Reimagining urban habitats to benefit people and nature

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ABSTRACT

Urbanisation is a leading cause of global biodiversity loss, imposing the most rapid and ecologically damaging impacts of any human driven land-use change. Despite the trend of biodiversity decline, urban nature provides many health, wellbeing and workplace productivity benefits to city dwellers. Hence, there is an urgent need to return nature to cities not only to conserve biodiversity, but also to maintain human experiences of nature. To meet this challenge, there are currently significant global attempts to re-green cities to improve environmental condition, including restoring habitat for biodiversity. However, many barriers to widespread implementation still exist, including competition for limited space, a lack of technical capacity, and a disengaged community. New approaches to urban restoration are urgently needed that suit the small fragments of space available, and that can deliver multiple benefits not only to conserve urban biodiversity but also to reconnect people with nature. To overcome these challenges, an 'ecology with cities' perspective, combining horticultural, ecological and social approaches to urban habitat management and restoration, is needed. Significant opportunities exist for urban ecologists and zoologists to engage with practitioners and the community to co-develop and implement approaches to successfully achieve the aim of creating biodiverse urban environments.

Key words: Biodiversity, urban greening, urban ecology, ecological interactions, social-ecological systems

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Introduction

Biodiversity worldwide is under threat from ongoing habitat loss and degradation, which is seen most acutely in urban areas (Seto *et al.* 2012). Despite this, urban areas can host high biodiversity, containing unique species and communities (Aronson *et al.* 2014; Ives *et al.* 2016), in addition to rare and threatened species, who persist in relict habitats that do not occur elsewhere (Soanes and Lentini 2019; Spotswood *et al.* 2021). The biodiversity that is still present in cities also provides services to society including a vast array of physical, emotional and cognitive health and wellbeing benefits (Taylor and Hochuli 2015; Tzoulas *et al.* 2007). Therefore, cities can and should play a substantial role in minimising their contribution to the current extinction crises (Knapp *et al.* 2020) and instead provide habitat for and recovery of these and other species (Oke *et al.* 2021).

Australia's Strategy for Nature 2019-2030 sets out a framework for all levels of government to protect and restore nature, with significant focus on natural resource management in Australian cities. This strategy has a key goal to 'Enrich cities and towns with nature' with actions including to increase the number and extent of urban greening initiatives, inclusion of ecologically diverse elements in the design and development of urban areas and promotion and inclusion of individuals and communities in doing and sharing activities that support urban nature. To this end, local and state agencies have invested significantly in urban greening activities to increase canopy cover (e.g. NSW State Governments 'Greening Our City program, previously known as the 'Five Million Trees' program), which are in line with global efforts by city and subnational governments to re-green urban areas and improve outcomes for biodiversity (https://cities with nature.org/). However, despite these efforts, significant challenges are faced in maintaining vegetation that is planted due to the combination of harsh environmental conditions in

cities (e.g. polluted stormwater inundation, constricted root zones, poor soils), and significant development pressure (Croeser *et al.* 2020).

A dominant approach to greening and restoration in Australian urban environments relies on planting trees to meet canopy cover targets (e.g. Hartigan *et al.* 2021). However, improving canopy cover alone is unlikely to meet the goal of enriching cities and towns with nature. Other aspects of urban vegetation have been demonstrated to significantly influence the habitat quality of urban areas, including the structural complexity and composition of ground cover and understorey vegetation (Burghardt *et al.* 2009; Narango *et al.* 2017; Threlfall *et al.* 2017). Green spaces such as residential gardens, parks and golf courses that contained greater areas of complex understorey supported significantly more species of birds, bats, and native bees than other green spaces with simplified vegetation (Threlfall *et al.* 2015; Threlfall *et al.* 2016). Urban plantings that contain a diversity of flowering species can also support significant abundance and richness of invertebrate communities, including native but also exotic plant species (Fernandes *et al.* 2023; Lequerica Tamara *et al.* 2021; Norton *et al.* 2019). These and other studies suggest that there are multiple approaches that can benefit biodiversity that include far more than improving canopy cover alone, helping to create or restore habitat for many different taxa.

The amount of area available to restore habitats or create new habitats in cities is limited (Soanes and Lentini 2019). There are many competing demands on the small areas of land available for planting in cities, including significant development pressure and infrastructure requirements (communications, water, sewerage assets etc) (Aronson *et al.* 2017). Considering creation or restoration of habitat in unusual or overlooked locations, such as road verges and railway easements has been suggested as one way of overcoming the challenge of finding suitable space for nature in cities (Soanes and Lentini 2019), however this practice is yet to be commonplace (Soanes *et al.* 2023). Whilst small patches of habitats have traditionally been overlooked in conservation practice (Fahrig and Storch 2020; Wintle *et al.* 2019), small areas including patches <1ha in size have recently been demonstrated to have high conservation value due to their accumulation of more species and a greater abundance of species than large patches, including locally significant or rare species (Riva and Fahrig 2022; Vega and Küffer 2021; Wintle *et al.* 2019). This suggests that creation and restoration of urban habitat could benefit from focussing on small areas.

The national vision of protecting and restoring Australia's biodiversity includes a focus on urban nature, yet our approaches in practice overlook the complexity of ecology in highly modified environments, leading to significant implementation challenges. Consequently, there is a significant role that urban ecologists and zoologists could play in conducting research to inform these efforts. We outline areas for consideration by future urban ecologists and zoologists that will contribute to national efforts to secure Australia's biodiversity, in places where the majority of Australians live and work.

Ecology at small scales

Cities can support significant diversity of plants and animals, including far more than the generally assumed common and generalist species (Aronson *et al.* 2014; Hahs *et al.* 2023; Spotswood *et al.* 2021). Urban areas can also provide heterogeneous habitats, that support taxa with very different resource requirements. For example, Hahs *et al.* (2023) recently found cities worldwide to support smaller species of birds, reptiles and beetles than less urban areas, in addition to species of amphibians and reptiles that have reduced mobility and smaller home ranges. These species may be able to exploit enough resources in urban areas to support their lower metabolic requirements, in comparison to larger or more mobile species (Hahs *et al.* 2023; Merckx *et al.* 2018). Many invertebrate taxa are supported in urban green spaces, including diverse communities of solitary bees, flies including hoverflies, and beetles (Lequerica Tamara *et al.* 2021), who also presumably can have relatively small home ranges in comparison to larger species and taxa. Many animals persisting and even thriving in cities can also have specialised resource requirements (e.g. some amphibian, reptile and wetland bird species could be classified as site specialists or mobile specialist as described in Hahs *et al.* 2023), partitioning niches between species and taxa, for example by occupying niches when other taxa are less abundant (e.g. hoverflies Lequerica Tamara *et al.* 2023). These ecological interactions occur at the scale of the resource, which for pollen and nectar seeking invertebrates is the scale of an individual plant. Hence, a wide array of ecological interactions are occurring in cities, including many at extremely fine spatial scales. Broad approaches to habitat creation and restoration, such as canopy cover improvements, that do not account for these interactions are unlikely to succeed because of a scale mismatch between the scale of the restoration activity and the scale of the ecological process aiming to be restored (Threlfall *et al.* 2021). Hence, in addition to significant opportunities to better account for urban nature by focussing on small patches of habitat, research focussing on ecological interactions at these small spatial scales is likely to provide much needed evidence to inform future restoration efforts.

Cities can play a vital role in conserving threatened plant and insect communities and species within urban environments (Hall *et al.* 2017). Given that 88% of flowering plants worldwide rely on animal-mediated pollination, particularly through insects (Kearns *et al.* 1998; Ollerton *et al.* 2011), the survival and reproduction of these threatened communities and plants can hinge on the presence of insect populations that thrive in urban settings. Urban greenspaces with greater floral diversity can host a more abundant and diverse insect population (Anderson *et al.* 2023; Lequerica Tamara *et al.* 2021), although many insect-plant relationships can be species specific where increases in plant diversity may not universally benefit all insect groups (Mata *et al.* 2017). Having a variety of flower species in urban green spaces can extend the flowering season, providing floral resources over a more extended period and accommodate various pollinator species (Anderson *et al.* 2023; Berthon *et al.* 2021b; Lequerica Tamara *et al.* 2023; Schmack and Egerer 2023). This diversity of pollinator resource is crucial not only for the resilience of pollinator communities (Memmott *et al.* 2004) but also for supporting a range of generalist and specialist floral visitors (Biesmeijer *et al.* 2006). Such functionally diverse pollinator communities are especially important for plants with specialized floral structures or those with brief or unconventional flowering periods. For example, recent studies reveal that plant-pollinator interactions occur all year round, and can be especially prominent in winter for taxa such as flies (Lequerica Tamara *et al.* 2023; Schmack and Egerer 2023; Tasker *et al.* 2020). These previously underestimated interactions are pivotal for managing urban environments with remnants of endangered vegetation. For example, in the case of the critically endangered Eastern Suburbs Banksia Scrub community in Sydney, Australia, many plants flower during the coldest months (Lequerica Tamara 2023). Although the proportion of winter-flowering plants pollinated by insects is yet to be determined, maintaining a year-round supply of floral resources that supports a diverse pollinator community could be the deciding factor in conserving this endangered community or facing its local extinction. Another example of urban plant conservation can be seen in the recent City of Melbourne Threatened Plant Living Collection Plan (Larke *et al.* 2023), which aims to support the role of the city green spaces in the cultivation and conservation of threatened plant species.

New approaches in urban horticulture

Significant effort has been made recently to improve plant selection for urban plantings to ensure urban greening efforts account for diversity and resilience, with particular focus on tree canopy (e.g. The City of Melbourne Urban Forest Strategy). For example, understanding which tree species are likely to succeed or fail in future urban climates has received much research attention (e.g. Kendal *et al.* 2018). In addition to a focus on canopy cover, other types of plantings have become popular in many parts of the world. In European cities, wildflower meadows have been planted extensively for aesthetic and biodiversity benefit, where they improve residents satisfaction with a site in addition to supporting richer and more abundant invertebrate communities in comparison to the mown grass that they replace (Fernandes *et al.* 2023; Hoyle *et al.* 2018; Norton *et al.* 2019; Southon *et al.* 2018). In Australia, diverse plant mixes that create patches of understorey habitat in streets and other small urban spaces are being trialled to support improved biodiversity and climate outcomes (Babington *et al.* 2023; Tan *et al.* 2021) akin to the meadow approach seen in other parts of the world. An example of this is the Woody Meadow Project, where diverse plantings of Australian trees and shrubs are being planted along roadsides, railway infrastructure and in parks to improve the quality of low maintenance landscapes (https://woodymeadow.unimelb.edu.au/). With flowers all year round, these plantings are attractive to people (Babington *et al.* 2023) and are also likely to promote pollinator biodiversity through diverse floral resources and different flowering periods (Fernandes *et al.* 2023). However, this remains untested, providing significant opportunities to determine how plant flowering traits and planting diversity influence pollinator richness and abundance. Some studies show that the influence of plant traits and planting diversity on pollinator richness and abundance is context dependent (Berthon *et al.* 2021a; Tasker *et al.* 2020), taxon specific (Lequerica Tamara *et al.* 2021), and largely determined by plant identity (Mata *et al.* 2021). The challenges are further complicated by the (generally untested) assumptions that habitat assessments focused on vegetative metrics are useful in predicting the conservation value of areas are for various faunal groups, something that has been shown to not be the case (e.g. Hanford *et al.* 2017). These projects highlight the need for researchers and practitioners to work closely together to co-create the evidence base to design landscapes to succeed in their aim of creating biodiverse urban landscapes (Aronson *et al.* 2017; Tan *et al.* 2021).

Engaging and working with practitioners and the community

Urban ecosystems result from a combination of natural, economic and social processes (Pickett *et al.* 2022). Landscape planning, management and policy in and of these environments must necessarily consider economic, social, cultural and natural features and processes (Parris *et al.* 2018; Pickett *et al.* 2022). As such, urban ecologists and zoologists seeking to successfully conduct urban research to achieve sustainability and improved outcomes for biodiversity must engage with policy makers, land managers and

the community to advance their pursuit. A recent analysis of examples of successful implementation of urban biodiversity conservation and restoration initiatives revealed several overarching enablers that facilitated successful biodiversity conservation or restoration projects (Soanes *et al.* 2023), including engaging with interdisciplinary teams and co-design and collaboration with many stakeholders including the community. This analysis also demonstrated that urban practitioners have an appetite for ambitious and novel restoration and conservation projects, highlighting significant opportunities for ecologists and zoologists to work with city managers to implement proactive and novel actions that support biodiversity.

Finally, one of the great opportunities for zoologists working in urban ecosystems is to embrace the simple fact that people are embedded as part of these systems, and that for many city dwellers, interactions with nature are often limited to these highly modified and undervalued systems. Connections to nature are central to promoting wellbeing for people in cities (Taylor *et al.* 2018), with considerable evidence showing that perceptions of nature are shaped by many values, including some that do not align with the more conventional measures of conservation status often adopted by biologists (Taylor *et al.* 2020). This offers significant opportunities for zoologists to encourage people to explore nature in their local environment, for example by engaging with relevant citizen science projects that can cater to diverse interests and approaches (Hall *et al.* 2021a). The restoration of urban habitats also gives opportunities to restore ecological function and reconnect communities with urban nature, particularly Indigenous communities (Hall *et al.* 2021b).

Conclusion

Practitioners and researchers working in urban areas can contribute significantly to averting the biodiversity crisis. A combination of big but also many small spaces can make a difference for biodiversity. Evidence suggests small interventions are beneficial, especially if the plant palette is diverse. Well-designed plantings for biodiversity can be attractive to people as well, and provide opportunities for improving our connections with nature. Future zoologists are needed to understand the ecology of small-scale interactions and to inform action and work directly with the land managers and communities.

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