale monitoring may overlook intra-city differences. Complex systems (such as urban green space and urban ecosystems) need several indicators for effective monitoring; complex systems cannot be assessed using a single indicator¹¹.



Research with impact: Urban Greening



Green streetscape in inner Melbourne.

— Photo by Judy Bush

Through a partnership with the Victorian, Western Australian and New South Wales governments to map and analyse the fine-scale distribution of urban vegetation in Melbourne, Perth and Sydney, and identifying suitable tree species for future-climate scenarios in cities around Australia, CAUL's work has supported local, state and

national government. But we all have an opportunity to contribute to urban greening. From transforming neglected streetscapes to evaluating the success of urban-greening initiatives, there are a number of ways different stakeholders can help to create greener cities.

Government and policy-makers

Parks, gardens, streetscapes, green roofs and other green spaces are high on the agenda of all levels of government. There are a range of opportunities that government and those working in policy can consider to improve urban greening initiatives and evaluate their impact.

- Learning from and implementing Aboriginal knowledge and practice. This could be achieved by co-designing programs with local Traditional Owner groups to enhance connection to place and promote shared custodianship of the local environment, while delivering mutual benefits. Supporting Indigenous advisory or reference groups within local governments would contribute to embedding traditional knowledge in policy and planning processes.
- Supporting First Nations-owned businesses for providing services such as design, materials, and maintenance, and employing Aboriginal and Torres Strait Islander people as urban rangers.
- Supporting a social-ecological approach to monitoring and evaluation by collecting and analysing multiple forms of social and biodiversity data, and collaborating with the community and multidisciplinary researchers to plan monitoring programs. This approach can help agencies measure the success of greening efforts for both ecological and social outcomes.
- Evaluating the impact of various types of vegetation on surface temperatures and thermal comfort, and arranging vegetation appropriately throughout the urban environment. This can help mitigate the urban heat-island effect, increase thermal comfort, and in turn reduce both health impacts and energy costs of urban heatwaves.
- Selecting a diverse range of trees that are suitable for future climate realities, targeting appropriate sites, and prioritising management and maintenance. These actions will future-proof the urban forest and also help cities adapt to increasing temperatures.



Industry and practitioners

CAUL research can provide guidance for professionals involved in urban greening actions, including landscape architects and urban designers. Key opportunities are listed below.

- Adopt a social-ecological approach to urban greening transformation projects. This approach values both biodiversity and social outcomes.
- Design urban development to ensure there is space for trees and greenery. This will help to ensure thriving vegetation as cities grow.
- Support the growing interest in native gardening by understanding the policies, rebates and incentives provided by local government agencies. Developing tailored packages that suit residents' interests (e.g. low maintenance, waterwise, biodiversity attracting, endemic species, bush foods) and life stage (e.g. building a home, moving into an established home, retirement) are also important.
- Consider designs that can benefit people's wellbeing. For example, urban green spaces that are safe and include interesting elements may boost creativity.

Community

There are a range of ways people can benefit from urban green spaces and contribute to the greening of their city.

- Reap the benefits of nature by spending more time in urban nature. Think beyond the park: there are lots of different forms of nature in our cities. Why not take a look at maps of green roofs in the city? Or check out where your local waterways are. You might find new and exciting places to explore.
- Contribute to urban greening. By planting shrubs or trees in your yard, or creating a flourishing balcony garden, you can help to reduce the loss of vegetation on residential land and contribute to a thriving urban forest.
- Support wildlife and connect local green spaces by planting native plants in your garden and on street verges. Choose a range of different plants so that something will always be flowering (including over summer) to provide food and habitat for native bees, birds, and other animals.
- Find out who your local Traditional Owners are as a fundamental step in understanding your place. Connect with local Indigenous knowledge by discovering the indigenous plants that belong to your area and how Indigenous people use them.
- Seek out opportunities to help with the planning and management of green areas in your neighbourhood. Can you contribute to community engagement and planning for new parks, or new approaches to biodiversity planting? Can you support urban green-blue spaces through citizen-science initiatives such as local friends groups, planting days and Waterwatch?
- Explore a cooler way to travel. By using the Shadeways platform, Bendigo residents can discover how a shady route can make all the difference on a hot day.



An example of a family-oriented home garden featuring native plants in suburban Perth.
— Photo by Natasha Pauli



The University of Melbourne's System Garden.
— Photo by Judy Bush



Resources

Looking for more information? These useful resources cover: the wide benefits of urban greening, guidelines for local governments to monitor and evaluate urban green spaces, governance perspectives of nature-based solutions and more.

App:

- [Shadeways](#)



Factsheets:

- [The benefits of urban greening](#)
- [Urban greening monitoring & evaluation](#)
- [Green-blue space governance factsheet series](#)



Reports:

- [Benchmarking urban vegetation cover: Melbourne, Perth, Sydney](#)
- [Urban vegetation cover change in Melbourne](#)
- [The City of Melbourne's future urban forest: Identifying vulnerability to future temperatures](#)
- [Benefits of urban green space in the Australian context](#)
- [Perspectives on understanding and measuring the social, cultural and biodiversity benefits of urban greening](#)



Academic papers:

- [Bringing nature back into cities](#)
- [Leaf my neighbourhood alone! Predicting the influence of densification on residential tree canopy cover in Perth](#)
- [Appraising the psychological benefits of green roofs for city residents and workers](#)
- [Investigating the benefits of 'leftover' places: Residents' use and perceptions of an informal green space in Melbourne](#)
- [The role of local government greening policies in the transition towards nature-based cities](#)
- [Turning down the heat: An enhanced understanding of the relationship between urban vegetation and surface temperature at the city scale](#)
- [Land-Use planning's role in urban forest strategies: Recent local government approaches in Australia](#)





Urban Biodiversity

Ant on white correa (*Correa alba*).
— Photo by Luis Mata





Introduction

Kirsten Parris and Sarah Bekessy

Continued global expansion of urban environments is expected to see 5.2 billion people living in cities by 2030¹, bringing dramatic changes for humans and biodiversity alike². Urbanisation threatens the persistence of many species and ecological communities in Australia and internationally: more than 3,200 plant and 3,900 animal species assessed by the International Union for the Conservation of Nature are considered threatened by residential and commercial development worldwide³. However, urban environments also offer unique prospects for biological conservation^{4,5}, which can in turn provide a range of important benefits for human health and wellbeing^{6,7}. Interaction with nature has been shown to reduce stress levels, blood pressure, cardiovascular disease, anxiety, depression, frustration and anger in humans, while improving mood, self-esteem, cognitive function, academic performance and productivity^{6,8,9}. These benefits diminish as biodiversity is lost from cities and towns and as people in cities become increasingly disconnected from nature⁸.

Sustainable cities are cities that work for people and nature together. Recent enthusiasm for ‘nature-based solutions’ to address liveability challenges¹⁰ has seen

urban greening become a common inclusion in urban planning. While this is an important advance, biodiversity is rarely considered in these initiatives¹¹ and even best-practice international examples of nature-based solutions often come without significant biodiversity gains. It is through the green spaces and other green infrastructure of a city that its human inhabitants can interact with nature and receive the many health and wellbeing benefits of biodiversity and ecosystem services. For these benefits to be realised, access to nature must be delivered within the urban fabric of cities, rather than marginalised in large reserves a long way from population centres^{12,13}.

In this chapter, we’ll present a variety of research from the CAUL Hub that demonstrates the importance of cities for biodiversity, including the importance of considering and highlighting Indigenous perspectives of biodiversity in urban environments. We’ll outline a range of practical strategies for supporting nature in urban landscapes where people live and work, and showcase some of the hub’s engagement activities that have allowed city-dwellers to engage more closely with the biodiversity in their neighbourhood.



Motorbike frog photographed in Fremantle, Western Australia.

— Photo by Kirsten Parris

Access to nature must be delivered within the urban fabric of cities, rather than marginalised in large reserves a long way from population centres.

Biodiversity in the city

Kylie Soanes and Kirsten Parris

Cities are built on biodiversity-rich landscapes and they continue to provide space and resources for thousands of species. An amazing diversity of native flora and fauna occurs in cities across Australia, from the well-recognised birds, bees and possums, to the lesser-known threatened orchids, colourful grevilleas and secretive bandicoots. There can be many challenges to sharing our cities with nature. Cities are built as habitat for people and present a range of threats to biodiversity including habitat loss, barriers to movement, pollution, anthropogenic noise and predation by domestic pets. Further, the presence and activities of other species in cities can sometimes lead to human–wildlife conflict. But cities and towns also present many opportunities to promote native plants and animals through novel habitats, creative conservation actions, and harnessing the ‘people power’ of volunteers, while creating opportunities for citizens to help nature in the city by engaging with urban-ecological research¹.



An amazing diversity of native flora and fauna occurs in cities across Australia, from the well-recognised birds, bees and possums, to the lesser-known threatened orchids, colourful grevilleas and secretive bandicoots.

Threatened species in cities

Australian cities host more than 360 different species of plants and animals that are recognised as threatened under federal legislation. Some of these are permanent urban residents like the Sunshine diuris orchid, southern brown bandicoot, and the green and golden bell frog, all of which make use of novel habitats and resources in cities. Others, like the swift parrot or regent honeyeater, may only be occasional visitors to our urban areas, stopping to feed or rest during seasonal migrations. The prevalence of threatened species in cities shows us the potential for conservation gains in urban environments if we shift our thinking away from the notion that biodiversity is something that can only thrive in large nature reserves a long way from people. Our research has shown that the role of urban environments in conservation, including threatened-species



conservation, is often overlooked and should be better incorporated into policy and recovery strategies².

‘Urban-restricted threatened species’ are a special case of threatened species in cities – those whose entire remaining distribution is encapsulated within a city or town (Figure 8). We identified 39 of these urban-restricted species in cities around Australia², including the Frankston spider-orchid (Melbourne), western swamp tortoise (Perth), Ginninderra peppercress (Canberra), spiked rice flower (Wollongong), Caley’s grevillea (Sydney) and Morrisby’s gum (Hobart). These threatened species are rarely found in conventional reserves, and instead use a wide range of other habitat types including roadsides, military land, schools, hospitals, cemeteries and airports. Local communities play an important role in their conservation, investing volunteer hours and raising funds to support the species and their habitats.

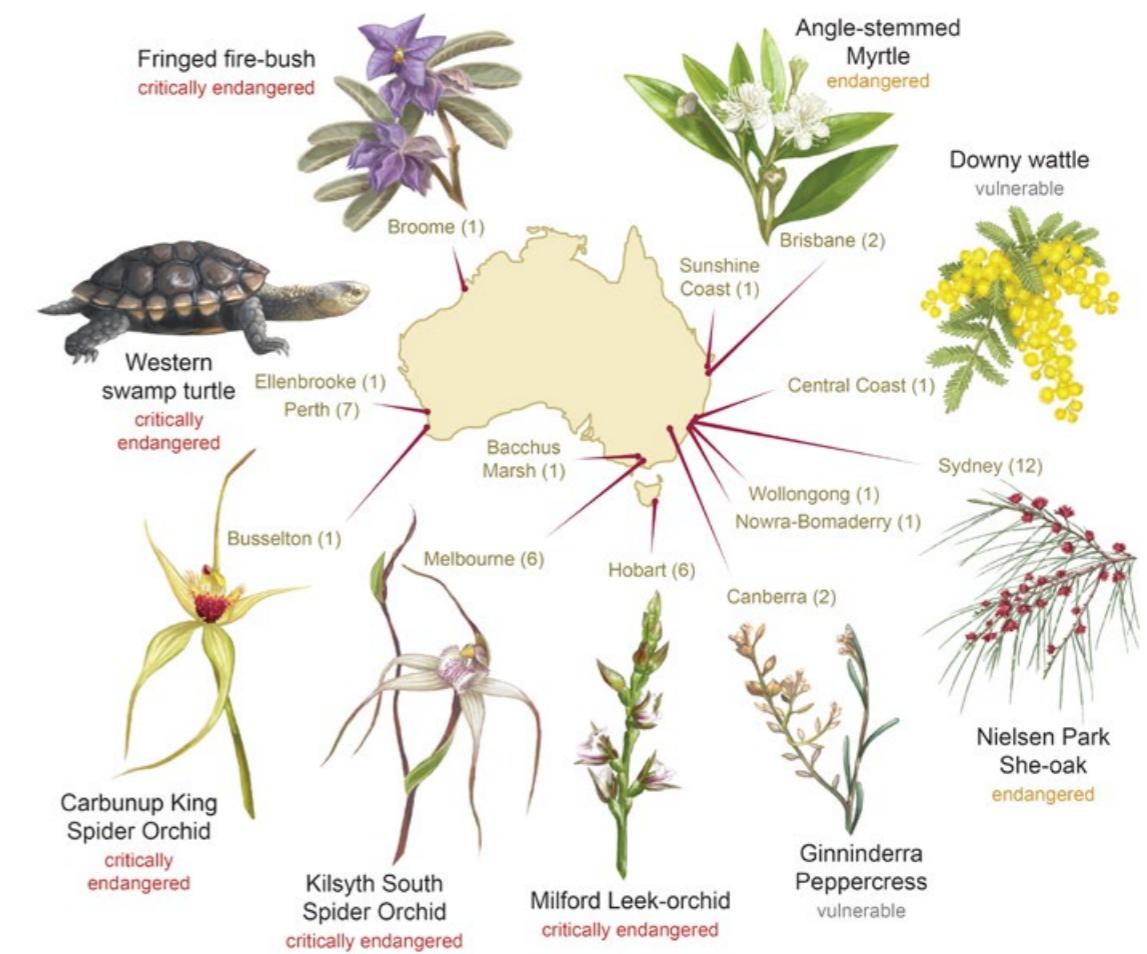


Figure 8. The location of urban-restricted threatened species across Australia. The number of species per location is indicated in parentheses. Select examples have been illustrated. — Artwork by Elia Pirtle.



Findings from the CAUL Urban Wildlife app

Cities offer an opportunity to engage a large urban population with nature and biodiversity research through citizen science. The CAUL Urban Wildlife App allows citizen scientists to contribute data to research questions about the distribution and behaviour of wildlife in cities. The app has four modules, each focusing on a different group of species: flying-foxes, frogs, beneficial insects, and possums and gliders. More than 300 users have contributed over 3,500 records to date. Citizen scientists have recorded two species of flying-fox, three species of bell frog, eight species of possum (including the critically endangered western ringtail possum) and more than 40 different types of insect pollinators including the blue-banded bee, yellow admiral and meadow argus.

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The app enables citizens to conduct surveys using the same field protocols used by ecologists, and to collect data that directly inform important research questions relating to urban biodiversity: a key feature that sets it apart from other wildlife apps. For example, these questions include: in which parts of the urban landscape do flying-foxes spend their time and what food plants do they favour? How do motorbike frogs make use of novel habitats in their urban environment, when closely related species are struggling in cities? Which beneficial insects (pollinators, predators and parasitoids) are persisting in Australian cities and how do they interact with plant biodiversity? The data collected through this app is helping researchers to address gaps in knowledge of the ecology, behaviour and distribution of native species in urban environments.



Images submitted through the CAUL Urban Wildlife app.

Sounds of nature in the city

Kirsten Parris

Sound is an important medium for human–nature connection in the city. The sounds of birds singing, frogs calling or cicadas chirping connect us with place, season and time of day even in highly altered urban landscapes. For example, different species of frogs call at different times of the year, marking the changing of the seasons. The four seasons of frogs in Melbourne were the creative inspiration for 'Frog Soundscape at The Living Pavilion', installed on the University of Melbourne's Parkville campus in May 2019. Arranged along the re-imagined Bouverie Creek, the soundscape provided a portal through which listeners could connect with the past – and possibly future – biodiversity of the creek and the Melbourne region more broadly. It highlighted the amazing variety of frog calls, embedded within other natural sounds.

In line with the imperatives of The Living Pavilion to illuminate Aboriginal ways of seeing, I presented the frog seasons with the corresponding Wurundjeri Seasons, which were showcased onsite through detailed signage. The frog seasons were aligned with the Wurundjeri seasons of Poorneet (Tadpole season) – frog spring; Buath Gurru (Grass-flowering season) and Garrawang (Kangaroo-apple season) – frog summer; and Waring (Wombat season) – frog autumn and winter³.





Indigenous perspectives of plants

Zena Cumpston

Aboriginal and Torres Strait Islander peoples across Australia have applied and honed scientific practices of observation and experimentation over countless millennia to harness the tremendous potential of plants. We have ingeniously utilised plants for medicines, to provide our nutritional needs, to express our culture and to develop innovative technologies.

As I am learning and researching more about First Peoples' plant knowledges, I am coming to understand better the landscape of knowledge production, especially related to limited and limiting perceptions of Aboriginal scientific practice and innovation. The lack of understanding of and failure to recognise the depth and breadth of our knowledges speaks to a wider deficit in truth-telling. Damaging perceptions that cast us as lesser and posit us as a homogenous people who were limping towards inevitable extinction before the arrival of a 'superior' race still abound. We, and our deep knowledges, are too often seen as being in the past, denying our dynamic place in the present. Our culture is often represented as fixed and stagnant, negating our efficacy and capacity to continuously adapt and innovate: foundational to our longevity as the oldest living culture on earth. Whilst it is true that we have suffered many losses and continue to suffer as a result of the ongoing circumstance of colonisation, we are powerful people. Our knowledges and the efficacy of our holistic approaches to systems of management are not lost. Our interactions with Country, both today and over time, are

highly valuable in all aspects of environmental management. These knowledges and practices are undoubtedly a key part of the arsenal of scientific knowledge we need to harness to meet the environmental challenges we together face.

I am committed to illuminating our deep knowledge and scientific practice, especially related to plant use. My desire to help people understand the depth and breadth of our plant knowledge, particularly young people, led me to develop a booklet that explores Aboriginal plant use¹. You can find a link to the booklet in the resources section at the end of this chapter. The booklet encourages the use and appreciation of indigenous plants as well as providing an accessible portal through which a wide audience may begin to understand the complexity of our scientific practice. It contains much information about resources for growing and exploring indigenous plants and has easily printable labels that people can put in their garden.

The booklet aims to help people understand not only Aboriginal perspectives of plants, but also the wide-ranging benefits of planting indigenous plants. They are useful as food, medicine and for making technologies, as well as being important as habitat for animals, reflecting the holistic circumstance of our ecological knowledge and practices.

Increasing the wider public's understanding of indigenous plants begins to cultivate a deeper connection. It is only through deep connection that we can foster a sense of custodianship and responsibility for Country, working together to care and to nurture.

The final section of the booklet lists resources that will enable people to continue on their learning journey. Taking the burden and responsibility of educating away from Aboriginal and Torres Strait Islander peoples is a strategy that I believe has the potential to bring transformative change. We must all take responsibility for educating ourselves about whose Country we are on and the deep knowledges held by Traditional Custodians.

Below I have listed three of my favourite indigenous plants. These examples provide some insight into the many ways these plants are important and their multi-purpose uses.

Increasing the wider public's understanding of indigenous plants begins to cultivate a deeper connection. It is only through deep connection that we can foster a sense of custodianship and responsibility for Country, working together to care and to nurture.



River mint (*Mentha australis*)

River mint is one of four species of mint that are native to Victoria. It is found right across south-eastern Australia, most often close to waterways and in forests. Diverse groups of Aboriginal peoples crush and inhale the plant as a remedy for coughs, colds and headaches. River mint also adds flavour to cooked foods, with its leaves used in earth ovens. A small herb with aromatic leaves, river mint is high in antioxidants, is antimicrobial, and is used by Indigenous peoples to benefit the stomach. It is delicious infused as a tea, added to cold drinks and dressings. Aboriginal peoples also rub it on the skin as an insect repellent.

Spiny-headed mat-rush (*Lomandra longifolia*)

Spiny-headed mat-rush is a large tussocky plant that is common throughout south-eastern Australia and is found across most of Victoria. The Wurundjeri people particularly favour this plant for weaving cultural items such as necklaces, headbands, girdles, baskets, mats and bags for carrying foods, as well as for making technologies such as eel traps and hunting nets. Its seeds, high in protein, can be collected and pounded into a bread mix, with the core of the plant and the base of the leaves eaten as a vegetable. Aboriginal peoples use the roots to treat bites and stings. *Lomandra* is a food plant for the caterpillars of several butterflies.

Nardoo (*Marsilea drummondii*)

Nardoo is a type of fern found in all states of Australia. Able to grow in dry ground at the edges of water, it is also aquatic and thrives in areas that are regularly flooded. Fruits are light-brown sporocarps, and usually appear when water recedes. Spores can be gathered and eaten as food by first roasting then grinding them between stones to remove black husks, leaving a powder that is mixed with water (causing expansion) to make a damper cooked in the ashes of a fire. The powder mixed with water can also be eaten uncooked as a gruel.



River Mint (*Mentha australis*).
— Photo by Alison Fong



Nardoo (*Marsilea drummondii*).
— Photo by Sarah Fisher



How can we create more biodiverse cities?

Caragh Threlfall, Kylie Soanes, Holly Kirk, Lucy Taylor and Julia Schiller

Cities can be places of high biodiversity value, but ongoing urban expansion and the needs of the growing human population mean urban biodiversity is in decline. Through careful planning and creative action, cities can present an opportunity to create spaces that are good for people and good for nature. However, current practice is limited by communication barriers between urban designers and planners, conservation practitioners and other stakeholders. There is currently a need to provide greater guidance on best-practice

biodiversity conservation and management that accounts for the unique challenges that cities present. We developed a series of cross-disciplinary projects and tools for planning and implementing positive actions for nature in cities. These include methods for using ecological theory to prioritise the spatial arrangement of new habitats, identifying successful urban conservation actions and incorporating biodiversity-focused design into urban planning.



Volunteers at an urban Banksia woodland restoration site.
— Photo by Cristina Ramalho



Dainty swallowtail butterfly.
— Photo by Holly Kirk

Linking nature in the city

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Wildlife in living cities needs freedom to move, in just the same way that human residents do. All animals explore their surroundings to find food, water, mates and safe places to rest or nest. Cities can be hard places for animals to thrive, as the resources they need for survival may be sparse and often separated by major roads and other barriers. Adding new habitat resources and preserving or enhancing existing patches of vegetation can help make our cities more hospitable for urban wildlife. However, councils often need to trade off the costs of providing biodiversity-focused resources with other infrastructure requirements. Ecological connectivity theory describes how easy or difficult it is for an animal to travel across a landscape. Measures of ecological connectivity can be used to identify places where adding new habitat will make the biggest contribution towards improving urban nature, maximising biodiversity benefits by linking nature in the city.

We worked with the City of Melbourne to build on existing metrics and develop a simple, step-by-step framework for measuring ecological

connectivity for seven species groups¹. The framework guides the user through the selection of appropriate habitat and potential barriers for any target species. Once these have been identified, the connectivity of the landscape is measured by mapping the area of habitat that the animal could access, given how far it can move. Our seven species groups included animals that have a diverse set of habitat requirements: insect pollinators, aquatic insects, amphibians, reptiles, woodland birds, hollow-using birds and hollow-using bats.

Figure 9 demonstrates how this framework was used to measure ecological connectivity in the City of Melbourne for insect pollinators such as the dainty swallowtail butterfly or blue-banded bee. These species can only travel relatively short distances (less than one kilometre) so finding ways to connect habitat patches across road barriers becomes especially important.

Local government and conservation practitioners can use this framework to plan biodiversity actions and assess the impact of different developments. The framework can also be used to identify landscape features that create barriers for nature (such as roads) and prioritise conservation actions at locations that would most improve connectivity².



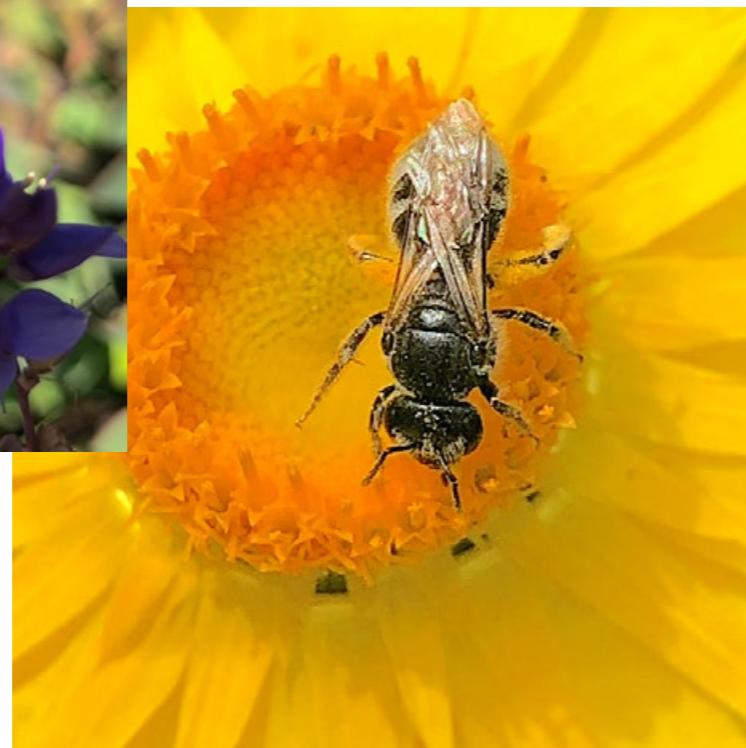
Figure 9. An example of how the ecological connectivity framework was used in Melbourne to identify connected habitats, in this case for insect pollinators.



Creating more connected and biodiversity-friendly cities using green roofs

CAUL PhD student Julia Schiller's research aims to develop a better understanding of the biodiversity value of green roofs. Due to their many benefits, green roofs are being promoted by Australian cities through different policy programs. If ecological requirements are taken into account during the design and planning stages of green-roof construction, these features may provide additional biodiversity habitat and serve as stepping-stones, connecting ground-level habitats and enabling animal movement across high-density urban areas.

To understand the potential of green roofs in this context, Julia is investigating the habitat characteristics that enable the use of green roofs by insects such as native bees. She aims to develop an easy-to-use planning tool that evaluates ecological connectivity in urban areas, which accounts for both horizontal and vertical isolation. The results of this project will help to create guidelines for where to put green roofs and the types of green roofs that are most suitable for urban biodiversity.



*Native bees using green roofs in Melbourne.
— Photos by Julia Schiller*

Practical actions for conservation

Urban land managers balance the needs of local biodiversity with the needs of local communities but have little guidance on how to implement actions that are good for both people and nature. To understand the current state of practice across Australia and to develop guidelines for urban conservation, we interviewed a range of practitioners from local and state governments and non-government organisations, and evaluated the types of conservation actions they have implemented³. The result was a national inventory of local actions – the first of its kind in Australia.

We found that while habitat restoration actions such as planting or weeding were common, almost all organisations spent equal or more time and resources engaging local communities in programs, projects or via educational activities. Across all types of biodiversity-conservation initiatives, three broad mechanisms commonly supported actions: 1) resource availability (human, financial, other); 2) actions or support derived from legislation, policy, organisational strategy or coordination; 3) research and the availability of data, evidence, or information.

Productive community engagement was often associated with successful and/or long-term urban conservation projects. High levels of community engagement were achieved when: 1) engagement was supported by organisational policies and strategies, 2) there was an engaged and valued community and volunteer workforce, 3) Indigenous advisory groups were engaged, and 4) human needs were taken into account, for example via designing multi-use spaces that integrated human and wildlife needs.

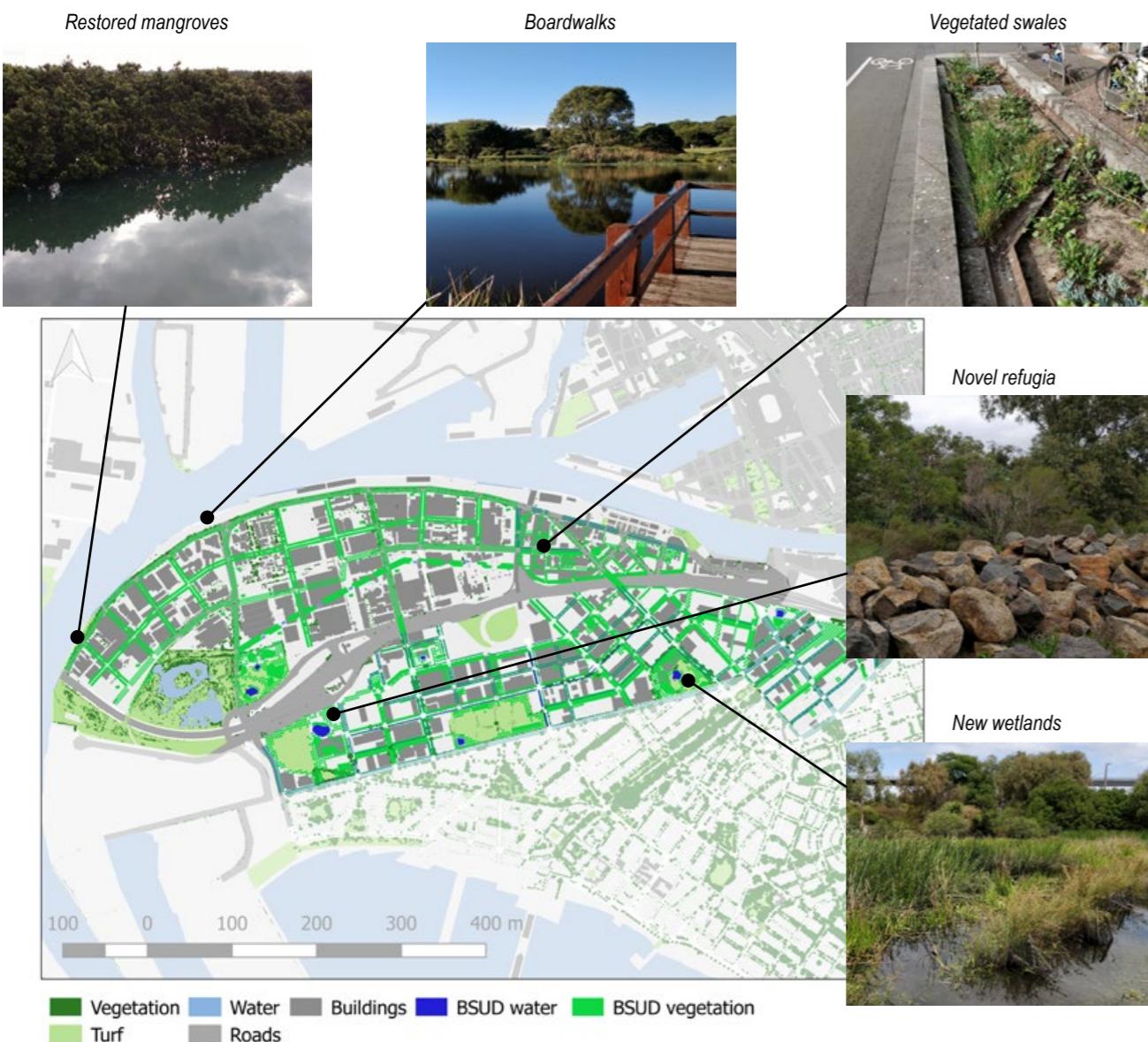
In our research, one interviewee described their organisation's conservation work with a core group of active members and hundreds of local volunteers who value their surroundings and want to be 'part of the solution'. The organisation consults experts, including local Indigenous Elders, to inform their activities. As a result, the interviewee spoke of good relationships with local Aboriginal groups. The organisation fosters strong relationships with local companies and runs team building days for staff that involve planting and weeding.

*Citizen scientists looking for tree hollows and hollow-using fauna, during the City of Melbourne Hollowblitz event.
— Photo by City of Melbourne*





One project involved restoring a site along a river in a residential area that was overrun with invasive weeds. Once the volunteers removed the weedy species, the riparian vegetation underneath recovered and a locally extinct bird species returned to the site. To protect the restored habitat, the organisation built a low fence along a path and raised funds to build a viewing platform so the community can enjoy the river without impacting the vegetation. The organisation's culture and policies laid the foundation for this culturally inclusive approach, the engaged community and volunteers did the work, and clever design ensured future enjoyment of the river while minimising the impact on the landscape.



Example of how biodiversity sensitive urban design (BSUD) can be used to identify candidate actions to enhance habitat for wetland-dependent species in Fishermans Bend, Melbourne.
— Figure adapted from Kirk et al. (2020).

Being inclusive of multiple knowledge systems and cultures within a program of urban-biodiversity conservation works was perceived as an enabler of conservation action. We engaged independent Indigenous agency INDIGI LAB to outline recommendations for future Indigenous engagement in urban-biodiversity actions⁴. These recommendations include consulting Indigenous people as key stakeholders at the beginning of any project and improving collaboration through networks that bring together both Indigenous and non-Indigenous biodiversity experts.

Building nature into the urban fabric

Despite the importance of providing for biodiversity in cities, many challenges must be overcome to ensure councils and developers consider planning for biodiversity from the outset. One of the major barriers is the perception that biodiversity-focused planning is difficult and counter to development objectives. We created a design framework that can be used to identify actions to improve habitats for urban biodiversity, based on ecological principles, which also align with other development objectives⁵. Biodiversity sensitive urban design (BSUD) ensures that sites are developed with a net benefit to biodiversity, creating on-site gains for both nature and people. This flexible framework encourages the inclusion of biodiversity throughout the development process, which helps to identify places where nature-friendly designs can be used to achieve the socio-economic goals of a development. BSUD is based around five key principles:

1. Maintain existing resources for nature and look for opportunities to create new resources.
2. Support animal movement across the landscape.
3. Reduce threats and the disturbance of urban nature.

4. Protect natural cycles, processes and create sustainable ecological communities.
5. Nurture positive interactions between people and nature.

BSUD follows a set of simple steps that allow urban designers and planners to create complementary solutions to both biodiversity and development objectives. Clear, site-specific biodiversity objectives are identified at the beginning of the process, informing the selection of target species for the development. Ecological knowledge about these species can be used to create detailed designs that meet the resource requirements of those species. Quantitative evaluation (using standardised ecological models) ensures that the best designs are chosen.

We applied the BSUD framework in a real-life planning scenario at Fishermans Bend, Melbourne – Australia’s largest urban redevelopment. By considering design for biodiversity at the initial planning stages, this project also demonstrated how the BSUD process can be an important tool for engaging a range of stakeholders in the consideration of urban nature alongside more traditional infrastructure goals. This overcomes communication barriers, helping to ensure the necessary biodiversity actions are carried through later parts of the urban-planning process.



The existing Westgate Park in Fishermans Bend serves as inspiration for new open spaces and streetscape habitat in the redevelopment.
— Photo by Holly Kirk



Research with impact: Urban Biodiversity



Hoverfly, Royal Botanic Gardens Melbourne.

— Photo by Luis Mata

The construction and expansion of cities often leads to the loss of biodiversity. While this loss of species and ecological communities negatively impacts the environment, it also impacts on the human experience of nature. A key question, therefore, is how to protect, restore or bring back important habitats and species within cities and support urban biodiversity despite ongoing development. To

solve this problem, we can engage with all levels of government, industry, and with Australia's urban-dwelling citizens to identify and implement practical solutions. From developing frameworks that guide conservation approaches, to working with Indigenous communities to co-design projects, here are some key takeaways that different stakeholders can consider.

Government and policy-makers

CAUL research can guide policy and action to promote positive outcomes for biodiversity in our cities. Opportunities include:

- Acknowledging the presence of threatened species in cities and towns in key documents guiding their conservation and recovery, such as recovery plans and conservation advices. This will ensure that decision-makers and land managers are aware of the importance of urban habitats for the persistence and recovery of threatened species, as well as other matters of national environmental significance. CAUL has increased recognition of urban environments as valuable places for biodiversity, including threatened species, as reflected in policy documents such as *Australia's Strategy for Nature 2019-2030*.
- Illuminating Indigenous custodianship and cultural landscapes provides opportunities to meaningfully engage – and co-design projects – with Indigenous communities and knowledge holders. Co-design and collaboration allows valuable knowledge and practice that has been under-resourced in the past to be utilised in a culturally appropriate and place-specific context. Engaging with Indigenous knowledge in this way would invite more holistic management practices that benefit biodiversity, while co-design ensures reciprocal benefit to Indigenous communities in the sharing and incorporation of this knowledge.



Optus Stadium parkland, Perth.
— Photo by Cristina Ramalho

Industry and practitioners

There are a range of ways industry and practitioners, such as builders, urban planners and landscape architects, can plan for biodiversity in the city and support retention and creation of novel habitats.

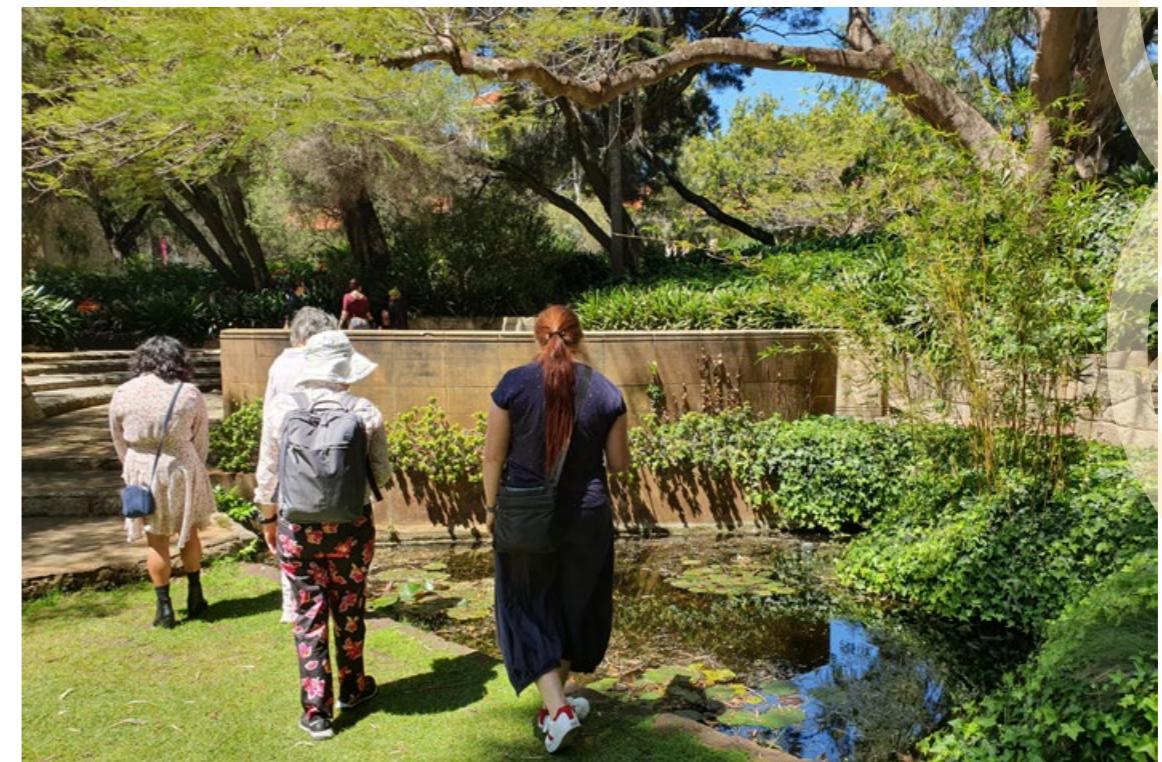
- Recognise and embrace the conservation value of small and unconventional habitats to improve conservation outcomes. Many urban species rely on small areas and lands not originally intended for conservation. For example, roadsides, golf courses and cemeteries have enormous potential to contribute to conservation. Partnerships with a diverse range of stakeholders and land managers can help identify ‘win-win’ scenarios where management practices benefit biodiversity without compromising the intended function of the space.
- Use CAUL’s ecological connectivity framework to prioritise the best spatial arrangement of new habitat, or identify places where ecological connectivity can be improved within the landscape. The framework, which is relevant to urban planners from both local government and the private sector, is currently being used by the City of Melbourne to identify which segments of the road network around the CBD should be selected for new urban-greening initiatives. Elton Consulting (NSW) is also using the connectivity framework to identify potential green corridors across the City of Sydney.
- Use the biodiversity sensitive urban design framework (BSUD) to plan for urban biodiversity. This tool is accessible to individual builders, urban planners, landscape architects and other development professionals working at a broad range of scales, from single buildings to multi-precinct designs.
- Consider adopting designs that incorporate innovative and creative ways to conserve biodiversity while achieving development goals, such as the parkland of Optus Stadium in the Burswood Peninsula, Perth. This project involved extensive engagement with the local Noongar community and features multiple Indigenous elements in the built infrastructure, plant choices, local materials, art and educational signage.

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Community

From choosing local indigenous plants for your garden to becoming a citizen scientist, here are a few practical ways community members can support biodiversity.

- Use indigenous plants in your garden to support local biodiversity and healthy ecosystems. CAUL’s ‘Indigenous Plant Use’ booklet is designed for parents, teachers, community groups and families and invites all to connect with Aboriginal plant knowledge.
- Get involved in community projects designed to conserve and promote awareness of urban biodiversity, such as planting days, land-care groups and sustainability festivals. Contact your local council to find out about groups and activities in your area.
- Contribute to research by using CAUL’s Urban Wildlife app to record sightings of bell frogs, insects, flying foxes, possums and gliders around the country. Having as many eyes as possible reporting on these species’ activities will help us build a clearer picture of the conditions that allow them to thrive.



Citizen scientists taking part in a field survey of motorbike frogs using the CAUL Urban Wildlife app.
— Photo by Jasmin Hartel





Children dressed up as frogs for Frog Fest at The Living Pavilion.
— Photo by Isabel Kimpton



Resources



Looking for more information? These useful resources cover: Aboriginal perspectives of indigenous plants, a national inventory of local biodiversity actions, a framework for improving ecological connectivity, citizen-science activities, and more.



App:

- [CAUL Urban Wildlife](#)



The Living Pavilion signage:

(Credits: Words by Zena Cumpston and Illustrations by Dixon Patten of Bayila Creative)

- [Story of place and plant story](#)
- [Eel story and Bouverie Creek](#)

Data/Lists:



- [Threatened Species in Urban Areas Map](#)
- [City of Melbourne biodiversity portal](#)
- [List of urban-restricted threatened species](#)

Factsheets/Reports:



- [Linking nature in the city](#)
- Conservation of urban biodiversity: a national summary of local actions ([PART I](#)), INDIGI LAB Review ([PART II](#))
- [The Living Pavilion research report](#)

Book/Booklets/Brochure:



- [Indigenous plant use](#)
- [The little things that run the city: 30 amazing insects that live in Melbourne](#)
- [The plants of Coranderrk \(Produced by Wandoon Estate Aboriginal Corporation\)](#)



Academic papers:

- [Biodiversity sensitive urban design \(BSUD\)](#)
- [Correcting common misconceptions to inspire conservation action in urban environments](#)
- [The seven lamps of planning for biodiversity in the city](#)
- [When cities are the last chance for saving species](#)



Future Cities



*Westgate Park in Melbourne.
— Photo by Luis Mata*



Introduction

Kirsten Parris

To create future cities that are better for people and nature requires a leap of imagination from what is familiar to what is possible, a leap beyond business as usual. But it also requires an honest reckoning with the state of our cities as they are today, and the attitudes, processes and policies that brought us here. Over its six years of operation, the CAUL Hub has made significant contributions to both these requirements, ranging from the philosophical to the practical.

Our research has provided an evidence base that describes the state of cities in Australia today, spanning outdoor air quality, indoor air quality, urban vegetation cover and its relationship with urban heat, the liveability of our neighbourhoods in capital and regional cities, urban green spaces and their many benefits, urban biodiversity, and the complex relationships between people and their environment.

Our research and engagement activities have also influenced people's ideas of what cities are and what they are for. We have striven to make space for Indigenous voices in cities, and to highlight that all cities are Indigenous places – that every city in Australia was built on the unceded lands of the nation's First Peoples, and that deep connections to land, water and sky in these places continue undiminished.

We have increased understanding of the value of urban nature for people but also for its own sake. Our research has demonstrated that cities are important places for biodiversity and its conservation, including for hundreds of EPBC-listed species from the Frankston spider orchid to the western swamp tortoise and the growling grass frog. Our work has revealed the many social benefits that nature provides us, within our everyday lives.

This chapter explores a few key elements of future cities as we imagine them. However, it's worth noting that there is no single, ideal future city but many possible cities that could provide for all their residents, both the human and the more-than-human.



Growling grass frog.
— Photo by Holly Kirk

There is no single, ideal future city but many possible cities that could provide for all their residents, both the human and the more-than-human.



Future cities recognise Indigenous place and culture

Marco Amati and Judy Bush

Indigenous knowledge systems and Indigenous science, developed over thousands of generations, are key to living sustainably in the Australian environment. The researchers and stakeholders of the CAUL Hub have been engaged on a collective journey towards an Indigenous-led and co-designed understanding of the city. We acknowledge that we are very early in this journey, and that we have taken missteps and wrong turns: there is still a long way for us to go. But our words here as non-Indigenous people are intended as a provocation to continue on this road, extending and expanding our understandings and practice in the future^{1,2}.

Historically, the term urban planning (or more specifically, town and country planning) establishes a false divide between cities and rural areas. Planning has also been tied to colonial administration, surveying and the expropriation of property.

On the other hand, in Australia, Country encompasses Indigenous peoples' relationship with and custodianship of their land. We recognise that Country is multi-layered, incorporating the sky, land, water and soil. It combines areas that are thought of as both urban and rural. As non-Indigenous Australians, it is our responsibility to acknowledge that for Traditional Owners, land was never ceded. It is also our responsibility to encourage our fellow urban decision-makers to take quiet and effective steps that will contribute to a restoration of Indigenous sovereignty. We acknowledge that Australia is not just one country in this sense, but Country for hundreds of diverse Indigenous nations.

The built environment, the clearing of vegetation, and the reshaping of hills and watercourses do not obliterate Country. As cities embrace greening initiatives, opportunities for expanding and deepening our understanding and engagement with Indigenous perspectives of Caring for Country emerge³. We are reminded of the need to recognise Country in policy-making through words and actions. Future cities are places of Indigenous culture and values, and policy makers have an opportunity to walk with Indigenous people in creating new approaches⁴.

Many Indigenous people have offered to share their deep knowledge of Country, providing insights to enrich our cities' social and cultural lives, to strengthen understandings of sustainable land management and acknowledge Traditional Owners' custodianship. All of us can take up that offer with respect and humility. Importantly, cities have a critical role in exacerbating or relieving the ecological catastrophe of which we are a part. A sense of Country therefore includes a holistic understanding of the effects of city life and reminds us to place this in the context of a relationship that is more than 60,000 years strong.

Vision for future cities

From our Indigenous Advisory Group

Here, we asked some members of our Indigenous Advisory Group, Maddison Miller, Jade Kennedy, Kirstine Wallis and Luke Briscoe, to share their vision for future cities.

Maddison: My vision for cities is a place that is responsive to its climate.

Jade: So, my vision for cities of the future, is that they are understood as Country, and when I say Country, I say that from an Aboriginal place.

Luke: For me, I'd like to see a vision for the cities where cultural indicators for various nation groups are established that will provide a guideline for how corporates and governments and industry engage better with Indigenous communities.

Maddison: I think that as we reach a point of no return in this climate emergency that we really need to be considering how we ourselves are situated on this earth and how we care for it.

Kirstine: My vision for the future of cities centres upon biophilic design principles, marrying up with First Nations' knowledge, sensibilities and sustainable management practices. Biophilia means love of nature and I see a parallel with First Nations' affinity with nature, a connection to the environment, to sustainable practice, resource management and to health and wellbeing.

Jade: So, my vision is, is that we start to share the same dreaming. That we acknowledge our history and our story and how our cities have come to be and we acknowledge that moment where we turn the page and we move back into that old way of being custodians within a shared space.

Kirstine: We need to design with Country, with community, and redefine our cities for connectivity, preservation, resilience and protection.

'My vision is, is that we start to share the same dreaming.'

—Jade Kennedy



CAUL's Indigenous Advisory Group members share their vision for future cities.

Future cities are healthy cities

Melanie Davern and Hugh Forehead

The liveability of our cities has never been more important, with increasing urbanisation and an increasingly urban population. This brings many challenges associated with increased traffic and congestion, hotter urban environments and rapid urban development. However, many of these problems can be addressed with established solutions. These include infrastructure supporting sustainable transport such as walking, cycling and efficient public transport; well-designed, energy-efficient housing; access to local shops, services and public open spaces; and urban-greening initiatives that improve air quality, reduce urban heat and provide significant amenity and value for urban residents. Some problems are more challenging, such as severe smoke pollution from wildfires. However, recent research is improving our understanding of these problems too.

Clean air is a key element of liveability that allows us to live safe, active lives, both indoors and outdoors. Scented cleaning products pollute indoor air with harmful chemicals and particles, but can be avoided by using non-scented alternatives. Cleaner technologies are needed to heat and cool our homes without significant greenhouse-gas or particulate pollution. Outdoors, pollution

from traffic decreases liveability, exposing people to health risks if they are walking or cycling near traffic. Air quality is usually much better even a single block away from busy or congested roads. Peak-traffic hours produce the worst pollution, a consequence of people needing to travel longer distances across sprawling cities to work or study, while relying on private motor vehicles for transport.

Better city design can avoid these problems. For example, parks, public open spaces and access to nature have never been more appreciated than during the COVID pandemic⁵. Traffic pollution will lessen over time, as fossil-fuel powered vehicles become more efficient and electric vehicles become popular. The easiest way to support healthy and liveable places with good air quality is through walking, cycling, and using public transport whenever possible. These forms of transport get you active, improve your health, clean the air and reduce your carbon footprint – all at the same time!

Clean air is a key element of liveability that allows us to live safe, active lives, both indoors and outdoors.



Measuring Australia's future liveability

Melanie Davern



Improving the liveability of Australian cities is an increasingly important objective across all levels of government. However to enhance a city's future liveability, we first need a well-defined understanding of the concept. RMIT University's Healthy Liveable Cities Group has defined liveability as a place informed by the social determinants of health. This understanding of liveability describes a place that is:

'safe, attractive, socially cohesive and sustainable, with convenient public transport, walking and cycling infrastructure linking affordable and diverse housing to employment, education, public open space, local shops, health and community services, and leisure and cultural opportunities⁶'.

Secondly, we need the ability to measure and monitor the progress of liveability at different scales in cities across the country. We created 35 liveability indicators that relate to nine domains of liveability, such as walkability, housing and transport (Figure 10). To help people visualise these indicators, we developed a digital planning portal called the Australian Urban Observatory (AUO). The AUO provides easily understood, mapped liveability indicators for Local Government Areas, suburbs and neighbourhoods across Australia's 21 largest cities, including the 13 largest regional cities. Uniquely, this portal allows us to visualise liveability at a granular level, revealing differences between cities, but more importantly, differences between neighbourhoods within cities. This level of detail can encourage investment in the areas that need it most, thereby supporting healthy, equitable and sustainable cities for all Australians. As our cities continue to grow and evolve, so too will the liveability indicators. We will continue to create new indicators to inform future policy and planning actions across large cities, regional centres and smaller towns.



Figure 10. Domains of liveability included in the Australian Urban Observatory.



Future cities embrace nature-based solutions and biodiversity

Judy Bush and Kirsten Parris

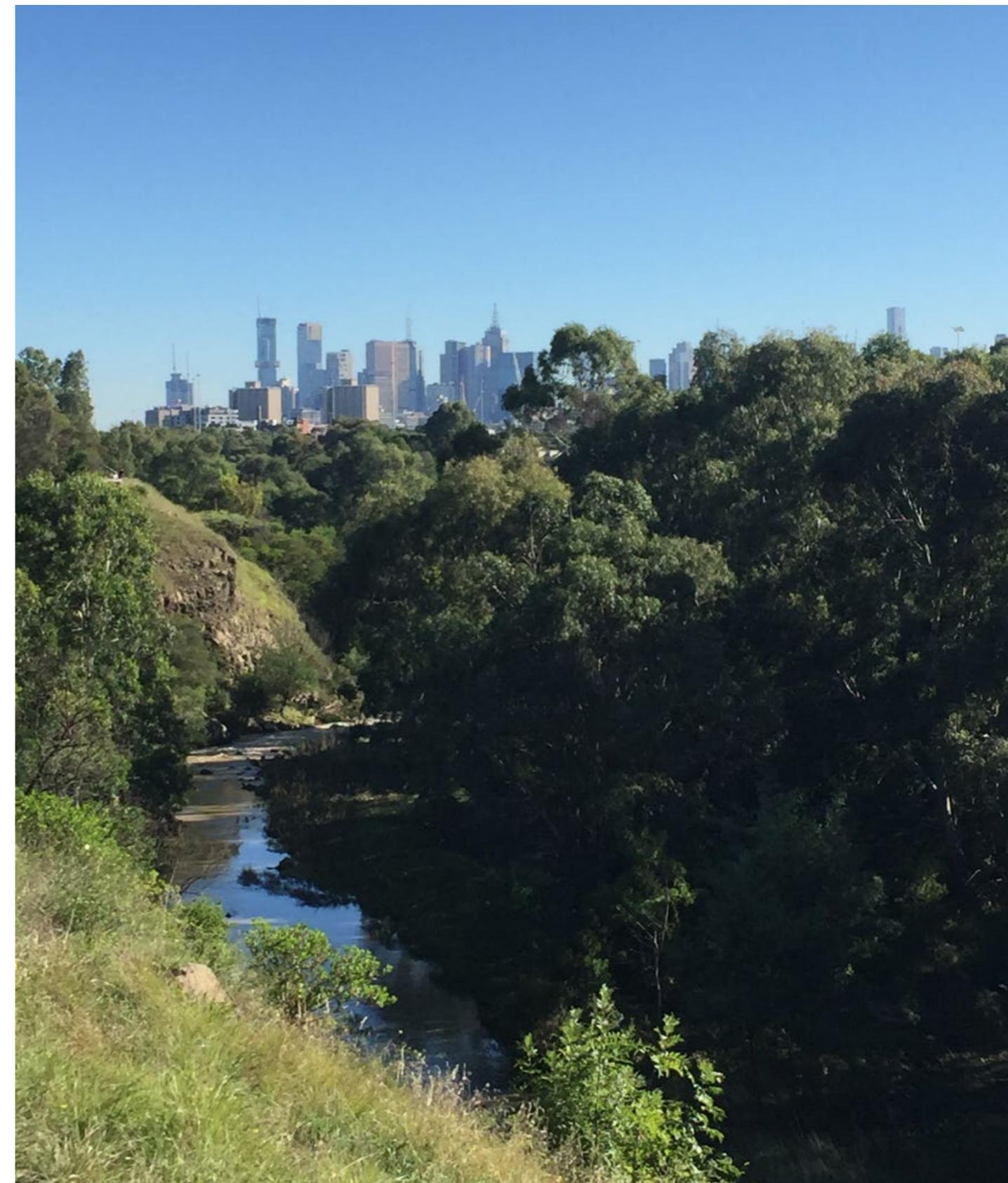
The resilience and sustainability of future cities will be strengthened by integrating nature-based solutions into urban planning and design⁷. Nature-based solutions (NBS) are ecosystem-based approaches for addressing a range of societal challenges including climate change impacts, food and water security, human health and wellbeing, and economic and social development.

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As NBS are multi-functional, governance systems must integrate multi-disciplinary approaches to planning and management⁸. Being multi-functional solutions, NBS may be less 'efficient' in providing single functions such as drainage compared with traditional hard-engineering approaches, yet their integrated outcomes can effectively achieve multiple objectives⁹. Future cities must ensure space is allocated for urban NBS: including ground-level space as well as space for tree canopies (above ground) and tree roots (below ground) to develop and thrive. Future cities that are resilient and sustainable will embrace nature-based solutions to urban challenges and will ensure governance, planning and management encompass and facilitate multi-functionality, multi-disciplinarity and effective collaboration.

Beyond nature-based solutions, there is an important role for cities in the conservation and promotion of biodiversity for its own sake. For far too long, standard approaches to planning, constructing and maintaining cities have focused on humans and our concerns, to the exclusion of other species. These approaches have been supported by a misconception that urban biodiversity is lacking or dull, and that urban environments are not important places for nature and biodiversity, including threatened species. Future cities must make space for the more-than-human, providing key resources that fungi, plants and animals need to survive and thrive, and recognising cycles and structures that help or hinder biodiversity in altered urban landscapes¹⁰. Biodiversity sensitive urban design can ensure that other species are considered throughout a new project or development, from the scale of a single house lot to an entire suburb or precinct¹¹. Neither offsetting biodiversity, nor attempting to move it somewhere that's more convenient, is a sustainable solution. Embracing biodiverse cities is the way of the future.

Urban green-blue spaces, such as the Merri Creek in Melbourne, are essential for healthy, resilient cities.
— Photo by Judy Bush





Future cities are better for people and nature

Joe Hurley and Kirsten Parris

The 20th Century taught us that modern life – and urban life in particular – cannot be understood without its connection to environment, to ecological systems. We humans rely on the health of the ecological systems that sustain us, as do the other species of Earth. It is in our cities that consumption of (and thus destruction of) ecological systems is concentrated. Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems. Sustainable communities support all three systems, providing for the needs of people and other species in the present without compromising future generations.

Sustainable development combines this ecological view with the need for human development, especially the needs of the world's poor and disadvantaged. It thus foregrounds fairness and justice alongside healthy ecological systems. Neither fairness nor justice nor ecological health are served by unfettered economic growth. A sustainable city, or perhaps more realistically, a city that evolves with sustainability principles at the core, is one that demands ecological health, human wellbeing, and fairness/justice as central in decision-making and action.

Our work has been guided by the principle of sustainability, with a focus on providing practical research outcomes to enhance the future sustainability of our urban environments. Cities are and must be ecological places. Healthy ecological systems in cities bring many benefits for humans and other species alike. For example, our research has demonstrated that a diverse, resilient and abundant urban forest is critical to human physical and psychological wellbeing. It has therefore demonstrated the importance of the urban forest as a critical infrastructure of cities, to be considered alongside buildings, roads and other engineered systems. Our research has provided new tools and knowledge to help evaluate, manage and enhance urban green infrastructure and urban biodiversity; to improve urban air quality both indoors and out; and to increase the liveability of our neighbourhoods, with the many health and social benefits that this brings.

As we move into the third decade of the 21st Century, we offer the work of the Clean Air and Urban Landscapes Hub to inform future cities – cities that are better for people and nature – across Australia and beyond.

Cities are and must be ecological places.

Green wall in Paris, France.
— Photo by Cristina E. Ramalho



Acknowledgements

Since its inception in 2015, the CAUL Hub has delivered a significant body of research, communication and outreach activities to support better cities for people and nature. This work has been undertaken by a small army of researchers from the University of Melbourne, RMIT University, the University of Western Australia and the University of Wollongong, alongside the CAUL executive team including Cathy Oke and Helaine Stanley (Knowledge Brokers), Martin Bush, Julia Cleghorn, Mika Zollner, Isabel Kimpton and Briena Barrett (Communications Officers) and Yelena Constantinou, Sally Zanic and Angela Bruckner (Business Managers). We thank everybody who contributed to the research featured in this e-book.

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Key terms

Some key terms used throughout the e-book and their descriptions can be found [here](#).

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The Living Pavilion

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