



Priorities for mainstreaming urban nature-based solutions in Australian cities

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ABSTRACT

Nature-based solutions, ecosystem-based approaches that deliver multiple benefits, including biodiversity habitat, have the potential to address a range of challenges that cities are increasingly facing. Nature-based solutions can contribute towards addressing intersecting climate change and biodiversity extinction crises. Mainstreaming nature-based solutions involves policy and planning approaches that shift from a reliance on grey infrastructure to integrating nature-based approaches in urban infrastructures. Mainstreaming requires integration across sectors, scales and stakeholders, as well as across policy domains and levels of governance. While much of the NBS research originates from European and North American contexts, Australian cities are distinctive; the priorities for mainstreaming NBS in Australian cities need to respond to Australia's distinctive context and local research in addition to learning from global research. In this perspective, we propose four priority pathways for mainstreaming nature-based solutions in Australian cities: i) addressing changing climate conditions and climate extremes, including heat and drought; ii) embedding an ecology and biodiversity focus, including threatened species, as well as considering the risks of 'ecological traps'; iii) localising approaches that bring together local knowledges, research, and practice; and iv) foregrounding Indigenous knowledges and Custodianship as decolonising approaches. Urban planning in Australia cities, as well as cities globally, needs to take an ecological shift and consider planning with and for nature. The proposed four pathways present a way forward for urban planning to facilitate a socio-ecological transition that can build more climate-resilient cities while strengthening ecological knowledge, memory, sense of place and cultural inclusivity.

1. Introduction

Cities continue to illustrate their capacities for, as well as the limitations of their adaptiveness to shocks and stresses. This has been seen most recently in response to the global Covid-19 pandemic, as well as to climate change impacts, and socio-economic disruptions. From urban parks becoming places of social encounter, and urban oases for mental and physical health; to urban waterfronts reinvigorated to restore ecosystem health for people and animals to thrive, urban environments have shown their importance as places for building resilience to 'bounce forward' from environmental, social, and economic disruptions and

challenges. In this time of pandemic response and recovery, there are two global agendas that are guiding future policy and urban developments: climate change and biodiversity conservation. Climate change responses are framed through the United Nations Framework Convention for Climate Change, and its associated annual Conference of Parties (COP) negotiations (most recently COP27 in Sharm el-Sheikh in November 2022). Biodiversity and ecosystems conservation and restoration are addressed through the Convention on Biological Diversity, and its COP meetings (COP15, in October 2021 and December 2022). Both global forums position nature-based solutions (NBS) as promising approaches in the portfolio of future resilience and transformation

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Box 1 CLIMATE-READY NBS

The recognition that climate change is one of the most significant threats to Australia's urban forests prompted the national horticultural industry to take action and find scalable solutions supported by robust science. The Which Plant Where (WPW) project - funded by Hort Innovation and the Australian Research Council - created the first climate-based plant species selection tool (www.whichplantwhere.com.au). Using experiments in the field and glasshouse, big data bioclimatic modelling, climate change scenarios, and species occurrences for more than 2500 plants, the WPW plant selector allows businesses, governments, organizations, and practitioners across Australia to select 'climate-ready' species and cultivars at each urban location. The tool provides climate-ready species lists for three periods - 2030, 2050 and 2070 - allowing practitioners to mainstream NBS in the short- and long-term and across spatial scales, from a local pocket-park to entire forests across more significant metropolitan regions.

policies [1]. Nature-based solutions are ecosystem-based approaches that deliver multiple benefits, including biodiversity gain, to a variety of challenges - including urban challenges of climate change and resilience building - while contributing to social, economic and ecological improvements [2].

Cities have key roles in addressing both climate change and biodiversity extinction crises [3,4]. Regarding climate change, action is required for both mitigation and adaptation, as cities are responsible for substantial greenhouse gas emissions, as well as experiencing significant climate change impacts, including heatwaves, bushfires, droughts, extreme weather events and sea level rise [5]. Regarding biodiversity, cities are often home to rich biodiversity, including threatened species, some of which are restricted to urban areas only [4,6,7]. The intersecting climate change and biodiversity crises are key drivers that require systemic solutions and as such, can be (employed as) windows of opportunity for mainstreaming NBS in cities.

'Mainstreaming' can be understood as the process by which new approaches are taken up in policy and practice, across sectors, scales and stakeholders [8]. Mainstreaming NBS as a combined social, spatial and institutional process requires shifting from a reliance on grey infrastructure as the default solution or 'business-as-usual' approach to considering and embedding NBS in urban environments [9]. Mainstreaming necessitates vertical and horizontal policy integration [10], and scaling up, investment and adoption in policy and planning [11]. Mainstreaming includes both processes for encouraging and facilitating shifts in policies and implementation, as well as ensuring these new approaches are sustained [8]. Mainstreaming as an institutional/governance process is facilitated through research and knowledge sharing, experimentation, and collaboration to underpin skills development, action-based learning, scaling up and down, and building public and political support [9,11]. As such, mainstreaming requires focusing on science-policy linkages, collaborative governance, and integrated policy approaches [1,8].

This paper's contribution is the identification of key priorities for Australian cities to mainstream NBS, mitigate and adapt to climate change, address the biodiversity extinction crisis, and contribute to increasing the sustainability and liveability of our cities and urban settlements. The priorities have been formulated from discussions at the Innovate4Cities (Oceania) conference, a virtual global and regional event, co-hosted by the Global Covenant of Mayors for Climate & Energy (GCoM) and UN-Habitat, and co-sponsored by the Intergovernmental Panel on Climate Change (IPCC) which was held in October 2021. As such, it advances the emerging debate for climate action of Australian cities that points to the importance of governance and urban planning to be transformed and innovate with nature-based solutions [3,12] by casting a closer look at the way ecological knowledge and ecological stewardship need to guide future action. While much of the NBS research originates from European and North American contexts, Australian cities are distinctive; the priorities for mainstreaming NBS in Australian cities need to respond to Australia's distinctive context and local research in addition to learning from global research. Australia's



Fig. 1. Climate ready (locally native *Banksia integrifolia*) street tree planting in Melbourne Australia.

unique and delicate ecology is a cultural artefact of deep time custodianship; Australia's First Nations peoples, the oldest continuous living cultures in the world, are the custodians of rich and diverse ecosystems and biodiversity [13]. Australia's biodiversity and landscapes have been actively managed and shaped by the Traditional Owners for tens of thousands of years, creating 'the biggest estate on earth', through their custodianship of Country [14]. Australia is also a highly urbanized nation, with large coastal cities, exposed to a range of climate change impacts including heatwaves, bushfires, drought, and sea level rise [5]. Despite these pressing climate change impacts, to date comprehensive climate change responses have been slow and inadequate at a federal level, leaving regional and local scale responses to fill the climate policy void [15]. As such, mainstreaming NBS in Australian cities presents both unique challenges and opportunities, as well as important examples and inspiration for cities globally.

Box 2**INTEGRATING ECOLOGICAL KNOWLEDGE**

Merri Creek, a tributary of the Yarra River in metropolitan Melbourne, forms part of the city's stormwater drainage 'infrastructure'. At the same time, the creek is a habitat corridor of regional significance, providing both vital habitat for a wide range of flora and fauna biodiversity, as well as greenspace for local residents – vital 'breathing space' and opportunities for connection with nature [36], demonstrating the potential for nature-based solutions to support multiple functions and benefits. Its restoration from a weed-infested drain to a treasured community asset has been overseen by fierce protection and advocacy from local residents and community groups [37]. Its restoration and ongoing ecological management is underpinned by ecological knowledges, which are informed by scientific research, Traditional Owners' aspirations, local knowledge and continuing revegetation experimentation [38]. In turn, citizen science and monitoring by Merri Creek Management Committee, an environmental coordination and management agency formed in 1989 with membership from local governments and community members, has informed scientific knowledge of biodiversity and threatened species, including for example, the Golden Sun Moth, which was rediscovered in Merri Creek's native grasslands and its habitat protected [38].

2. Priorities for mainstreaming nature-based solutions in Australian cities

Stemming from the policy and science context in Australian cities, we propose four interrelated pathways that need to guide efforts for NBS mainstreaming, from strategic urban planning agendas to urban practice for achieving climate resilience and sustainability. The four pathways for design and maintenance of NBS include: i) addressing changing climate conditions and climate extremes, including heat and drought; ii) embedding an ecology and biodiversity focus, including threatened species, as well as the risks of 'ecological traps'; iii) localising approaches that bring together local knowledges, research, and practice; and iv) foregrounding Indigenous knowledges and Custodianship as decolonising approaches. The pathways are overlapping and interrelated, rather than rigid and predetermined, acting as 'stepping stones', which together could foster momentum for increasing NBS implementation [16]. As such, the pathways propose to take into account socio-ecological conditions and capacities, including ecological knowledges and stewardship, to guide action towards mainstreaming NBS. These pathways are discussed further below.

First to mainstream NBS in Australian cities, efforts need to focus on ensuring the resilience of NBS to climate change pressures and extremes, including heatwaves and droughts (Box 1, Fig. 1). As NBS are living (and potentially long-term) systems, species selection and system design must account for current extremes and future climate projections. Planners and policymakers need to factor into their decisions that past ecological and environmental performance of species and ecosystems does not guarantee future performance in a rapidly changing climate, urban fabric and society. Australia's climate has already warmed 1.4 °C since records began in 1910, resulting in the increased frequency, severity, and duration of heatwaves [17]. During the 2019–2020 summer drought, repeated heatwaves hit Western Sydney, reaching the hottest daily temperature on Earth at 49 °C on 4th January 2020. Hundreds of trees were severely damaged or entirely defoliated by this extreme weather event, particularly exotic species to Australia introduced by the early settlers [18]. While this event caused hundreds of thousands of dollars in tree replacement costs, securing Australia's urban forests for climate change, through planting with climate-ready species, will require many million dollars, substantial political will, and decades to be accomplished. While expensive, mainstreaming this type of NBS could create significant employment and business opportunities, help redress social inequalities due to availability and access to green space, and contribute towards re-establishing meaningful ties to Aboriginal cultural heritage.

As well as increasing temperatures, there has been a significant decline in winter rainfall in Australia's southeast and southwest, and decreased streamflow across southern Australia since the 1970s [17]. In addition, changes to precipitation patterns are also associated with more extreme rainfall events that generate urban flooding and threaten

objectives for the sustainable runoff management [19]. Therefore, for NBS to be a viable alternative to conventional engineering approaches, they need to be socio-ecologically designed to deliver multiple services to climate extremes and to changing climate in the future. A better understanding of the climate safety margins of ecological, social, and technical elements underpinning NBS – as well as their interactions – is paramount to envision, design and implement climate-ready NBS while fortifying their resilience and sustainability [20]. 'Locality' and 'context' dictate how ecological, social, and technical (e.g. horticultural and landscape construction) elements of NBS function and interact. For instance, small vegetated patches along Adelaide's urbanized coast provided much lower thermal and cooling benefits than similarly-sized patches further away from the coast [21]. The same greening efforts and NBS initiatives located in different places might generate vastly different benefits and outcomes for cities and communities. Thus, as climate, social and environmental changes reshape our cities, ambitious and effective planning and governance approaches cannot rely anymore on 'one-size-fits-all' thinking; integrated place-based and multifunctional

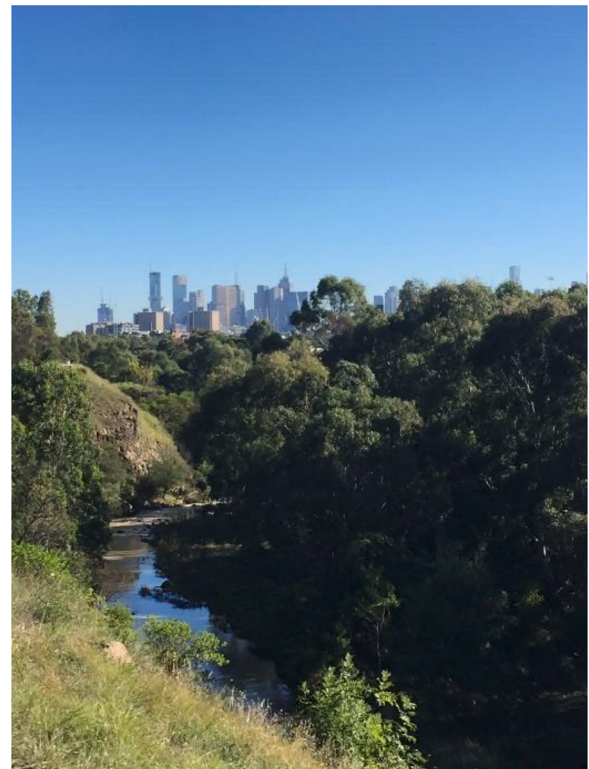


Fig. 2. Merri Creek, Melbourne.

Box 3 ADDRESSING LOCAL CONTEXT

Melbourne's water utilities manage water supply, sewerage disposal and treatment, and stormwater drainage. Since the Millennium drought, they are increasingly engaged with actions that go beyond their 'business-as-usual' engineering approaches to water management, to include approaches that acknowledge the roles of water in urban landscapes, for liveability and cooling, health, wellbeing and supporting biodiversity habitat, strengthening and extending the implementation of nature-based solutions. Further, in acknowledging and working towards these objectives, they are building partnerships and collaborative approaches with local governments and communities. Recent examples include 'Greening the West', where the water utility City West Water (now Greater Western Water), brought together a diverse coalition of organisations to plant trees across the region to provide cooling and liveability benefits [43]; and 'Greening the Pipeline', a strategic vision of Melbourne Water to transform an obsolete infrastructure easement into an accessible linear parkland and community space, that incorporates water sensitive design and local stormwater management features [44].

approaches can help ensure NBS can be complemented and sized across spatial and temporal scales [22].

Second, the design of NBS needs to integrate ecological knowledges. This is particularly so for Australia, an island continent with rich endemic biodiversity. Australia is also highly urbanized. Its cities are hotspots for biodiversity [6,23], with rich flora and fauna and urban landscapes providing valuable habitat, including refuges for native biodiversity [24,25] and threatened species, some of which are restricted to urban habitats only [26]. Indeed, Australia's urban biodiversity highlights and reinforces the importance of reframing our understandings of urban environments. One way is to move away from the assumptions that 'overlook the conservation value of urban environments [which] stems from misconceptions about the ability of native species to persist within cities and towns' [27]. Another way to consider how urban environments can contribute towards biodiversity conservation efforts, is in unconventional habitats [27], small conservation reserves [28], and novel habitats [29].

Urban environments provide the potential for creating novel ecosystems and habitats, utilizing urban resources that include garden plantings and stormwater collected across urban catchments (Box 2, Fig. 2). For example, retention and use of stormwater in constructed wetlands and swales can enhance biodiversity habitat [27,30]. However, such urban habitats also have the potential to create 'ecological traps': research has found that frogs that colonised constructed wetlands with high levels of water pollution (due to polluted stormwater sources) can have reduced levels of reproductive success [31]. This reinforces the importance of integrating ecological knowledges and monitoring for the design and ongoing management of NBS. Such scientific input can contribute towards 'a better understanding of the ecological consequences' [31] and how to restore and manage novel ecosystems to most effectively contribute towards biodiversity conservation objectives [29].

When considering ecological knowledge as a pathway for mainstreaming NBS it is critical also to engage, unpack and address underlying issues of past, present and future ecological injustices. Ecological injustices, which are driven by and are the product of many complex and violent processes, policies and practices, can help us engage with ideas of justice from a multispecies or more-than-human lens, as well as a decolonising perspective that foregrounds First Knowledges [32]. Ecological justice considerations in NBS mainstreaming can reveal the inequalities and biases that arise from privileging some forms of knowledges over others and highlight the misrepresentation and devaluation of other life forms, besides humans, in NBS planning and design [33,34]. As such, weaving ecological knowledge through a justice framework can help us consider nonhuman lives with capabilities and desires and aspirations to flourish, and with the capacity to be knowledge enablers and co-creators, and active, intentional agents [35]. This in turn, can enable alternative, multispecies thinking practices for including the others, human and nonhuman, as active and intentional agents in a political, decision-making processes for mainstreaming NBS

[35].

Third, to mainstream NBS, efforts need to be focused on localising their planning, design and management, so that they respond to the unique landscape, social, cultural, governance and political context [39]. We need to consider the local conditions in terms of both urban form and socio-cultural context. Localising includes considering 'sense of place' or specific place meanings [23,39]. Bringing a multi-layered and multi-scalar sense of place lens to this 'localising' effort can provide a pluralistic and dynamic understanding of how the lives of humans and nonhumans and their ecologies are entangled and affected by each other. From this relational self-others-ecologies perspective we can also unpack negative and positive understandings in terms of what is valued or devalued [40]. Going further, a senses-of-injustice-in-place [34] can help NBS efforts identify perceptions of disempowerment, anonymity, apathy, and misrepresentation, and in turn work to gravitate these senses into actions of empowerment, visibility, and collective action for mainstreaming NBS. Having a deep and pluralistic understanding of the local meanings and connections that people have with urban nature and



Fig. 3. Constructed wetland, inner Melbourne.

Box 4**FOREGROUNDING INDIGENOUS KNOWLEDGE AND CUSTODIANSHIP**

In 2017, the *Yarra River Protection (Wilip-gin Birrarung murrn) Act*, the first legislation in Australia to be co-titled in the Traditional Owners' language, legally recognised the river as a single living and integrated natural entity. The Yarra River is known as Birrarung, 'a river of mists and shadows' by the Wurundjeri, the Traditional Owners. The Act sets out the values of the river and its landscape and defines principles for the protection of its ecological health. Importantly, the Act establishes a new, independent statutory authority, the Birrarung Council, which includes Traditional Owner representatives, to provide advocacy and advice. The Birrarung Council seeks to foreground Traditional Owners' voices in the discussions and decision-making processes for the river's stewardship [50].



Fig. 4. Yarra River-Birrarung.

their capabilities can (re)direct NBS strategies to reactivate human-nonhuman or people-nature relations to promote empowered stewardship actions. This will further allow for socio-cultural meanings and understandings of NBS to be considered, voiced, appreciated and ultimately incorporated in urban planning and governance towards more socio-ecologically inclusive landscapes [41].

Localising NBS approaches and designs also requires responding to local climatic conditions. Australia's experiences of the Millennium drought (2001–2009) informed new approaches to 'water sensitive urban design', which aim to adopt ecosystem-based approaches to treating stormwater runoff, improving stormwater quality and utilising stormwater for healthy urban landscapes [42]. Water sensitive urban design approaches necessitate active engagement with urban planners and designers, as well as water and drainage engineers and urban forest managers, to plan, design and manage urban streets, parks and waterways so as to ensure that stormwater is transformed from being seen as a drainage problem, into being utilised as a valuable element of integrated NBS solutions [42]. This new climatic awareness is reflected in nature actions that reflect a new relationship with water in sensitive approaches towards the landscape (Box 3, Fig. 3).

Fourth, to mainstream NBS in Australian cities, it is vital to foreground Indigenous knowledge and custodianship, to decolonise the process of design, creation and management of landscapes and ecosystems. 'For millennia, reciprocal relationships with plants have provided both sustenance to Indigenous communities and many of the materials needed to produce a complex array of technologies. Managed through fire and selective harvesting and replanting, the longevity and intricacy of these partnerships are testament to the ingenuity and depth of Indigenous first knowledges' [45]. To mainstream NBS in Australian cities, an inclusive process that brings together Indigenous knowledges and Western (scientific) knowledges [32] and of ways of connecting with nature and appreciating nature, needs to be championed [46]. This includes respectful engagement with the relationships and

responsibilities of caring for Country, and increasing dialogue, collaboration, and co-creation with First Nations Peoples to ensure Traditional Owners' aspirations are understood and respected (Box 4, Fig. 4). Indigenous-led natural resource management, such as the Narrap Team of the Wurundjeri People, whose traditional Country includes much of Melbourne, Australia, seeks to address key aspirations by providing 'a holistic approach to working on our traditional Country', and in doing so to 'to rediscover and document Wurundjeri Traditional Ecological Knowledge' [47].

From a local focus to a national focus, what needs to progress is a process of decolonisation of urban ecology and thereafter decolonising NBS. To plan our cities, and our urban NBS, requires 'embedding considerations of Country as a whole, which are based on thousands of years of practice. Consideration should focus on who makes decisions, how decisions are made, and what is considered in those decisions' [48]. Understanding that landscapes are cultural artefacts, and that plants have deep cultural significance opens the possibilities for 'a healthier, more sustainable future' [45]. This requires a dismantling as well of how we plan, design and implement NBS. To do this requires co-emergence with place/space through a relational and ethical understanding in the process of 're-imagining geographies of co-existence' [49, p. 468]. Rather than NBS mainstreaming being a techno-pragmatic planning exercise, a relational approach can also inform urban planning and governance of NBS as a process of continuous co-creation and emergence of knowledges and practices that enable us to care as Country [49, p. 468, emphasis in original].

3. Conclusion

In a changing climate, we propose that Australian urban planning needs to take an ecological shift and consider planning *with* and *for* nature. The proposed four pathways represent interrelated interventions [16] that together aim to facilitate a socio-ecological transition in urban planning and governance that can build more climate-resilient Australian cities, while strengthening ecological knowledge, cultural heritage and inclusivity, and health and wellbeing. Building from the rich experience and knowledge about the challenges Australian cities face, we contend that the pathways will be facilitated through stronger science-policy-planning collaboration. To progress towards NBS mainstreaming requires transformative environmental governance in cities, that will make biodiversity conservation a priority rather than an option [51]. To prioritize nature in urban planning agendas and mainstream NBS as systemic solutions to achieve this, new productive interfaces (collaborations) between science, society, and those representing nature are required [52]. To progress mainstreaming pathways, therefore, new partnerships, coalitions and new forms of collaborative governance, and systemic thinking, founded on diverse ecological knowledges, are needed.

Our call for mainstreaming of NBS prompts further questions that focus in on applying the priority pathways: How can planning mechanisms consider social-ecological and spatio-temporal scales, and how can these be applied in NBS planning? Who makes decisions, how are

decisions made and which knowledges are considered in these decisions? With our contribution, we aim to foster new discussions and perspectives on the socio-ecological conditions and capacities required for NBS mainstreaming in Australian cities (and how these could be translated to other global contexts) alongside experiences, exemplar cases, and a discussion of required conditions.

Declaration of Competing Interest

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

Data availability

No data was used for the research described in the article.

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