Urban Ecosystems (2022) 25:741–752
https://doi.org/10.1007/s11252-021-01187-3

Citizen science in cities: an overview of projects focused on urban Australia

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Accepted: 10 November 2021 / Published online: 18 November 2021

Abstract
Citizen science offers a unique opportunity to connect urban-dwellers with the often hidden natural world upon their doorsteps and to contribute to authentic research that increases knowledge of urban ecology and biodiversity. With the majority of Australia's population residing in large cities, this diverse potential pool of participants in science creates a significant opportunity to increase the spatial and temporal scale of research. Herein, we provide an overview of Australian urban citizen science projects based on an analysis of the projects listed in the Australian Citizen Science Association's Citizen Science Project Finder. We draw out key features (such as those with research questions specific to cities such as reintroduction and persistence of species in urban environments) from urban citizen science projects that make them suitable for the urban environment and use these features to suggest recommendations for further expansion and development of this important subset of projects. We conclude that the number and diversity of urban citizen science projects is relatively low in Australia, and advocate for an increase in initiatives that can tap into a large pool of potential participants for the benefit of science and society.

Keywords Citizen science · Ecology · Urban · Cities · Biodiversity · Australia

Introduction

Globally, citizen science has experienced unprecedented growth over the past decade, largely due to advances in, and availability of, technology which has facilitated the involvement of millions of people in science (Bonney et al. 2014; Roger et al. 2019). Citizen science can include (but is not limited to) a broad range of activities, from analysing scientific data, sharing health information, mapping galaxies and making new low-cost technologies (Bonney et al. 2014; Chandler et al. 2017; Roger et al. 2020). Citizen science can also deliver a level of spatial and temporal granularity often not possible with conventional scientific research (Chandler et al. 2017; Adler et al. 2020). When coupled with its potential to engage communities meaningfully in science, this potential to increase both the temporal and spatial scale of science, uniquely positions citizen science to affect genuine scientific, social and environmental outcomes (Bonney et al. 2014). The value citizen scientists receive from participating is manifold and varied, often providing a sense of community, a mechanism to contribute and increased scientific literacy, social interaction, and purpose (West and Pateman 2015). Recently there has been considerable debate about the use of the term and definition of citizen science (Cooper et al. 2021). For this paper, we consider citizen science to be an enabler of *anyone* without formal scientific credentials to engage in authoritative knowledge production.

With a large and diverse pool of potential participants available in cities, urban ecosystems and urban species have great capacity for the focus of citizen science projects (Adler et al. 2020). Urban-centred citizen science projects can provide data from areas not typically accessible to professional scientists such as backyards and school grounds (Saunders et al. 2018; Gracanin et al. 2020). Furthermore, they have the potential to collect observation rich, continuous data sets -which are rare even in professional settings- thereby providing a detailed window into urban ecology (Callaghan et al.

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2018, 2019). Urban projects can also help address fascinating scientific questions with a range of projects and methodologies employing citizen scientists to better understand various aspects of ecology in cities (Saunders et al. 2018; Callaghan et al. 2019; Gracanin et al. 2020). Finally, given the socially and culturally diverse nature of cities (Forrest and Dunn 2011), urban based projects have the potential to attract a wide range of participants (cultures, backgrounds, ages and mobilities). Given the increasing recognition that the quality of science can be significantly enhanced by increasing the diversity of people involved in science (Nielsen et al. 2018; Swartz et al. 2019), urban based citizen science projects should be considered good for science (Brouwer and Hessels 2019).

Citizen science can serve as an important reminder that urban living does not preclude opportunities to observe, learn and contribute to our understanding of the natural world; it just means we sometimes need to look a little closer (Zellmer et al. 2020). Urban landscapes are largely perceived to be dominated by introduced species and less complex in species composition (Threlfall and Kendall 2018). However, species richness has been observed to actually increase for some species as is the case of urban grasslands (Soanes et al. 2018). In addition, the capacity for species to persist in urban environments or indeed for urban environments to serve as a last chance refuge, has been well described (Soanes et al. 2018; Soanes and Lentini 2019). Therefore, finding pockets of wild spaces in urban settings or recording observations at microscales can often result in surprising local-scale diversity (Soanes et al. 2018). With its highly urban population, growing cities, and unique flora and fauna, the importance of learning more about Australia's urban biodiversity and its role in conservation is critical (Threlfall and Kendall 2018; Soanes and Lentini 2019).

Australia's population predominantly lives in cities with over 70% of 23.4 million people now living in a major city (72% major cities and 10% outer or regional area) (Australian Census Data 2019). This percentage is set to grow, with the number of Australians living in major cities increasing annually (Australian Census Data 2019), reflecting a growing global trend of increased urbanisation. Due to urbanisation and lifestyles built largely around inside recreation (e.g. gyms and television), urban dwellers are increasingly disconnected from nature (Kesebir and Kesebir 2017). Citizen science urban ecology projects are one mechanism to reconnect people of all ages with nature, by focusing attention on the natural phenomena within local environments. A broad range of projects could provide opportunities to involve communities in science by monitoring and reporting what is often, quite literally in their own backyard.

Below, we provide an overview of Australian urban citizen science projects. Our aims are to showcase examples of existing projects and provide recommendations for how to further increase their scale, fill critical information gaps and increase participation and retention in projects. We hope this will pave the way for further initiatives by demonstrating that citizen science is a tool that can be used not only to improve management outcomes but also to grow the public's appreciation of nature in cities, by increasing awareness that nature is not just confined to wild spaces.

Urban citizen science projects in Australia

To explore the breadth of urban focused ecology citizen science projects in Australia, we undertook an analysis from August through to November of 2020 of existing Australian citizen science projects using the Australian Citizen Science Association's (ACSA) Citizen Science Project Finder (2020), which is hosted by the Atlas of Living Australia (ALA). The ALA is a digital, open infrastructure that pulls together Australian biodiversity data from multiple sources, making it accessible and reusable (Belbin et al. 2021). ACSA is a member-based association that seeks to advance citizen science through the sharing of knowledge, collaboration, capacity building and advocacy. The ACSA Project Finder was designed as a resource to discover and connect with citizen science projects in Australia, by helping members of the citizen science community learn about each other's projects and provide opportunities to volunteer or get involved. To undertake our analysis, we refined our search terms to 'active' and 'ecology' projects which focused on urban areas. Our analysis excludes ad hoc citizen science (which is not tied to a project and therefore not included in the Project Finder) that can be undertaken using one of the many applications for collecting data e.g. iNaturalist, eBird. We excluded them as they are not discreet projects but rather a means to collect data at any time and in any environment. Their exclusion from our analysis does not mean that we do not perceive value in this approach and recognise that ad hoc observations are providing valuable data (Mesaglio and Callaghan 2021). We also acknowledge there are additional citizen science projects not listed in the Project Finder, such as school-based projects or those with fixed participants. Still, our approach provides a snapshot of the range of urban focused citizen science projects in Australia on which to base our recommendations.

Despite the benefits of urban based citizen science ecology projects, only 19 (or 5.3%) out of a total of 458 active citizen science projects (192 active and ecology projects) listed in the ACSAs Project Finder (Table 1) had a specific focus on urban environments. Given the number of people living in urban environments in Australia, this constitutes a significant underrepresentation of projects tailored for urban dwellers. Furthermore, most of the 19 projects focused on four major cities in Australia (Sydney, Brisbane, Perth and Adelaide) with notable omissions of other capitals

Table 1 Australian projects developed to involve citizen scientists in the study of urban environments. Projects were identified by searching the Australian Citizen Science Association's Project Finder and using 'active', and 'ecology' in the search terms and reviewing the refined list for urban projects. All projects can be accessed via https://citizenscience.org.au/ala-project-finder/

City/State	Specific Location	Project	Project aims	Data collection and visualisation method	Status and Date Commenced	Target species
Sydney, New South Wales	Urban setting but can include green spaces within the city	City of Parramatta Wildlife Survey	Increase understanding of the fauna that inhabit Parramatta city This information will aid in the management of the City of Parramatta's natural areas	Online form with all data automatically integrated and able to be visualised within the ALA	Ongoing January 2020	All urban fauna species observed in the Parramatta region
Sydney, New South Wales	Urban setting but with a focus on green spaces within the city	Mosman Wildlife Surveys	Volunteers record native wildlife found across parks and reserves intended to assist the environmental department of Mosman Council with the future management of bushland habitat and fauna populations	Online form with all data automatically integrated and able to be visualised within the ALA	Ongoing January 2020	All urban fauna species observed in the Mosman area
All urban areas throughout Australia	Urban backyards	Backyard species discovery with BushBlitz	Encourage the general public to look more closely at the organisms living around them, to record what they find and, in doing so, to contribute to knowledge of Australia's biodiversity	App (iNaturalist) All records added to the ALA. Data can be visualised on iNaturalist platform	Ongoing April 2020	All urban species observed by participants in the local area
Urban wetlands in South Australia	Urban wetlands	Monitoring urban wetlands	Investigate factors that influence volunteer engagement and continued support in conservation projects. In addition, it measures species diversity of South Australian bird life in urban wetlands	Point survey count method (paper based) survey location guided by coordinator after contacting them. No known data visualisation available	Fixed period of time June 2020-August 2020	Bird life at designated urban wetlands across the Greater Adelaide Region

Table 1 (continued)

City/State	Specific Location	Project	Project aims	Data collection and visualisation method	Status and Date Commenced	Target species
All areas but with a focus on urban environments	All urban environments	Big City Birds	Engage the general public to report sightings of five focal species of birds. All five species have been observed adapting to human modified areas and increasing their population in urban areas. This project aims to improve understanding of the behaviours that have allowed some bird species to adapt to the challenges and opportunities of urban living	Tailored app "Big City Birds" or via the dedicated project website. Data visualised on project's website	Ongoing November 2020	The project focuses on five bird species: Sulphur-crested Cockatoo, Australian White Ibis, Little Corella and Long-billed Corella Additional species can also be reported
Sydney, New South Wales	Marine	VIZ-Sydney Diving Visibility Reports	Track the quantity of 10 target fish species in dive sites around Sydney to understand their presence across the year(s)	Free text report on community's Facebook page with an indication of location, time, visibility in metres and the species observed. No known data visualisation available but images on Facebook page	Ongoing June 2019	Ten target species: Grey Nurse shark, Angelshark, Angler fish, Eastern Gobbleguts, Port Jackson shark, Giant Australian Cuttlefish, Dusky Whaler Shark, Australian Cownose ray, Little Penguin, Sea Turtle
Sydney, New South Wales	Marine	Sea Turtle Tracking in Sydney	Track individual sea turtles in the waters around Sydney to understand their quantity and site presence across the years. A secondary goal is to provide photographic evidence of their health status and trigger rescue operations whenever required	Photograph uploaded to the community's Facebook page with an indication of location, time, visibility in metres. No known data visualisation available but images on Facebook page	Ongoing June 2019	Sea Turtle species

Table 1 (continued)

City/State	Specific Location	Project	Project aims	Data collection and visualisation method	Status and Date Commenced	Target species
Brisbane, Queensland	All locations in an urban setting	Angle Stemmed Myrtle	Determine the location and numbers of Angle Stemmed Myrtle (*Gossia gonoclada*) in the Brisbane area. The Angle Stemmed Myrtle is an endangered species and help is required to document locations across Brisbane	Email or phone reports of sightings No known data visualisation available	Ongoing December 2019	Angle Stemmed Myrtle
All urban environments	Urban backyards/gardens	Solitary Urban Bees in Urban Gardens	Inform the design of solitary native bee homes and target species for an Australian urban garden	App (iNaturalist) All records imported to the ALA. Data can be visualised on iNaturalist platform	Ongoing November 2019	Native solitary bees
Sydney, New South Wales	All locations in an urban setting	Inner West Microbat Monitors	Monitor microbats at sites in the Inner West Local Government Area	Recording bat calls on high frequency recorders and visual counts of bats. Supervised counting. No known data visualisation available	Ongoing March 2019	Microbat species
Brisbane, Queensland	All road locations in an urban setting	B4C Roadkill map	Help local catchment groups and citizens of Brisbane City develop a record of road kill data. This data will be used to improve and reduce the road kill hot spots by implementing fauna infrastructure for safer fauna passing	Dedicated project app to record image of species killed with online form automatically integrated and visualised with the ALA. Additional functionality to record other variables	Ongoing May 2019	All fauna killed on Brisbane city roads
Western Australia	All locations in an urban setting	Bees in the Burbs in a Biodiversity Hotspot	Inform, raise awareness, and share science-based recommendations for saving native bees. It has secondary objectives of encouraging citizens to go outside and observe native bees, and collect data on when and where native bees are	Spreadsheet accessed via dedicated project website and Facebook group. Sightings can be uploaded to Facebook	Ongoing August 2016	All species of bees

Table 1 (continued)

City/State	Specific Location	Project	Project aims	Data collection and visualisation method	Status and Date Commenced	Target species
All urban environments	All locations in an urban setting with a focus on backyards and green spaces	Birds in Backyards	Find out what influences bird diversity in gardens and yards, urban bush lands, parks and public areas Birds in Backyards is a research, education and conservation program focusing on the birds that live where people live	Observations are made via an app or dedicated website. Findings/ sightings are summarised on project website	Ongoing January 1980 Run quarterly each season	All bird species where people live (not restricted to only urban areas)
Sydney, New South Wales	Peri urban environment	Blue Mountains Urban-bush Interface Monitoring	Monitor impacts of climate change, tourism and urban development on ecosystems at the urban-bush interface in the upper Blue Mountains	Phone app restricted to Scenic World staff not open to the general public. Data automatically integrated and able to be visualised within the ALA	Ongoing April 2018	All flora and fauna observed by Scenic World Staff in the Blue Mountains region
Logan, Queensland	All locations in an urban setting	Wildlife sightings in the city of Logan	Encourage exploration of the outdoors and gather data on native plants and animals in the City of Logan to improve management	Online form accessed via dedicated project webpage. No known data visualisation available	Ongoing June 2018	All flora and fauna
Brisbane, Queensland	All locations in an urban setting	Feral Deer Reporting and Management	Understand and record the numbers and locations of feral deer to help inform management	iNaturalist app and all records imported into the ALA and also via online form on dedicated project website. No known data visualisation available	Fixed December 2019-December 2020	Rusa deer Red deer Fallow deer
Brisbane, Queensland	All locations in an urban setting	Bringing back the Richmond Birdwing Butterfly to Brisbane	Collect observations of *Pararistolochia praevenosa* a food plant of the Richmond Birdwing Butterfly to improve habitat planting	Online database via dedicated website. All data integrated and visualised within the ALA	Ongoing June 2017	*Pararistolochia praevenosa* (Australian vine) and the Richmond Birdwing Butterfly
Perth, Western Australia	All locations in an urban setting	City of Kalamunda biodiversity monitoring	Record the organisms in the City of Perth and make that data freely available globally	Online form with all data provided integrated and visualised within the ALA	Ongoing May 2017	All flora and fauna in the Perth region

Table 1 (continued)

City/State	Specific Location	Project	Project aims	Data collection and visualisation method	Status and Date Commenced	Target species
Sydney, New South Wales	Urban setting but with a focus on green spaces within the city	Tempe Birdos	Record bird data through monthly surveys at Tempe Reserve and Lands	All records submitted via online form direct or entered after the survey to the Atlas of Living Australia. Data able to be visualised in the ALA	Ongoing September 2011	All bird species in the region

Table 2 Urban citizen science projects that provide their data to the Atlas of Living Australia (ALA) directly and number of observations (called a record in the ALA) associated with each project

Project Name	Number of observations
City of Parramatta Wildlife Survey	2
Mosman Wildlife Surveys	7
Bringing back the Richmond Birdwing Butterfly to Brisbane	56
City of Kalamunda biodiversity monitoring	233
Blue Mountains Urban-bush Interface Monitoring	241
B4C Roadkill map	384
Tempe Birdos	1556

(e.g. Melbourne Victoria, Hobart Tasmania, Darwin Northern Territory) and other major cities throughout Australia (although four projects were not city specific). Many of the 19 identified projects also did not provide an easy way to participate in the project such as easy links to platforms to record and upload data (with some projects requesting participants email or phone in information) (Table 1). We were also unable to find any scientific papers where results from any of the 19 projects had been published. While the age of some of the projects can partially be attributed to this gap (Table 1), publications would further strengthen the validity of a citizen science approach in urban environments and add another metric of project success.

Encouragingly, some of the urban projects did make use of phone applications (7 out of 19) which are often the easiest way to increase participation and also ensure data collected has appropriate metadata (time and date) which are essential for quality assurance and quality control. In addition, nearly all projects ensured the data were accessible to the participants and general public with provision to centralised databases such as the ALA or websites where data could be easily viewed and queried, including easy export of data (Table 1). Seventeen projects were listed as ongoing with no clear time frames or progress steps embedded into the design (based on entries into the Project Finder). This makes it difficult for participants to understand how long their contribution will be required and when key milestones will be met. Without clear targets, participation is more likely to wane or limit initial uptake. For seven of the projects we were able to easily query the data and report on the number of observations contributed (Table 2).

Of the 19 projects focused on urban environments, eight facilitated broad census-type approaches focused on birds or all flora and fauna in a region (Table 1). While documenting broad-scale urban wildlife patterns is of course extremely important and useful, the potential exists for urban citizen science projects that are more targeted and guided by

narrower research questions. For example, van der Ree et al. (2006) found that some species are adapting to urban environments and thriving or re-colonising areas they were once extirpated from, often in response to increased availability of resources and habitat. As cities continue to grow and expand, exploration of which species are able to persist and recolonise in urban and peri-urban environments and which have been pushed out is incredibly valuable. Additionally, projects seeking to understand what morphological, biological or ecological species traits lend themselves to urban environments would be incredibly important for policy-makers and urban planners. For example, in our analysis only Big City Birds (Fig. 1) had an explicit aim of understanding species adaptations to living in urban environments.

Regarding more narrowly targeted research, citizen science projects could be potentially valuable for documenting threatened species' distribution and persistence in urban environments. Recent literature has documented the importance of cities as refuges for threatened species (Soanes and Lentini 2019). Ives et al. (2015) found that 30% of Australia's threatened species occur in cities and that a small subset of these are actually highly restricted to cities, especially for flora, such as the fringed spider orchid (*Caladenia thysanochila*) whose distribution is found entirely within a region of Melbourne. Additional research is required to identify and develop focused recovery planning and active management and improvement of urban habitat (van der Ree et al. 2006; Ives et al. 2015; Soanes et al. 2018). However, despite the potential for citizen science projects to contribute to this goal, only two of the 19 projects found focused on a threatened species: The Bring Back the Richmond Birdwing Butterfly project and the Angle Stemmed Myrtle projects (both based in Brisbane). Increasing the number of such projects focus on threatened species in cities could generate the information needed to help shape urban conservation actions and urban design.

Indeed, increasing the awareness of the importance of cities for the protection of populations in a variety of urban habitats remains an ongoing challenge (Soanes et al. 2018; Soanes and Lentini 2019). Many spaces in urban environments such as riparian corridors, road verges and disused railway lines can play an important role in connecting habitat patches across urban areas (Soanes et al. 2018). For example, trees along median strips can facilitate gene flow and connectivity among populations (Threlfall and Kendal 2018). Our search of the Project Finder did not find any citizen science projects with the aim of understanding abundance and patterns of persistence over time in different types of habitat in the urban environment. Citizen science projects that focus on this information could help to generate information needed by planners and raise the profile of urban areas for achieving conservation outcomes (Callaghan et al. 2018).

Fig. 1 The Big City Birds citizen science project focuses on the behaviour of five species of birds that allowed them to adapt to the challenges and opportunities of urban living. Image by Spotteron, supplied by John Martin, and used with permission

Recommendations for urban-ecology citizen science initiatives

Further considerations and efforts are needed to grow participation and maintain momentum in citizen science. Based on our findings and personal experiences, we have developed the following recommendations for those considering designing and developing new citizen science projects in cities.

1. Increase the number of urban based citizen science projects thereby tapping into a large pool of potential participants and addressing gaps in existing citizen science approaches.
2. Give serious consideration to the accessibility of projects to ensure projects are easy to contribute to and join (e.g., via apps and websites) and minimising complicated mechanisms of participation (such a requiring calling to report data). Clear pathways for involvement can be achieved by designing or utilising accessible tools or project infrastructure and data collection methods. This is all the more important given the culturally and linguistically diverse nature of cities.
3. Articulate a common purpose focused on urban ecology and provide clear time commitments and milestones to increase uptake and provide time-poor participants with an understanding of the requirements and goals from the outset.
4. Develop targeted research questions which help address gaps in knowledge, such as projects that focus on adaptability and suitability of species to urban environments.
5. Design projects that improve awareness and understanding of threatened species distribution and persistence in urban environments and how to conserve them.
6. Ensure data are accessible and easy to visualise by non-scientists, and participants understand how they will or can be used to inform basic scientific and applied goals and how the project will be evaluated more broadly.

Challenges of urban citizen science

The challenges associated with citizen science have been widely documented (Bonney et al. 2014; Chandler et al. 2017; Ceccaroni et al. 2019; Adler et al. 2020; Roger et al. 2020), and it is not our intent to fully detail them here. However, we do acknowledge that full realisation of citizen science's potential will take time and require iterative research and invigorated practice to address the authenticity, validity and ethical use of citizen science data for scientific research. To do so, additional investment in support infrastructure and tools, standards and training are required. While issues with data quality and interoperability have been given the most prominence in the literature (Bonney et al. 2014; Chandler et al. 2017), recent studies have documented that accuracy can be comparable to expert-collected data provided that the proper training and tools are used (Aceves-Bueno et al. 2017; Mesaglio and Callaghan 2021). While we acknowledge a citizen science approach is not always appropriate (e.g. safety, technical requirements, sensitive data), the citizen science and research communities need to elevate discussions of and advocacy for citizen science, and demonstrate that, when properly resourced, citizen science can deliver comparable data and results with the potential to inform policy (Mesaglio and Callaghan 2021). This is especially true for urban environments where the majority of the world's people now reside.

An important but complex challenge for the citizen science community to address are more formalised human and animal ethical considerations in project design and implementation. For example, open sharing of sensitive species and culturally significant data has been raised as a concern (Roger et al. 2020). To some extent this is being overcome by the adoption of website features such as species filters (whereby locations for species of concern cannot be identified by the public) or low-resolution spatial data being provided instead of an exact location. There are additional efforts underway globally to address these issues more fully. But animal ethics and the necessary approvals in a citizen science context remain an emerging issue that ethics committees have not routinely considered in the past. Recently the journal 'Citizen Science Theory and Practice' released a dedicated issue on human ethics (Rasmussen and Cooper 2019) and the issues are extensive and beyond the scope of this article to address in full. However, properly addressing human ethics will be particularly challenging given citizen science largely operates at an extra institutional basis (Rasmussen and Cooper 2019). Outstanding issues that require further consideration include equitable access to published studies that use citizen science, lack of oversight and recourse measures, proper attribution, attracting greater diversity and issues of exploitation and payment. It will be an ongoing challenge to ensure these issues are adequately considered but at the same time do not hinder or limit citizen science through structures and processes that are largely inaccessible to the public.

Running citizen science projects designed for urban dwellers also requires perhaps more focused attention in certain contexts and areas in design, implementation, and communication. To attract the wide diversity of participants a city has to offer, urban citizen science projects need to be more mindful of language, social and cultural barriers when communicating about the project. Genuinely making sure projects are more open and accessible can add extra costs and

complexities to designing projects such as producing materials in multiple languages and accessible formats. Project coordinators may also need additional training to work effectively with a wide range of communities to properly address their concerns and tap into their local knowledge. Perhaps the greatest barrier to increasing the number of urban ecology citizen science projects is convincing urban dwellers of the benefits of citizen science in urban areas and that they can make important contributions. One example of a global initiative that is trying to change this narrative is the Great City Nature Challenge (https://citynaturechallenge.org/). The Great City Nature Challenge has been running since 2016 and is founded on a competition among cities, with participating cities encouraging urban observers to gather the most observations about nature over a given time. Projects such as this can greatly increase urban dwellers understanding of biodiversity; however, what is also needed is interpretation and use of the observations for decision-making (reported back to participants) to demonstrate genuine impact and maintain enthusiasm.

Conclusions

Cities are an extreme example of how humans modify their environments (Adler et al. 2020). Professional scientists alone cannot achieve the scale and resolutions needed to fully understand and monitor how urbanisation affects global and local biodiversity. Due to its potential to engage tens of thousands if not millions of individuals, citizen science may represent a more sensitive tool for measuring ecological changes in cities, compared to the more detailed but less frequent and spatially isolated monitoring common to traditional scientific research. Citizen science could also help shift the overriding narrative that cities are dominated by introduced species and are less complex in species composition. This shift may in turn afford greater concentrated effort towards conserving remaining urban green spaces. By involving members of the public in scientific research, citizen science can help researchers and policymakers understand global problems and support local solutions (Roger et al. 2019). For example, Tulloch et al. (2020) highlighted the role citizen science has in monitoring the increased use of urban and peri-urban habitats of bird species after Australia's horrific 2019–20 bushfire season. They noted that citizen scientists are helping document species moving into and using urban habitat as refuges after their habitats burned. Given Australia's population distribution, emerging questions such as the extent of cities as refuges represents an opportunity to trial novel citizen science approaches that could attract a greater diversity of participants from densely populated towns and cities.

Changes in urban environments require close and careful monitoring, and participation in citizen science has the potential to grow public appreciation and understanding of nature and an awareness that it is not confined to wild spaces. In doing so, citizen science can be a quantitative lens to observe our urban environments that can lead to increased understanding of them and how they change, (Callaghan et al. 2019; Mesaglio and Callaghan 2021) and provide an opportunity for urban residents to reconnect with nature (Ives et al. 2018). Such connections can be enabled by networks such as the Clean Air and Urban Landscape Hub (CAUL) in Australia (https://nespurban.edu.au/) and the Urban Wildlife Information Network (UWIN) in North America (https://urbanwildlifeinfo.org/). As global cities continue to expand both in size and human population density, understanding their ecology and the interplay between humans and the natural environment will become all the more crucial. Although our analysis was focused on Australia, we feel the recommendations stemming from it have broader application. However, our primary finding of underrepresentation of urban settings within citizen science projects should be examined in other countries. Despite the challenges, citizen science is one mechanism to better understand our relationship with urban environments. We urge citizen science practitioners to adopt our recommendations thereby enabling residents to engage in their surroundings, share their knowledge and views, generate new knowledge, and, ultimately, play a part in informing the management of biodiversity and greenspaces in their local urban environments.

Acknowledgements We acknowledge and pay respect to the Gadigal people of the Eora Nation, the traditional owners of the land on which we research, teach, work and collaborate at both the University of Sydney and CSIRO. We also acknowledge the feedback from two anonymous reviewers and the editor whose input significantly improved the paper.

Authors' contributions ER & AM conceptualised the manuscript; ER took the lead in writing with contribution from AM.

Funding N/A.

Data availability N/A.

Code availability N/A.

Declarations

Ethics approval N/A

Consent to participate N/A

Consent for publication Yes. We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere.

Conflicts of interest Erin Roger is the former Chair of the Australian Citizen Science Association and employed by the Atlas of Living Australia (based in CSIRO Sydney). Alice Motion is the Host Representative of the Australian Citizen Science Association as a member of the School of Chemistry at the University of Sydney. She is co-chair of the Citizen Science Node at the University of Sydney.

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