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Education

The city nature challenge: A global citizen science phenomenon contributing to biodiversity knowledge and informing local government practices

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Abstract

The bioblitz phenomenon has recently branched into cities, presenting exciting opportunities for local governments to channel participants' efforts toward local issues. The City Nature Challenge (CNC) is one such initiative that has been quickly taken up by hundreds of municipalities worldwide. Despite high levels of participation, we still lack a framework for evaluating how the CNC contributes to local biodiversity knowledge and to inform local government practices. In the present article, we develop such a tool and present a case study that illustrates its applicability. We demonstrate that the collected records contributed to a better understanding of contemporary, local biodiversity patterns and provide a more realistic representation of understudied groups such as insects and fungi. Importantly, we show that the CNC presented local governments with a cost-effective tool to make informed, evidence-based management and policy decisions, improve education and engagement programs, foster cross-council collaborations, and support a stronger sense of environmental stewardship within the local community.

Keywords: bioblitz, codesigned research, community engagement, iNaturalist, urban environments

During the last two decades, the use of the term *citizen science* has exponentially grown within and beyond the scientific literature. This growth reflects the increasing number and diversity of initiatives that synergistically bring together professional researchers and the general public to advance knowledge across a wide array of scientific disciplines (Bonney et al. 2014, Pocock et al. 2017). Citizen science, also referred to as *community science* (Heigl et al. 2019), has gained worldwide traction because of an increasing interest from the general public to contribute to the scientific endeavor. Citizen scientists' contributions have been further facilitated by calls for open science (Murray-Rust 2008, Cribb and Sari 2010) and innovations in web-based and app technologies (Newman et al. 2012). The nature and approach of citizen science projects can be very diverse, with citizen scientists being involved in some or most aspects of the project (Shirk et al. 2012). However, they all aim to achieve similar overall objectives. First, they aim to advance fundamental knowledge and contribute applied tools to solve pressing problems. Second, they aim to bring together input from a diversity of stakeholders in the project design and execution (Kurle et al. 2022). By doing so, they aim to facilitate a relationship among the several parts involved in managing an issue (Roger and Klistorner 2016). Research that promotes diversity of the participating actors not only creates community connections; it also facilitates knowledge transfer and crowdsourcing (Roger and Klistorner 2016) and strengthens the learning experience (Newman et al. 2012, Hartman et al. 2019). Ultimately, it has the potential to catapult changes in management, policy, and governance (Couvet and Prevot 2015, Lowman et al. 2019). Although citizen science projects have made lasting and meaningful contributions across a wide range of disciplines (Pettibone et al. 2017), we draw attention in the present article to projects that were specifically focused on advancing knowledge of biodiversity, promoting education in biodiversity conservation, and increasing the public's involvement with biodiversity-oriented practices at the local scale (Bonney et al. 2009, Dickinson et al. 2010, Dickinson et al. 2012, Pocock et al. 2018).

Biodiversity-based citizen science initiatives have gained enormous momentum, fueled by people's concerns with global environmental change, particularly current and predicted rates of habitat transformation and species loss. Often, citizen scientists

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are recruited as volunteers, to work either independently or alongside professional researchers, to boost the resourcing capacity of projects to collect biodiversity data across larger areas and longer time periods (Pocock et al. 2017). A key challenge is striking the balance among flexibility in data collection, data quality, and the number of volunteers; more elaborate data collection protocols are likely to achieve higher-quality data sets, usually at the expense of smaller and less diverse groups of volunteers (Brown and Williams 2019). A notable example of biodiversity-oriented citizen science projects with well-developed sampling designs, trained volunteers, and long-term professional oversight are those led by the Cornell Ornithology Lab (Bonney et al. 2009), who have successfully built strong connections with their volunteers to study diverse aspects of bird biodiversity, ecology, and conservation (Bhattacharjee 2005). Other initiatives with more relaxed data collection protocols may achieve broader participation; however, their power to answer specific research questions may be more limited. A quintessential example of initiatives with more relaxed data collection protocols are bioblitzes. These are short to medium duration biodiversity surveys, aimed at finding and identifying as many species as possible at a given location, during a specific timeframe (Haywood and Unger n.d.). Bioblitzes are typically organized in natural areas of particular significance, often but not exclusively where biodiversity knowledge is scarce but highly valuable to guide local management. Despite not necessarily being driven by a specific research agenda, bioblitzes are well known for their contribution to contemporary biodiversity knowledge (Ballard et al. 2017, Spear et al. 2017) and the documentation of species not previously known to Western science (Lambkin and Bartlett 2011, Barrett 2015, Cassis and Symonds 2016, Vendetti et al. 2018, Fagan-Jeffries et al. 2019). Importantly, bioblitzes contribute to increase the participants' engagement with nature and conservation, especially those with no previous expertise (Lundmark 2003, Roger and Klistorner 2016, Postles and Bartlett 2018). Recently, the bioblitz movement has percolated to urban environments; this is a largely underexplored space in biodiversity and education research and practice that we believe presents an exciting opportunity to advance knowledge and highlight the value of nature in cities.

Surveying biodiversity across urban environments is key to understanding and quantifying the effects of anthropogenic pressures on biodiversity (Aronson et al. 2014). Greenspaces within cities and towns support ample microbial, fungal, plant, and animal diversity (MacGregor-Fors et al. 2016, Gallo et al. 2017, Threlfall et al. 2017, Aronson et al. 2018, Baldock et al. 2019, Mata et al. 2021). Equally importantly, they provide many sociocultural benefits to people who interact with them (Flies et al. 2017, Lai et al. 2019, Maller et al. 2019, Mata et al. 2020). Remnant bushland, public parks, and other types of greenspace typically visited by urban bioblitz participants embody the day-to-day opportunity to be in contact with nature for the majority of city dwellers. Not surprisingly, a wide range of urban stakeholders—from researchers, practitioners, built-environment professionals, conservationists, and policymakers to wildlife gardeners, Indigenous communities, ArtScience advocates, and friends-of groups—are increasingly and often synergistically working toward promoting and demonstrating the benefits of urban greenspaces for both people and the rest of nature (Aronson et al. 2017, Lepczyk et al. 2017, Nilon et al. 2017, Parris et al. 2018, Soanes et al. 2019, Cumpston 2020, Mata et al. 2020, Mumaw and Mata 2022, Renowden et al. 2022). Urban bioblitzes provide an opportunity to simultaneously gather biodiversity records across greenspace networks (Rega-Brodsky et al. 2022) and strengthen the link between city dwellers and the governance of biodiversity and ecosystems in urban environments (McPhearson et al. 2016). By leading these initiatives, local governments and naturalist groups are key players in channeling citizen science efforts toward specific local issues and in promoting the use of a centralized data collection repository across participants and projects (Kobori et al. 2016). In this study, we focus on the City Nature Challenge (CNC for short), because we recognize that it represents an outstanding example of a global biodiversity-oriented urban bioblitz event (box 1).

Although the CNC and other related projects (e.g., the Great Southern Bioblitz) have been very successful in contributing biodiversity records and have been readily taken up by hundreds of municipalities and shires across the world (box 1), there is limited evidence on how data produced by urban bioblitzes are contributing to increased biodiversity knowledge at the scale of local governments. We argue that the CNC provides a unique opportunity to quantify how biodiversity knowledge changes at the local government scale. Specifically, we contend that data derived from the CNC can be easily analyzed in the context of a given local government area or areas to assess the number and identity of species that are likely locally extinct, are currently present but have not been recently recorded, and have not previously been recorded, whether because they have remained historically undetected or have only been recently introduced into the area (figure 3). In the present article, we present empirical evidence to support these points using a case study from Melbourne, Australia, that embodies the power of citizen science to advance biodiversity knowledge and citizen engagement in urban environments. We then discuss how local governments have been taking up and translating new knowledge acquired during the CNC to inform and improve their urban nature and community engagement practices. Finally, we argue for ways in which the theoretical advances and empirical protocols we present in this study may be robustly transferred to inform the practices of other local government areas and discuss the benefits of scaling up our evaluation approach to regional and global scales.

City Nature Challenge 2021: The Melbourne Eastern Metropolitan Area node

The Melbourne Eastern Metropolitan Area was a node of the CNC 2021 constituted by eight local government areas from eastern Melbourne, Australia (box 2). Council staff led the organization of the node and teamed up with local naturalist groups, learned societies, and friends-of groups to run biodiversity surveys together. They also engaged academic researchers to codesign the evaluation that led to this work.

During the CNC 2021, the 291 participants of the Melbourne Eastern Metropolitan Area node contributed 4638 biodiversity records representing 974 taxa across nine broad taxonomic groups (supplemental tables S3 and S4). These records indicate that the participants found around 1% of the 2112 species that had not been recorded recently—that is, in the last three decades—for this area (supplemental table S5, figure 4e), therefore providing evidence these species have not gone locally extinct. The participants also documented about 10% of the 4206 species that had been recently recorded for this area in biodiversity repositories (supplemental table S5, figure 4h). In addition, the participants found 135 taxa that had never been recorded in this area (figure 4g), increasing the local species richness by almost 4% (supplemental table S5). At least 22 of these newly recorded

Box 1. City Nature Challenge.

The City Nature Challenge (CNC for short) began in the United States in 2016, when staff at the Natural History Museum of Los Angeles and the California Academy of Sciences conceived a friendly competition between San Francisco and Los Angeles to see which city could record the largest number of species by the largest number of participants during 8 days (https://citynaturechallenge.org). Over the following years, an increasing number of cities have joined this initiative (figure 1a) and called on their residents to find

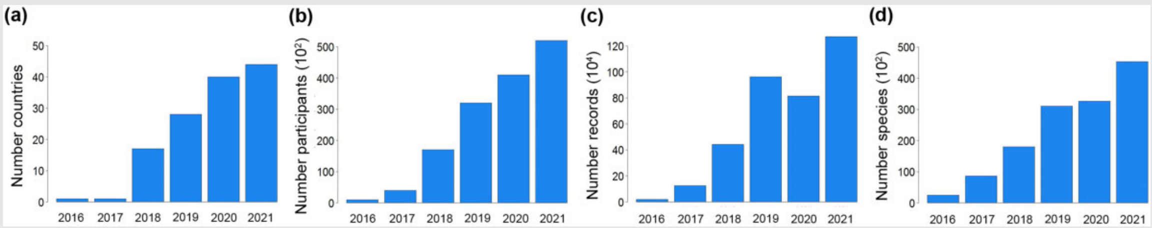

Figure 1. The number of countries (a) and participants (b) per year who took part in the City Nature Challenge from 2016 to 2021, along with the number of records contributed (c) and species found (d) per year for the same period.

and document an increasing amount of urban biodiversity (figure 1b–1d). In just 6 years, the CNC has evolved to be an internationally recognized urban bioblitz event. Every year, at the end of April, citizen scientists globally come together for 4 days to document the largest possible number of species in urban areas. By 2021, CNC initiatives spread to over 400 cities across more than 40 countries. During 2021, over 1,200,000 records of more than 45,000 species were collected by approximately 52,000 participants (supplemental table S1). These figures, however, varied greatly across the participating countries (from 36 to 567,129 records contributed by a single country; figure 2), with the United States and South Africa being the countries contributing the largest number of records (supplemental table S2). Despite the competitive nature of the CNC, where urban nodes compete against each other to tally the highest count of local species, this initiative allows participants worldwide to collaborate and contribute to document biodiversity patterns at global level.

Record collection is done through media, commonly photographs, and shared into virtual platforms—often iNaturalist (see appendix A in the supplemental material). This is a nondestructive, open source, and media-verifiable sampling approach that leads to presence-only data (i.e., absence of species is not documented directly). Once observations are uploaded to the virtual platform, they can be seen and identified by the entire virtual community within the platform. The fact that observation contribution and identification can be done simultaneously or at different times or by different people makes participation in the CNC open to anyone, and equally importantly, tailored to anyone's interests and skills. It is perhaps the flexible nature of this methodology and its inclusivity regarding participation what has driven its rapid uptake worldwide.

Coordination across CNC nodes to collect observations in a common virtual platform results in large spatial coverage of biodiversity in urban areas, and provides a transparent way to compare observations across cities by anyone within or outside the CNC community. Observations collected through the CNC are openly available to download and use by anyone; scientists increasingly include urban biodiversity data collected by citizen scientists in their research (Rega-Brodsky et al. 2022). Moreover, observations that are identified to a certain degree of community consensus (e.g., *research grade* in iNaturalist) are automatically shared with other global biodiversity information platforms (e.g., Global Biodiversity Information Facility, Atlas of Living Australia). Finally, lessons learned through CNC data are quickly absorbed by local governments and organizations to make more-informed management decisions, update policy, or create tools to deliver education programs (see the "Lessons learned: Uptake of City Nature Challenge findings by local government" section).

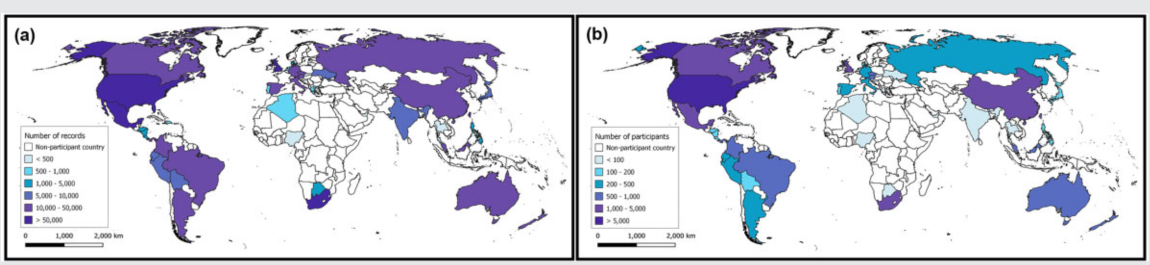

Figure 2. (a) The number of observations collected across countries that participated in the 2021 City Nature Challenge. (b) The number of participants for each country during the 2021 City Nature Challenge.

species were introduced to Victoria (supplemental table S3, supplemental figure S2).

Even though biodiversity repositories point to an overwhelming interest in documenting birds over other taxonomic groups, the CNC participants recorded a high level of diversity for other groups—in particular, plants, insects, arachnids, and fungi (supplemental table S4). The records from the Melbourne Eastern Metropolitan Area node also showed that the highest number of rediscovered and newly recorded species belong to these taxonomic groups. These findings indicate that the CNC provides

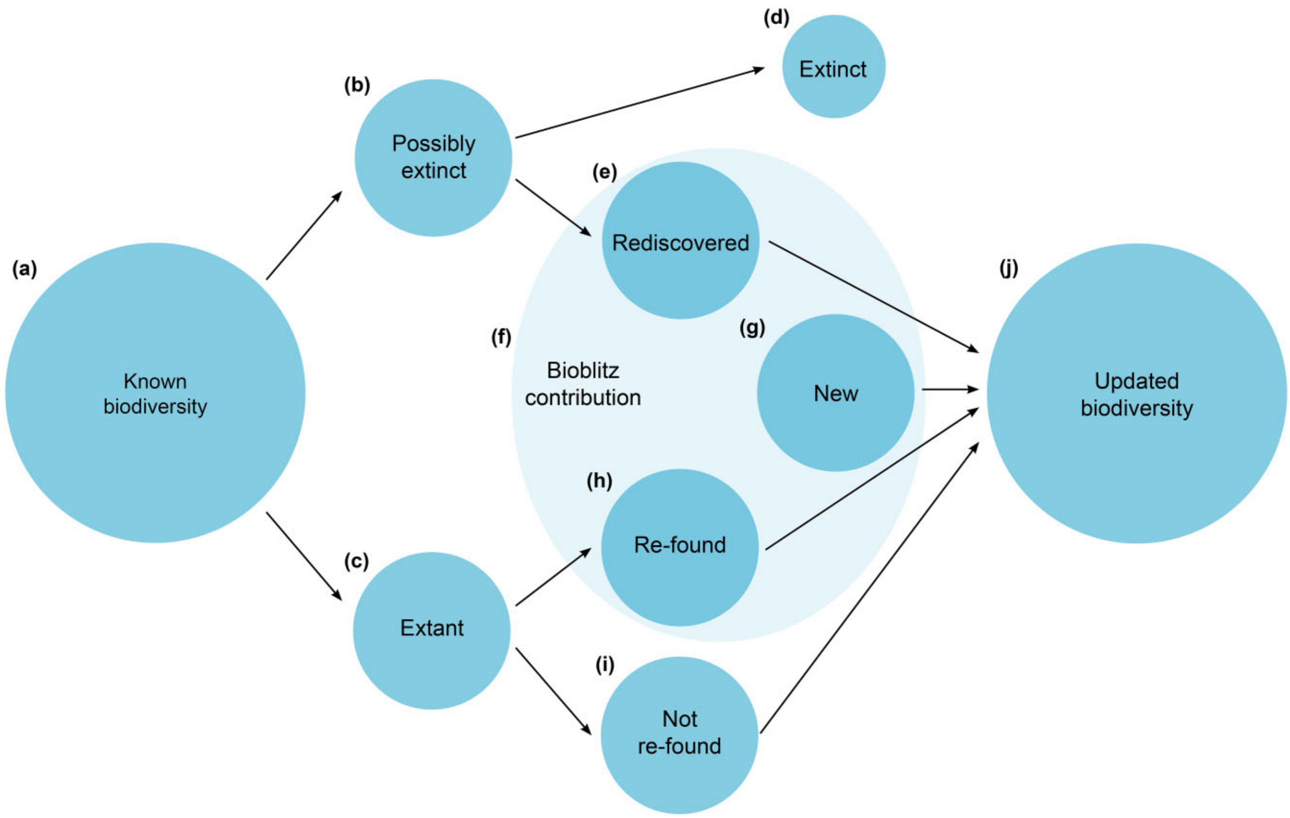

Figure 3. Conceptual framework of the contribution of citizen science events to local biodiversity knowledge. (a) The biodiversity known to the area before citizen science activity (species with historical or recent records on biodiversity repositories). (b) Possibly extinct species (species with historical but no recent records on biodiversity repositories). (c) Extant species (species with recent records on biodiversity repositories, with or without historical records). (d) Extinct species (species for which records will not be found anymore because they have gone locally extinct). (e) Rediscovered species (species with historical, but no recent, records—thought to be possibly extinct—for which records have been found during citizen science activity). (f) Species found during citizen science activity. (g) Newly discovered species (species without neither historical nor recent records that were found during citizen science activity). (h) Rediscovered species (extant species, with recent records on biodiversity repositories, found during citizen science activity). (i) Not re-found species (extant species, with recent records on biodiversity repositories, missed during citizen science activity). (j) Updated biodiversity known to the area after citizen science activity.

a way to gather records for taxonomic groups that traditionally have poor representation across global biodiversity repositories, especially in terms of recent records (e.g., insects; figure 4). Although the differences were subtle, the analytical framework proposed in this work (figure 3) provides an updated picture of local biodiversity with a better representation of traditionally understudied groups (e.g., arachnids, fungi; figure 4) and a slightly larger proportion of species introduced to Victoria (supplemental figure S2).

Using the biodiversity records collected by the participants in the Melbourne Eastern Metropolitan Area node, we also investigated different aspects of participant engagement. Out of the 291 citizens who collected records across this node, about 10% were organizers—including council officers and experts corunning the events—and 90% were members of the public. The participants showed large variation in the number of records and species they reported, with CNC organizers contributing around 10 times more than the members of the public (supplemental table S5, figure 5a, 5b). While over half of the participants contributed five or fewer records, eight participants only—all of them CNC organizers—contributed over a third of the totality of records (figure 5c). Consequently, the contribution of records by the participants was overall skewed toward small values.

Then, we turned our attention to the participants of the Melbourne Eastern Metropolitan Area node and their relationship with the iNaturalist data collection platform (supplemental table S6). Around 5% of existing iNaturalist users (i.e., those who had previously contributed records to this area) also contributed records during the CNC. Furthermore, the number of local iNaturalist users increased almost 8% during the same period (supplemental table S5).

Finally, we focused on the biodiversity records that the participants of the Melbourne Eastern Metropolitan Area node collected from urban greenspaces and examined whether their collection was spatially uniform. We found that the participants did not contribute observations evenly across greenspaces, both within and across councils (supplemental table S5, figure 6a, 6b). The participants collected one or more records from slightly over a quarter of the greenspaces across the node (supplemental table S5, figure 6a). Overall, the probability that the participants had visited individual greenspaces increased strongly with the size of the greenspace (supplemental table S5), with more records being contributed from larger greenspaces, whereas the probability that the participants had visited greenspaces smaller than 100 square meters was close to zero; at least a fifth of the greenspaces above 1,000,000 square meters were visited by the participants (figure 6c).

The unstructured and opportunistic nature of biodiversity records collected during the CNC likely resulted in some spatial and taxonomic biases within the records contributed by the

Box 2. Evaluation approach for the Melbourne Eastern Metropolitan Area node of the 2021 City Nature Challenge.

The Melbourne Eastern Metropolitan Area node of the 2021 CNC was born as an *ad hoc* collaboration between the City of Boroondara, the City of Greater Dandenong, the City of Knox, the City of Manningham, the City of Maroondah, the City of Monash, the City of Stonnington, and the City of Whitehorse (supplemental figure S1). This area collectively houses about 1.27 million inhabitants (Australian Bureau of Statistics, https://dbr.abs.gov.au) and covers approximately 650 square kilometers, with slightly over 10% of that area being open greenspace.

The notion of these local governments working together toward what eventually became the Melbourne Eastern Metropolitan Area node of the 2021 CNC was initially prompted by a simple question from one officer to others in neighboring councils “Would any of you be interested in coordinating a bioblitz for your Council as part of the City Nature Challenge?” Officers from six local governments indicated a willingness to do so, and two more were recruited by the time the 2021 CNC commenced. The extent of participation was flexible and up to each council on the basis of what they were willing and able to do. Other than officer time to organize, costs were limited to delivering and promoting online activities associated with learning how to use iNaturalist in the lead up, and surveying activities that showcased different elements of nature (typically led by someone with local knowledge or expertise). The councils’ communications departments were engaged to assist with creating a webpage, online event registration, and social media marketing. The main organizer of the surveying activities were local government staffers, who reached out to local biodiversity champions (usually members of environmental groups) and not-for-profit learned societies (e.g., Entomological Society of Victoria) to host and lead individual events. In general, activity leads were remunerated for their contributions. Local government buy-in was largely motivated by the opportunity to collaborate with peers and the relative simplicity of getting involved (set up an iNaturalist project, organize as many or as few activities as each local government felt possible, and use existing communication methods to promote and encourage participation).

The CNC evaluation for this node revolved around three pillars: assessment of the local knowledge gained from the biodiversity records contributed during the CNC, analysis of the CNC participants’ engagement, and evaluation of the use of available greenspace by CNC participants.

To assess whether the CNC resulted in significant local knowledge gain, we summarized the CNC findings in light of existing biodiversity knowledge (figure 3), represented by biodiversity records previously available in open source, global biodiversity repositories for the same area.

To analyze CNC participants’ engagement, we first looked at the contributions made by different participant types (i.e., members of the public versus CNC organizers). Then, we checked the degree to which the already existing iNaturalist community contributed records to the CNC, and the growth of the iNaturalist community during the CNC.

Finally, we evaluated the use of greenspace across the Melbourne Eastern Metropolitan Area node by CNC participants. To do this, we estimated the percentage of greenspaces where at least one record was collected, and then investigated whether the probability of greenspaces being visited depended on greenspace size.

A detailed explanation of our methodological approach, including data sourcing, statistical models and code is given in the supplemental material (appendix B).

participants of this node (Geldmann et al. 2016, Mesaglio and Callaghan 2021). Notably, more than half of the observations were recorded from a handful of large greenspaces. This trend was likely exacerbated by the fact that the biodiversity surveys organized by the Melbourne Eastern Metropolitan Area node were largely run from well known, large greenspaces. What is more, the expertise of the organizers or facilitators of these activities likely resulted in a larger contribution of records and species for particular taxonomic groups they were experts on. For example, the involvement of the Entomological Society of Victoria in several events certainly drove the large contribution of insect records (figure 4e, 4g–4h). Reporting preferences toward common or more familiar species, as well as those easier to detect, have been previously highlighted in the citizen science literature (Di Cecco et al. 2021, Johnston et al. 2022). In the Melbourne Eastern Metropolitan Area node, 20 of the most highly reported 25 individual species were birds or plants. In addition, the timing of the CNC may have an impact on the diversity of the taxa found for some groups, especially in the southern hemisphere; although fungi abound in April, other groups such as grasses and herbs may not be easily found or identified at this time of the year. Running other citizen science activities complementary to the CNC can help to overcome this limitation. Particularly, the Great Southern Bioblitz (www.greatsouthernbioblitz.org), which runs toward the end of the year and shares methodology and platforms with the CNC, represents an excellent opportunity to gain some synergy and amplify the diversity of taxa that citizen scientists can find in this node.

Beyond their contribution to understanding of local—and, ultimately, global—biodiversity, ongoing CNC-type events present local governments with cost-effective tools to make informed, evidence-based management and policy decisions. When citizen science initiatives are diverse (e.g., cover different areas within a management unit) and sustained through time, findings can support medium- and long-term conservation actions (Kobori et al. 2016). Examples include prompt protection of endangered or charismatic species (e.g., Park Victoria’s Data Discovery Program in Victoria, Australia), creation and monitoring of healthier habitats for humans and other species (e.g., Rakali as an indicator of river restoration success in Australia), planning for future climate scenarios, and early management of introduced species (e.g., European firebug in Melbourne, Australia; Mata et al. 2022). Local governments and conservation groups are key actors in transforming citizen science findings into real, tangible management actions.

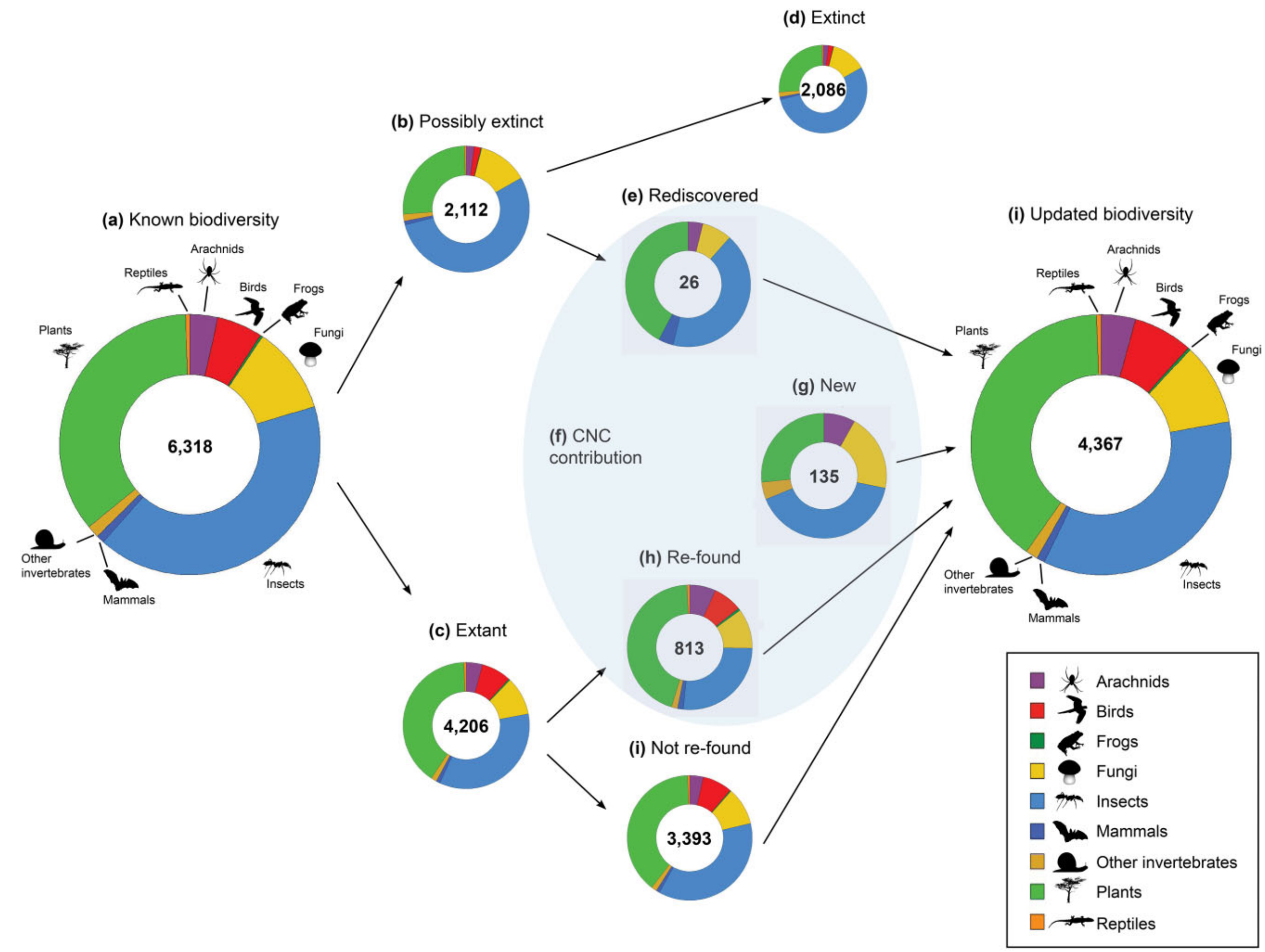

Figure 4. Contribution of the observations collected during the 2021 City Nature Challenge to local biodiversity knowledge from the Melbourne Eastern Metropolitan Area node. See supplemental table S4 for summaries of each taxonomic group.

Lessons learned: Uptake of City Nature Challenge findings by local government

For many of the participating municipalities the Melbourne Eastern Metropolitan Area node during the 2021 CNC was the first opportunity to organize and run an urban bioblitz event. Some of the aspirations and lessons learned through this experience are shared below.

Education and engagement programs

One of the overriding benefits of the CNC bioblitz experience was the opportunity to facilitate activities that invited local people and communities to connect with nature through organized events or that encouraged people to capture records as part of their day-to-day routine. The participants included a wide cross-section of the broader community, with young people, older people, and people from culturally and linguistically diverse (CALD) backgrounds taking part, and the organizers received positive feedback about their experiences working alongside biodiversity experts, and participating in hands-on learning approaches. The use of the iNaturalist platform also opened up opportunities to connect with nature in a nonphysical space, with features such as commenting and agreeing with observations enabling access to biodiversity for other community members who had reduced capacity to visit the bushland environments in person for various reasons.

Another positive benefit was the increased exposure for local conservation groups and bushland reserves. Through the CNC bioblitz activities, the local community had a chance to become more aware of their local reserves and biodiversity, and for some people, particularly the CALD members of the community, the time spent in these places fostered a greater familiarity and appreciation for these sites. The experiences and greater familiarity are also likely to create deeper appreciation and passion for the local environments, which could translate to a more active network of citizens who may go on to participate in a wider range of programs, including wildlife gardening, nature strip planting, friends-of groups, and other related programs focused on sustainability and environmental stewardship.

The overarching hope is that events such as the CNC will help empower and enable residents to become stewards of biodiversity and seek out practical ways to continue to support local biodiversity in their gardens, streets, and local parks and reserves.

Citizen scientists

Participating in the CNC bioblitz provided individuals with the tools and knowledge to become more active citizen scientists and contribute high-quality data of the biodiversity in their neighborhood. Over time, there is the potential to create an expanded network of citizen scientists with a collective identity similar to other volunteering groups. These groups could self-organize or work in

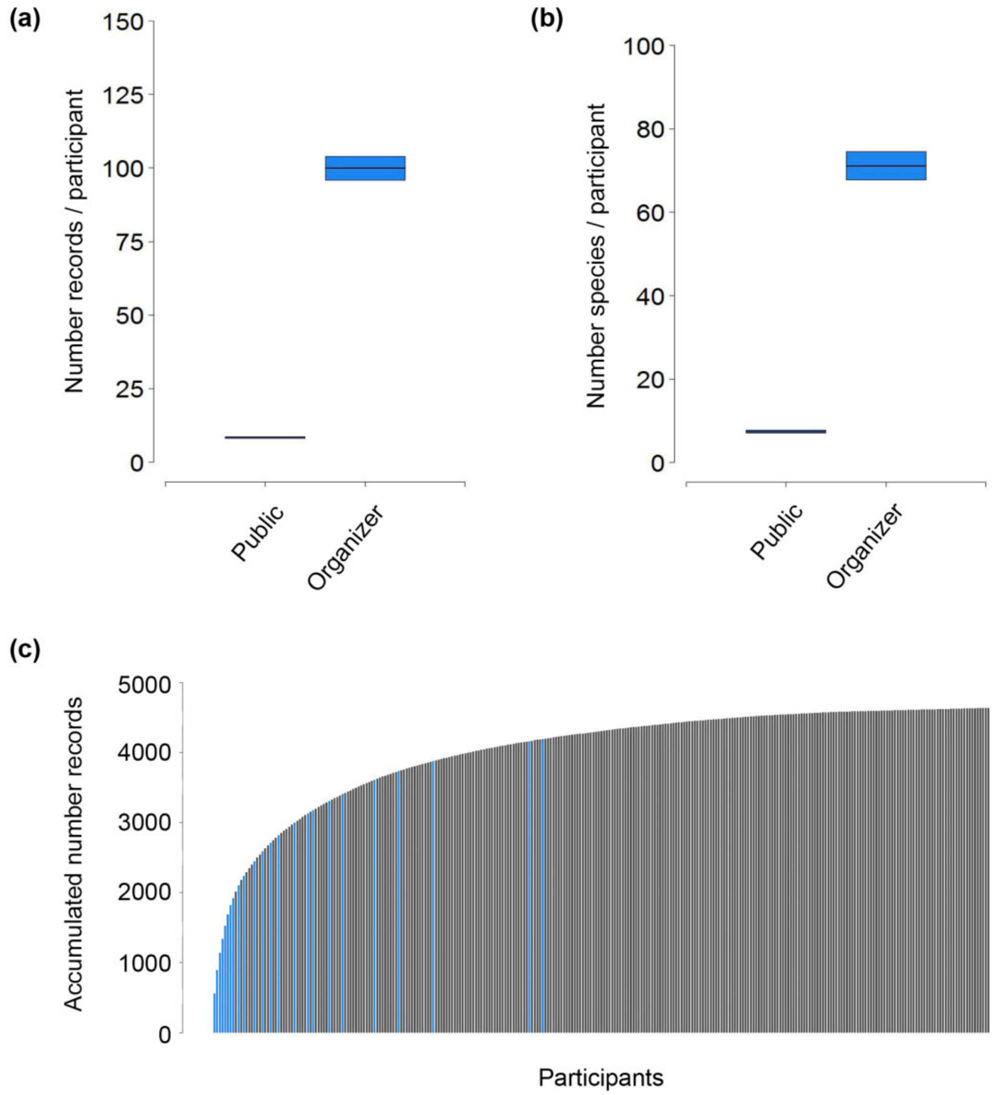

Figure 5. Participants' contribution to the 2021 City Nature Challenge across the Melbourne Eastern Metropolitan Area node. (a) Number of records contributed by different types of participants (members of the general public versus CNC organizers). Black lines represent mean estimates and blue areas the associated 95% credible intervals. (b) Number of species contributed by different types of participants (members of the general public versus CNC organizers). Black lines represent mean estimates and blue areas the associated 95% credible intervals. (c) Accumulated number of records contributed by participants. Participants are ordered from largest to smallest contribution in number of records, with members of the general public (n = 267) shown in black and CNC organizers (n = 24) show in blue.

partnership with local councils to begin documenting biodiversity more strategically across time (e.g., seasons or throughout the day or night) and space (e.g., surveying areas where there are information gaps), or to target particular species or groups. This will build a more comprehensive data set that is updated more frequently than would be possible if local councils were commissioning surveys. Given that there are spikes in iNaturalist users during the CNC bioblitz events and that the drop after the event remains at a higher baseline than prior to the event, there is a strong indication that this will become a reality for many local councils. We note that the common thread linking citizen scientists participating in CNC bioblitz events—independent of whether they have been organized by local governments, not-for-profits or nongovernmental organizations—is the iNaturalist platform, which brings together all the data collected by citizens scientists irrespective of who or how they were encouraged and motivated to do so. The CNC provides an appealing entry point into the world of collecting biodiversity data. The challenge remaining, then, is how to retain citizen scientists across events and increasingly develop their capacity to collect quality data.

Municipality led conservation programs and applied research

The potential for bioblitz events to become a key source of information for local governments is still in the foundational stages, because the events to date have largely been framed as community engagement and education activities that encourage connection to nature and provide an entry point into citizen science. However, as the citizen scientist movement grows, there is increasing potential for them to contribute timely, targeted, and high-quality records that can be used to inform policies and practices around management, education, and other areas of codeveloped research. This model of citizen science can also be used to

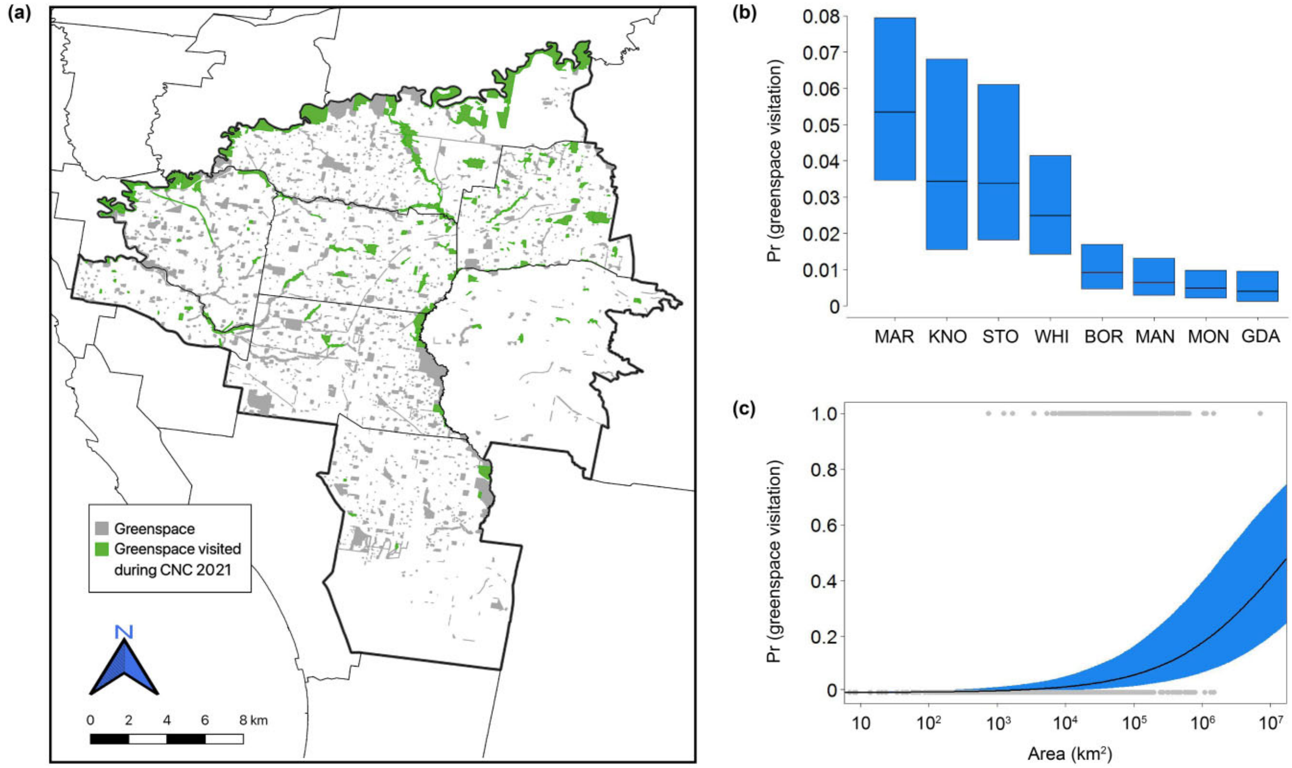

Figure 6. (a) Greenspaces visited during the 2021 City Nature Challenge (in green) from all the available greenspaces (in grey) across the Melbourne Eastern Metropolitan Area node. (b) Probability of greenspace visitation across the eight city councils that formed the Melbourne Eastern Metropolitan Area node during the 2021 City Nature Challenge. Black lines represent mean estimates and blue areas the associated 95% credible intervals. (c) Effect of area on the probability of greenspace visitation. The black line represents the mean estimate, the blue area the associated 95% credible interval, and the grey dots the data used to fit the model.

monitor the outcomes from projects to feed into adaptive management programs and evaluate success. The data collected can also be used as evidence to support funding requests, inform advocacy around key issues, and generally develop a deeper understanding of biodiversity in the local context.

The applied research and direct input of data into decision-making is not just limited to biodiversity resilience plans; it can also be used for planning, designing, improving, and protecting urban greenspaces and habitat connectivity corridors; informing climate response plans; and monitoring and managing invasive species or biosecurity risks. Because multiple councils have collaborated during the CNC, there is also the opportunity for thinking and working at larger scales, pooling resources, and sharing learning to accelerate progress toward improved outcomes.

Next steps toward future vision

Although citizen scientist participation in urban bioblitzes such as the CNC have enormous potential to benefit biodiversity outcomes, there are still many gaps in our knowledge about how to maximize this potential. Some areas for additional investigation are presented below.

First, how do different approaches to event organization influence the outcomes in terms of biodiversity records across time, space, and taxa? This question can be investigated for local events but really benefits from taking a larger picture look at events at the global scale. For example, what role does the participation of experts or friends-of groups have on the type of data collected and long-term citizen science uptake or biodiversity stewardship? Can strategic messaging (e.g., a focus on reptiles or nature strips) or selection of event locations (e.g., parks or suburbs with very few records) help fill data gaps in a constructive way?

Next, how can the bioblitz model be adjusted to allow for biodiversity records to be collected across different seasons? For example, the timing of the CNC is toward the end of the active period for biodiversity in the southern hemisphere, so participation in the Great Southern Bioblitz can help complement records collected during the CNC. Encouraging the continued use of iNaturalist to record incidental biodiversity sightings outside of the formal bioblitz and empowering local groups to take on their own coordination of local collection events under the model described in the previous section will also help ensure records are collected over a broader spatial and temporal scale.

Finally, how long does it take to develop a consistent picture of biodiversity for an area through the bioblitz model of citizen science? Are there ways to accelerate this journey through activities identified in the previous steps or to provide clear demonstrations of how data are currently being used to inform management practices or policies? This is where the real strength of the framework we present in figure 3 and the analysis we present in figures 4–6 come to the fore.

Scaling up to regional and global scales

We have shown that the contribution of biodiversity-based citizen science activities to the current biodiversity knowledge can be analyzed through a simple, reproducible approach (figure 3). Tools to evaluate the success of different dimensions of citizen science are urgently needed (Jordan et al. 2012, Kieslinger et al. 2018, Schaefer et al. 2021). In the present article, we demonstrate that the biodiversity data collected through bioblitz-type activities can be used to evaluate both their contribution to biodiversity knowledge and some aspects of participants' engagement. Social metrics to evaluate satisfaction, learning, or connectedness to nature could complement this approach to provide a more comprehensive picture. The approach presented in this work can be readily taken up by, potentially, every participating node of the CNC on a given year and across years to evaluate nodes' relative success. Moreover, the evaluation could be easily scaled up, with the totality of records collected yearly through the CNC compared with the totality of known biodiversity worldwide—for example, as compiled in the Global Biodiversity Information Facility (www.gbif.org).

Our shared experience of the 2021 CNC as a collaboration between city practitioners and biodiversity researchers has delivered enormous benefits for identifying a shared vision of how to maximize benefits from future bioblitz events. By working together and blending our individual knowledge and experiences we have begun to form a grander shared vision of the role that bioblitz style events can play in growing biodiversity knowledge, decision-making, and stewardship in the urban context. We look forward to working together on the next steps and sharing our progress with the broader global community.

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Supplemental Material

Supplemental data are available at *BIOSCI* online.

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