CITIZEN SCIENCE:
THEORY AND PRACTICE

How Citizen Science Projects Contribute to Urban Biodiversity Monitoring and Conservation Frameworks—A German Case Study

COLLECTION:
CONTRIBUTIONS OF CITIZEN SCIENCE TO THE UN SDGS

RESEARCH PAPER

SILKE L. VOIGT-HEUCKE
MORITZ MÜLLER
JULIA ROSTIN

*Author affiliations can be found in the back matter of this article

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ABSTRACT

Urban ecosystems provide diverse habitats for plants and animals. Policies can protect these ecosystems. To do this, policy frameworks need robust datasets to monitor and report on trends. Citizen science (CS) projects can make a valuable contribution by helping to build, refine, and supplement datasets. The overall aim of this study was to identify and characterize the contribution of CS projects to urban biodiversity monitoring and conservation frameworks in Germany. To gain an overview of the CS landscape in relation to urban biodiversity, we first examined German project platforms and were able to identify a geographical concentration in Berlin. We then focused on the contribution of CS to biodiversity monitoring in Berlin. We created an online questionnaire and conducted interviews with 22 Berlin-based CS project coordinators. In particular, we asked: How does their CS project contribute to the monitoring and conservation of urban biodiversity? What is the type of citizen engagement? What are the objectives of their CS projects, and what are their challenges? What are the outputs of their CS projects, and how do they publish their data? Finally, what is their knowledge of global, national, and local conservation frameworks? Our findings show that CS projects in Berlin are making a meaningful contribution to biodiversity monitoring. However, there is considerable potential for development, particularly in terms of awareness of policy frameworks and the sharing of data. We recommend increasing opportunities for exchange between policymakers and practitioners, and creating interfaces for data sharing to unlock the potential of CS projects for urban biodiversity conservation.

CORRESPONDING AUTHOR:

Silke L. Voigt-Heucke

Museum für Naturkunde Berlin, Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany

silke.voigt-heucke@mfn.berlin

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INTRODUCTION

The human impact on the world's ecosystem is of such importance that the term Anthropocene has been introduced as a new and predominant geological age (Crutzen 2002). At the present time, according to the Federal Agency for Nature Conservation, more than two thirds of the total German population live in densely populated areas (BfN 2018). Looking at developments worldwide, estimates suggest that the trend of urbanization will continue well into the 21st century (Brockerhoff 2000). To consolidate existing strategies and develop innovative ideas, it is necessary to harness the knowledge of humankind and involve the public. One powerful approach to do so is citizen science (CS) (e.g., Hecker et al. 2018; Hyder et al. 2015; Phillips et al. 2019). It has been highlighted as a valuable method to generate research for conservation efforts (e.g., Turrini et al. 2018; Cooper et al. 2007), and has great potential in urban biodiversity research (Wang Wei et al. 2016; Theobald et al. 2014). At the same time, it strengthens citizens' trust in science, promotes understanding of the respective research topic, and thus also contributes to the education of the participating citizens (Haywood and Besley 2014; Roche and Davis 2017; Shirk et al. 2012). In addition, environment-related citizen science projects can increase participants' awareness of environmental issues and foster their sense of ecological responsibility (e.g., Ballard et al. 2017; Bonney et al. 2014; Shirk et al. 2012). Citizen science has already played an important role in providing support and information for biodiversity programmes and frameworks. In Germany, for example, the so-called Krefeld study of insect mortality by the Entomological Society Krefeld has attracted public attention: This long-term study involves citizen scientists in the development and data collection. One of the project's findings was recently published, highlighting that surveys in 63 German protected areas between 1989 and 2016 found a decline of 76 per cent (up to 82 per cent in midsummer) in the biomass of flying insects (Hallmann et al. 2017). The study highlighted that access to data and insights from citizen scientists is essential for biodiversity monitoring and conservation—not only for science, but also for assessing environmental impacts as part of policy action programmes and strategies.

In order to preserve and protect biodiversity at a global, local, and regional level, policy frameworks with measures and strategies have been developed. As early as 1992, the importance of biological diversity and its global endangerment was addressed at the UN Conference in Rio de Janeiro, Brazil, and the Convention on Biological Diversity (CBD) was adopted. It contains binding targets under international law for conservation, but also for the equitable and sustainable use of biological diversity. Germany has agreed to this convention and developed the National Strategy for Biodiversity (NBS) in accordance with Article 6 of the CBD (BMU 2007). This was approved in 2007 and contains general measures for the conservation and sustainable use of biological diversity (BMU 2007). At the state level, for example, Berlin as the German capital also adopted the Berlin Biodiversity Strategy in 2012 (SenStadtUm Berlin 2012). Conceptually, the Berlin strategy echoes the German NBS, but goes into greater depth on the importance and protection of urban areas. According to its own formulation, the Berlin strategy "[...] shows exemplary ways in which biological diversity can be preserved and promoted in a modern metropolis—for the benefit of the people living here" (SenStadtUm Berlin 2012). The Berlin strategy, for example, directly addresses increased support in the field of environmental education and nature conservation with "Goal 38 Social Engagement." The statement clearly articulates that the social engagement of volunteers contributes significantly to the conservation of biodiversity (SenStadtUm Berlin 2012). The German NBS also takes up the term citizen science and illustrates the contribution to monitoring tasks with concrete project examples (BMU 2007).

Given that policy frameworks at global and local levels are in critical need of biodiversity data to meet their reporting obligations (Geijzendorffer et al. 2015), community engagement in biodiversity monitoring should not be limited to a few lighthouse projects, such as the Krefeld study, but needs to be established on a broad scale. This is particularly true for urban ecosystems, where conservation is inextricably linked to the engagement of densely populated urban communities. We therefore aimed to conduct a study to assess and better understand the contribution of citizen science projects and the knowledge of project coordinators in relation to urban biodiversity monitoring and conservation frameworks in Germany.

First, we conducted a desktop search to obtain a general overview of the German CS landscape in relation to biodiversity in urban areas. We surveyed different platforms for urban biodiversity CS projects and systematically categorized them according to organizational structure, project initiators, geographical location, and disciplines. The question of potential initiators for CS projects in general has been addressed several times in the scientific community prior to our study (e.g., Ballard et al. 2017, Pettibone et al. 2017; Phillips et al. 2021, and Sforzi et al. 2018). An analysis by Pettibone et al. (2017) of the German citizen science project platform *Bürger schaffen Wissen* showed that most projects were initiated with or by non-university institutions, followed by NGOs, and in third place by or together with universities. However, according to our research, there has been no geographic analysis of CS projects related to urban biodiversity research. It is likely that it is in densely populated areas that the public's need for urban nature is most apparent, and that a variety of opportunities to

explore and protect it arise for CS projects. Thus, potential initiators of CS projects, such as universities, research institutions, and NGOs, may also benefit from engaging with urban communities in particular. To better explore the potential of citizen science in relation to urban nature, it is necessary to analyse existing projects in detail. In general, previous studies focusing on the overall CS landscape have shown a focus of CS projects in the life sciences, especially in the subfields of biology, ecology, and conservation (e.g., Hecker et al. 2018; Kullenberg and Kasperowski 2016). However, to the best of our knowledge, we are not aware of research to date that focuses exclusively on understanding the structure of CS projects that focus on biodiversity monitoring in urban areas.

Second, using Berlin as an example, we aimed to specifically identify and categorize the contribution of CS projects to biodiversity monitoring and conservation. The German capital Berlin is not only home to 3.7 million people (Amt für Statistik Berlin—Brandenburg 2019), but also to about 20,000 additional animal and plant species (SenStadtUm Berlin 2012; SenUVK Berlin 2019). Despite the establishment of biodiversity programs and strategies such as the European Habitat-Directive, the *Natura 2000 Network*, and the regional *Berlin Biodiversity Strategy* (2012), biodiversity in Berlin is under pressure. With about 44% of all occurring animal and plant species, a higher proportion is endangered than at the federal level (Saure and Kielhorn 2005). To assess the contribution of CS projects to urban biodiversity monitoring, we examined the structure and objectives of CS projects, the dissemination of results and data, and the knowledge of project coordinators about global, national, and regional biodiversity frameworks.

METHODS

IMPLEMENTATION OF OUR RESEARCH AND STUDY PERIOD

We conducted a two-fold study, desktop research, and an online questionnaire among CS projects in Germany and Berlin from March 2021 to February 2022. All data and information on CS platforms and CS projects in Germany and Berlin refer to this period.

DESKTOP RESEARCH ON CITIZEN SCIENCE PROJECTS RELATED TO URBAN BIODIVERSITY MONITORING AND CONSERVATION IN GERMANY

A survey of citizen science platforms for projects related to urban biodiversity monitoring and conservation in Germany

We systematically surveyed the platforms *Bürger schaffen Wissen*, *GoNature* and *GoVolunteer* for CS projects related to the protection and monitoring of urban biodiversity. While *Bürger schaffen Wissen* is aimed directly at citizen science, *GoNature* and *GoVolunteer* are aimed at volunteers. The *GoNature* platform focuses specifically on volunteer tasks in nature and species conservation. Subsequently, an expansion of the desktop search was carried out for projects that are not listed on an official German project platform. In the course of the search, another project platform explicitly for volunteer nature conservation projects in Berlin was included: *Freiwillick Grün—Das Ehrenamtsportal für Umweltschutz*. We set exclusion criteria for selecting projects to decide whether we classify a project as citizen science, following the definition of the *German Green Book Citizen Science* (Bonn et al. 2016). We therefore used the following criteria to choose projects for our further research. In the given project, (1) citizen scientists work on a voluntary basis, (2) new scientific knowledge is actively generated, and a scientific question is posed, and (3) the engagement of citizen scientists is an important and essential part of the project. If a project fulfilled all the requirements, it was included in a results' table together with further information such as the names of the project initiators, the geographical location, and the presence on a project platform.

A categorization by scientific discipline of citizen science projects for monitoring urban biodiversity and conservation in Germany

We classified all identified projects according to their biological discipline, following existing literature (e.g., Pettibone et al. 2017) and using the disciplines of zoology, botany, biodiversity, and environmental science. Following Moczek et al. (2021), we based our categorization of project initiators into overarching categories on a previously tested categorization by *Bürger schaffen Wissen*. The initiators were classified based on the project-related information on the project platforms *Bürger schaffen Wissen*, *GoNature*, and *GoVolunteer*.

ONLINE INTERVIEWS WITH PROJECT COORDINATORS OF BERLIN CITIZEN SCIENCE PROJECTS RELATED TO URBAN BIODIVERSITY MONITORING AND CONSERVATION

Design of the structured online interviews with citizen science coordinators

To better understand the contribution of CS projects to urban biodiversity monitoring and policy frameworks, we created a structured online interview for project coordinators and conducted face-to-face interviews via video calls. We used Berlin as a case study because we had previously found a high number of projects with a broad spectrum in the German capital during our desktop research. The questionnaire was created online with the in-house programme "survey-tool" of the Museum für Naturkunde Berlin (MfN). Individual

questions could be skipped at any time if a project coordinator requested. There were no mandatory answers. All online interviews were conducted by a single interviewer, Julia Rostin. All figures and graphs were created using R.studio.

The online questionnaire included: (1) the project coordinators' assessment of their CS project's contribution to biodiversity monitoring and urban biodiversity conservation, (2) questions about the nature of citizen engagement, (3) the project's objectives, (4) the project's challenges, (5) the publication of results and data sharing, (6) the project coordinators' personal views on citizen science and urban biodiversity conservation, and (7) the project coordinators' awareness of policies and frameworks.

Project coordinators were first asked to make a statement about whether their project contributed to urban biodiversity monitoring and conservation in Berlin through citizen science. The concept of biodiversity was explained and clearly defined based on the CBD definition (CBD 2016).

The online questionnaire then consisted of a series of closed-ended questions. Depending on the question, the option to answer these questions varied. For example, questions about the type of citizen participation allowed multiple answers. In terms of the objectives of CS projects, only two objectives could be chosen.

The questionnaire contained two questions with scalable responses. The first question asked the project coordinator to rate general statements about CS and the conservation of biodiversity. A Likert scale was used to measure participants' personal attitudes. The scale consisted of a multi-level ranking: (1) agree; (2) rather agree; (3) neutral, (4) rather disagree; (5) disagree. The questions on personal attitudes allowed project coordinators to answer at their own discretion and without reference to a project. The second question asked about the project coordinators' personal knowledge of international (SDGs: UN Sustainable Development Goals, CBD: UN Convention on Biological Diversity, EU Biodiversity Strategy for 2030), national (National Strategy for Biodiversity, Urban Nature Master Plan), and local (Berlin Biodiversity Strategy, Strategy for Bees and other Pollinators in Berlin, Strategy Urban Landscape Berlin, Charter for Berlin Urban Green) conservation frameworks. The question was differentiated with the following response options: (1) I know the policy framework, and its content is known to me; (2) I know the name, but the content is unknown to me; (3) Neither the content nor the policy framework is known to me.

Categorization of the type of engagement of citizen scientists and project objectives

Our categorization of the type of engagement of citizen scientists and the overall project objectives were based on a previously conducted survey on CS projects in *Bürger schaffen Wissen* (Moczek et al. 2021). This ensured that the data obtained from the online interview questionnaire were comparable to the results of the survey by Moczek et al. (2021).

RESULTS

DESKTOP RESEARCH ON CITIZEN SCIENCE PROJECTS ON URBAN BIODIVERSITY MONITORING AND CONSERVATION IN GERMANY

Our analysis of the *Bürger schaffen Wissen*, *GoVolunteer,* and *GoNature* platforms revealed a total of 32 CS projects in Germany related to urban biodiversity. An extension of our desktop research added three more projects that were not mentioned on any of the platforms. This increased the total number of CS projects involved in monitoring and conserving urban biodiversity to 35. The proportion of CS projects related to urban nature on *GoVolunteer* and *GoNature* was very low compared with the total number of participation opportunities presented on each platform. *GoNature* listed 12 projects in the urban biodiversity category at the time of our survey. On the *GoVolunteer* project platform, there was no separate section on urban biodiversity or CS. *Bürger schaffen Wissen* was the most frequently represented platform. Thus, out of 35 projects, 33 (91%) were on the platform. *GoNature* (6%), *GoVolunteer* (9%), and *Freiwillick Grün* (3%) had a much smaller share. Three projects (9%) could not be found on any project platform so far. Looking at the total number (n = 35) of projects related to urban nature in Germany, 13 projects (37%) had an indirect reference, while 22 projects (63%) could be directly related to nature in the city.

Categorization of disciplines of citizen science projects

Our categorization of biological disciplines revealed a focus of CS projects on monitoring and conserving biodiversity in zoology. About half of the 35 projects (54%) had a zoological focus. Seven projects (20%) could be classified as environmental sciences. Five projects (14%) focused on biodiversity research. Four projects (12%) dealt with botanical research issues.

Categorization of initiating institutions of citizen science projects

The majority of projects (14 projects, 40%) were initiated by research institutions (e.g., the Leibniz Association). Nine of the projects (26%) were initiated by organizations belonging to the categories "associations, NGOs, foundations" and three projects (9 %) by "universities." Six projects could be assigned to the categories "educational institutions" and "private individuals." None of the projects were initiated by the media.

Categorization of locations of citizen science projects

There are 16 federal states in Germany. We assigned the location of the projects to the respective federal state. Our analysis showed that 19 projects (46 %) had not only local, but also a nationwide scope. Eleven of the projects (11%) were located in the federal state and also the capital of Germany, Berlin. The rest of the projects were distributed among the federal states of North Rhine-Westphalia (9 %; n = 3), Baden-Württemberg (6 %; n = 2) and one project each in Hesse, Bavaria; and Hamburg. Of the 16 federal states, ten were without a CS project with an urban biodiversity reference.

ONLINE INTERVIEWS WITH CITIZEN SCIENCE PROJECT COORDINATORS IN BERLIN

Based on our desktop research and further enquiries, we were able to contact a total of 23 CS projects related to urban biodiversity and operating in Berlin. We received a response from 22 of them (96% response rate). Their 22 project coordinators then completed the online questionnaire about their respective CS projects and shared their personal attitudes: Three questionnaires (14%) were completed online by the project coordinators themselves, and 19 (86%) were conducted online in a Zoom interview.

The project coordinator's assessment of their citizen science project's contribution

Twenty-one project coordinators agreed that their project made a valuable contribution to the monitoring and conservation of urban biodiversity. One project coordinator decided not to answer this question.

The type of engagement of citizen scientists

Citizen scientists were most often involved in data collection (91%), followed by communication of results (41%) and scientific analysis (32%). Three projects (14%) involved citizens in project development (Figure 1). In eight of the CS projects (36%), citizen scientists were involved in only one activity, while in 14 projects (64%), more than one type of engagement of citizen scientists was reported (multiple answers were possible; Figure 1).

The overall objectives of citizen science projects

When asked for a maximum of two overarching project objectives, 18 project coordinators indicated that their projects contributed to "environmental education and awareness" (82%), 13 project coordinators chose "doing science," that is, working on a scientific issue (59%), and 9 chose "opening up science through participation" (41%; Figure 2). None of the 22 project coordinators indicated that their project was strengthening civil society or creating innovation (Figure 2).

The challenges in citizen science projects

When asked if the CS approach brings challenges to the research project, the majority (68%) of project coordinators (n = 15) agreed (Figure 3). The project coordinators most frequently assigned the identified hurdles in the area of time management (55%) and resource management (41%), and legal issues and research methods were mentioned as challenges by four project coordinators (18%). No one stated that the complexity of the research question was a barrier to the project (Figure 3).

Data publication, dissemination, and sharing with authorities of citizen science projects

Most project coordinators (n = 16; 73%) stated that their CS project uses its own project website to publish data. This was followed by the use of scientific publications (59%) and contributing to open databases (50%). Thirteen project coordinators (59%) agreed to share their data upon request. One project (5 %) had not yet published any data.

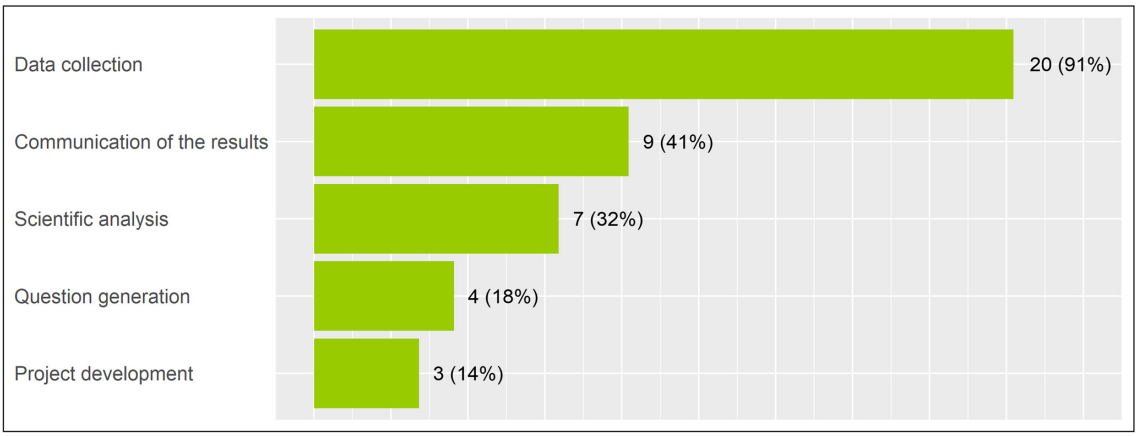

Figure 1 Types of engagement of citizen scientists in citizen science projects related to urban biodiversity in Berlin. Frequencies and percentages (multiple answers possible, n = 22).

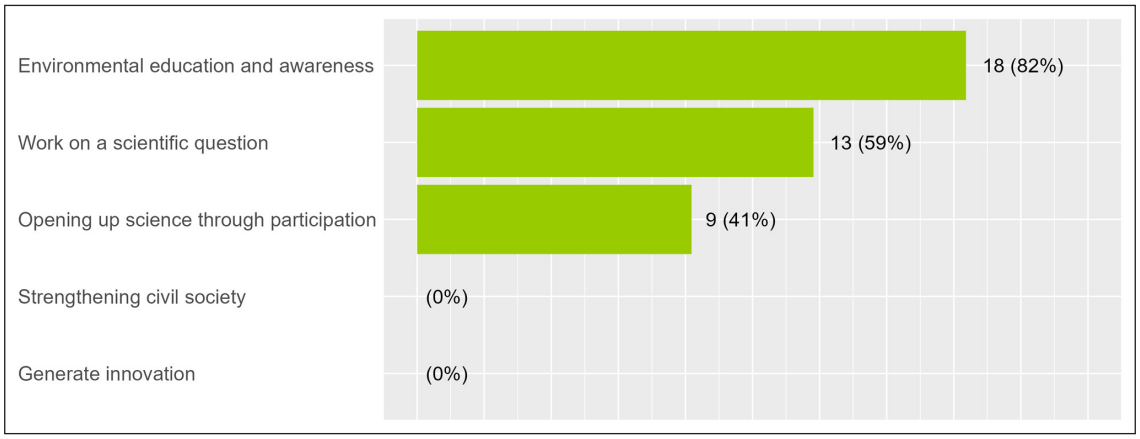

Figure 2 Objectives of citizen science projects related to urban biodiversity in Berlin. Frequencies and percentages (maximum of two answers possible, n = 22).

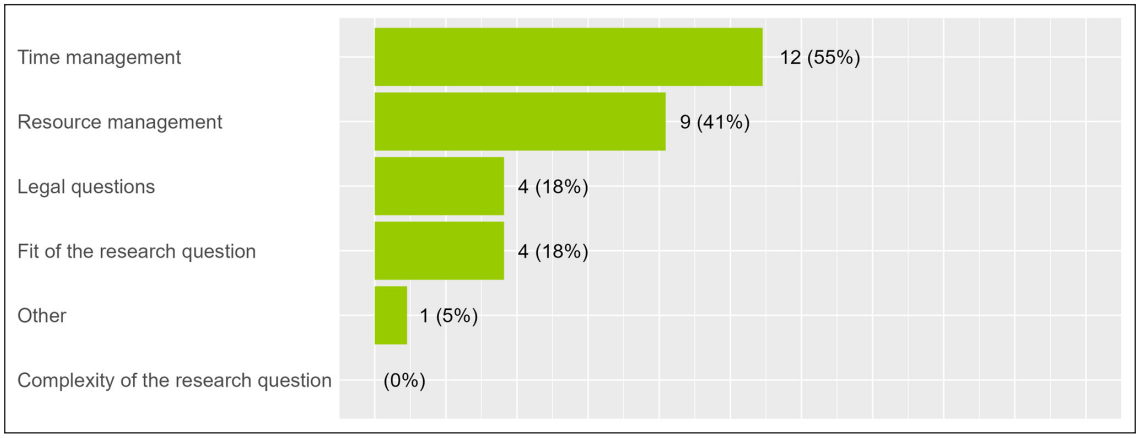

Figure 3 Project coordinators' assessments of the challenges in their citizen science projects in Berlin. Frequencies and percentages (multiple answers possible, n = 22).

Eleven project coordinators (50%) responded that they had shared their project's data with authorities (Figure 4). When asked with which authority the data was shared, the Berlin Senate Department for the Environment, Transport and Climate Protection (the supreme nature conservation authority in Berlin) was named most frequently (n = 9). This was followed by the lower nature conservation authorities in Berlin (n = 7), the German Federal Agency for Nature Conservation (BfN; n = 3), and the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMU) and the Federal Ministry of Education and Research (BMBF) with one mention each. One project coordinator was unable to make a statement. Ten projects (45%) had not shared their data with any authority at the point of our questionnaire (Figure 4).

Personal opinions of citizen science project coordinators

The majority of project coordinators agreed with the statements that CS projects make an important contribution to research (82%) and conservation (55%) of urban biodiversity (Figure 5). Their opinion on the adequate dissemination of data to authorities was much more negative; only two respondents (9%) fully agreed with this statement. The statement about sufficient awareness of biodiversity conservation among the population was shared by only one person (5%). The statement about the availability of data was much more mixed. The majority of respondents answered this question neutrally. No statement was made by one person (5%) in each case about the data obtained from data dissemination and the degree of awareness of the urgency of biodiversity conservation (Figure 5).

Awareness of policy frameworks of citizen science project coordinators

All project coordinators participating in the online interview questionnaire (n = 22) were aware of some policy framework related to urban nature and biodiversity (Figure 6). With regard to the knowledge of individual frameworks and strategies, most participants were familiar with the content

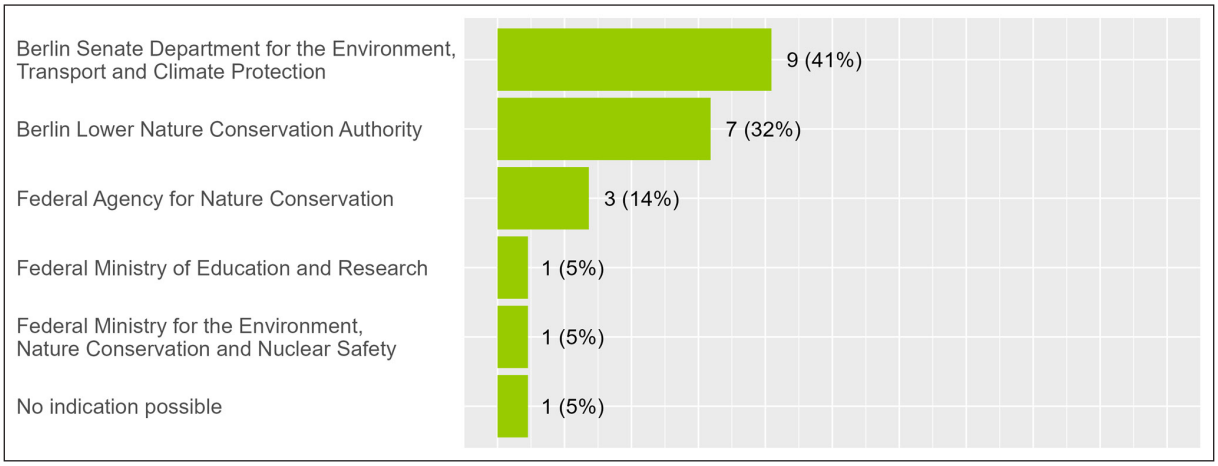

Figure 4 German public authorities with which citizen science projects related to urban biodiversity in Berlin are sharing their data. Frequencies and percentages (multiple answers possible, n = 12).

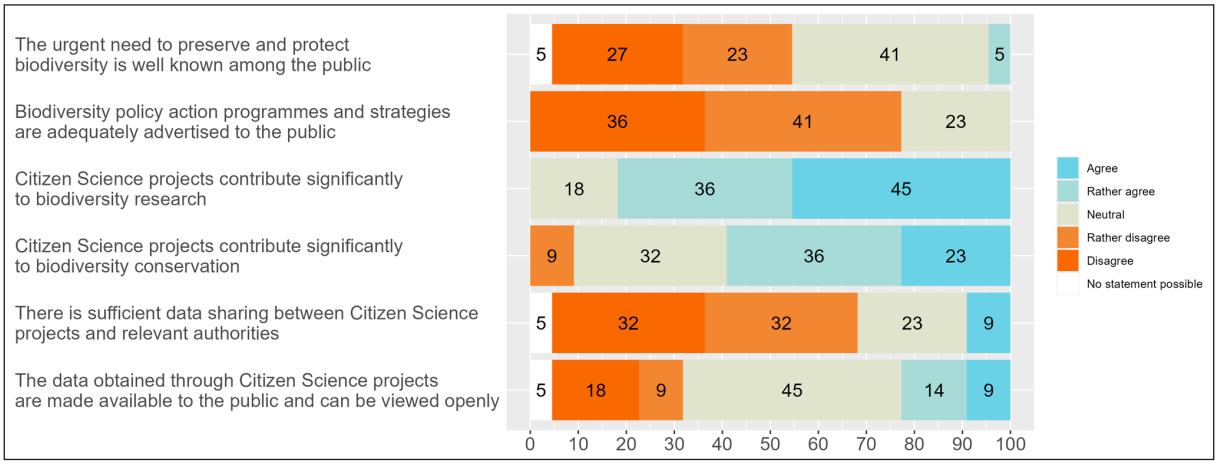

Figure 5 Personal opinions of project coordinators on citizen science practices, urban biodiversity monitoring, and data management. Percentages (5-Point-Likert-Scale, n = 22).

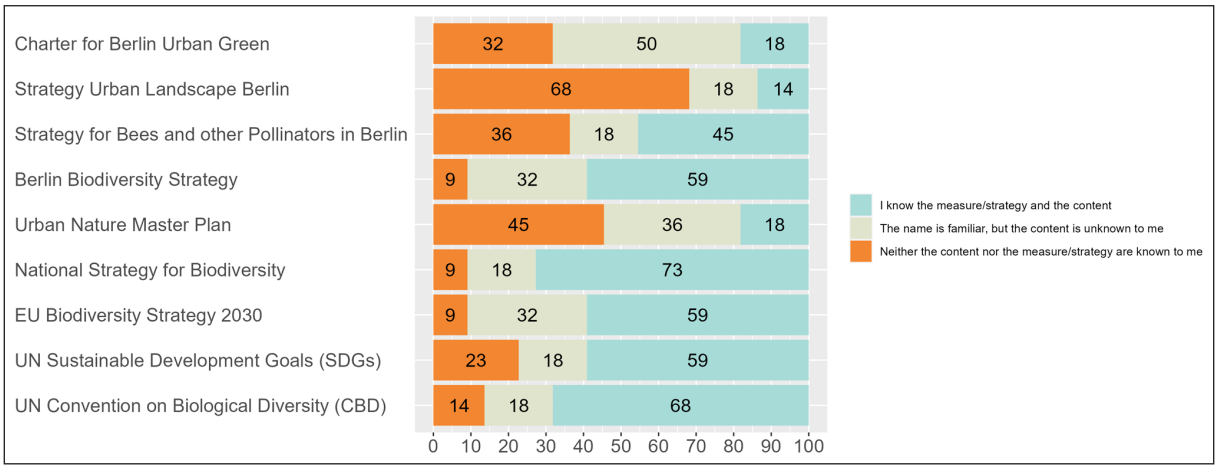

Figure 6 Knowledge of international (SDGs: UN Sustainable Development Goals, CBD: UN Convention on Biological Diversity, EU Biodiversity Strategy for 2030), national (German National Strategy for Biodiversity, German Urban Nature Master Plan), and local (Berlin Biodiversity Strategy, Strategy for Bees and other Pollinators in Berlin, Strategy Urban Landscape Berlin, Charter for Berlin Urban Green) policy frameworks and strategies related to urban biodiversity monitoring and conservation by project coordinators. Percentages (n = 22).

of the German National Strategy for Biodiversity with 16 statements of familiarity (73%) and the Convention on Biological Diversity (CBD) with 15 statements of familiarity (68%). The Berlin Biodiversity Strategy was known content-wise to only 13 project coordinators (59%). However, the German Urban Nature Master Plan (45%) and the Urban Landscape Strategy in Berlin (68%) were not known at all to many project coordinators (Figure 6).

DISCUSSION

In this study, we first conducted a desktop search for urban biodiversity CS projects on German project platforms, and then assessed and classified the contribution of CS projects in Berlin using an online questionnaire. We also assessed the CS data shared with authorities and the knowledge of Berlin-based CS coordinators of conservation frameworks in Germany. To the best of our knowledge, this has not yet been put together in a publication in this form.

We found an interesting accumulation of CS projects related to urban biodiversity in the federal state and German capital, Berlin. This is not surprising given that Berlin is one of the most productive centres of higher education and research in the world. It has the largest concentration of universities and colleges in Germany, with 4 universities and 27 colleges offering a wide range of research disciplines. And although Berlin is the most populous city in Germany, it has a high level of biodiversity with around 20,000 animal and plant species (SenStadtUm Berlin 2012; SenUVK Berlin 2019). It is known as a capital with lots of green spaces, parks, rivers, and forests, reflected in the many nature-related CS projects.

In our desktop research of the platform, we found that more than 50% of the CS projects on monitoring and protecting urban biodiversity examined animal species and, to a much lesser extent, focused on botanical questions. This difference has already been substantiated by previous surveys of citizen science projects and evaluations of project platforms (e.g., Heinisch 2019; Moczek et al. 2021). It is a common pattern that more CS projects focus on zoological questions than botanical ones. There are many reasons why there are more zoological than botanical projects. Zoology may be more accessible and visible to the public than botany. According to Dickinson et al. (2010), botanical identification is more difficult than animal identification because plant species are generally more numerous, more variable in morphology, and less well known. This can make it more difficult to design effective botanical citizen science projects that can be undertaken by non-experts.

In our questionnaire among Berlin-based CS projects, the majority of project coordinators agreed that CS makes an important contribution to urban biodiversity monitoring and conservation. The two most frequently chosen objectives of the projects were environmental education and raising awareness, followed by scientific work and addressing a scientific issue. Other surveys of German-language CS projects (e.g., Turrini et al. 2018) also came to the same conclusion. Considering the coordinators' assessment of the aim of environmental education in their projects, it seems that CS projects in general could be an excellent way to introduce citizens to the issue and to create or increase awareness of biodiversity loss. Regular monitoring of flora and fauna is essential for effective biodiversity conservation (Geschke et al. 2019). One way to support monitoring and improve data is via CS (e.g., Pocock et al. 2018). CS volunteers are already making a significant contribution to the compilation of Red Lists for threatened animal and plant species in Germany (BfN 2021). In our online interview, Red List work was also mentioned as a contribution to biodiversity monitoring and conservation. Visualizing data flows from CS projects to local authorities and into (national or international) biodiversity frameworks could be a useful way of incentivizing data sharing, for example, through network or flow diagrams.

An interesting finding of our questionnaire was the assessment of CS project coordinators that time and resource management was by far the greatest challenge in their CS projects. There may be several reasons for this. Projects rely on volunteers to donate their time for data collection or other tasks. However, citizen scientists may have limited availability due to work or family commitments, which can make it difficult to coordinate schedules and tasks in a timely manner. In addition, CS projects often involve volunteers with different levels of experience and expertise. This can make it challenging to distribute tasks and ensure that they are completed efficiently. Finally, and most importantly, CS projects often have limited funding, which restricts the number of employed staff that could help mitigate these challenges.

Only 50% of projects in our survey reported sharing data with authorities. We can only speculate whether this is a representative figure for citizen science as a research field. There may be many reasons why CS projects do not share their data, either with authorities or the public: (1) *Lack of awareness*: Some CS projects may not be aware that they can share their data with authorities, or may not know how to do so. (2) *Lack of resources:* CS projects are often volunteer-driven and may not have the resources to share their data with authorities. (3) *Privacy concerns:* CS projects may collect data about sensitive species or locations, and may be reluctant to share this data due to privacy concerns. (4) *Intellectual property concerns*: In some cases, CS projects may be conducting research that they hope to publish

in high-ranking journals, and may be reluctant to share their data out of concern that it could be used by others without their permission. (5) *Political considerations*: Some CS projects may be conducting research on controversial topics and may be reluctant to share their data out of concern for how it might be used otherwise.

It is important to note that 50% of the projects in our study did share their data with authorities. And, out of these projects, most shared their data with local authorities. Interestingly, the project coordinators we interviewed were more familiar with larger policies and frameworks, such as the CBD, the EU Biodiversity Strategy 2030, or the SDG framework. Few, for example, were aware of Berlin's Urban Landscape Strategy, even though the data from the CS projects they coordinate may be used to make informed decisions within this strategy. Local biodiversity polices and frameworks may be (more) unknown, as local governments and communities lack the resources or capacity to disseminate and implement these strategies. This may be due to limited funding, expertise, or time of authorities. Moreover, biodiversity conservation may not be seen as a priority by local politicians or decision-makers, who may prioritize other issues that are seen as more pressing or urgent.

The fact that policy frameworks such as the German National Strategy for Biodiversity already address the value of CS projects in the field of monitoring, however, illustrates great potential from the perspective of policymakers. Hecker et al. (2019) were able to illustrate a general interest in CS in political programmes and strategies. Biodiversity policy frameworks and strategies inevitably require monitoring data to verify their effectiveness. Despite the existing potential, CS data have rarely been incorporated into societal and policy decision-making processes (Hecker et al. 2018; Nascimento et al. 2018). In the CS projects we surveyed, the most common type of citizen involvement was data collection. This was also the result of a previous survey in German-speaking countries (Turrini et al. 2018). An important reason for the prevailing approach of involving citizen scientists mainly in data collection may be that these projects are presumably easier to design and implement, and can involve a higher number of participants (e.g., Kullenberg and Kasperowski 2016; Theobald et al. 2014).

We would like to point out that our study has addressed only project coordinators of CS projects and not, additionally, citizen scientists themselves. Possibly, the contribution of CS could be elaborated if both project coordinators and citizen scientists were included. Especially with regard to examples on the protection of biodiversity, it would be interesting to find out whether attitudes towards the environment, environmental knowledge, or environmental awareness change measurably in citizen scientists through participation in a CS project. Studies on the impact of CS projects do exist, but evaluations often suggest that more sensitive metrics need to be developed to demonstrate, for example, a significant change in the attitudes of citizen scientists towards the environment (Brossard et al. 2005). Showing the impact of biodiversity CS projects on participating citizen scientists, however, is crucial to provide evidence-based justifications for funding and policy decisions, as well as to increase public awareness and support for conservation efforts.

CONCLUSION

CS projects can be used as a powerful tool for monitoring urban biodiversity and providing a framework for conservation. Our results show that CS projects are making valuable contributions in Berlin, but that this contribution can be increased. In the opinion of the project coordinators we interviewed, the contribution of the project is particularly important in terms of providing scientific knowledge, engaging in environmental education, and raising awareness. To further increase the contribution of CS projects, one possible goal is to further encourage and expand data sharing with authorities. Only half of the projects surveyed shared data with government agencies to contribute to policies and strategies. Through CS projects, both researchers and policymakers could be empowered and enabled to use citizen-generated data to identify key threats to urban biodiversity and to develop strategies for its conservation.

Creating interfaces between CS projects and government agencies could be a way to facilitate or enable networking as well as data sharing on both sides. Public research institutions, such as natural history museums, may play a significant role in this respect. For example, the natural history museum in Berlin (Museum für Naturkunde Berlin, MfN) is in the process of establishing a Citizen Science Center and could therefore provide a suitable interface. Possible instruments for networking are workshops for CS project staff on the topic of data management, dissemination, and sharing.

It is critical to emphasize that the responsibility of sharing data should not lie solely with one actor in CS projects, either initiators or responsible authorities. Instead, the interest in sharing and sustainable use of the data obtained should be shared equally by all parties involved. Another premise for the sustainable use of data obtained in CS projects is greater recognition of CS data. We believe that CS data on biodiversity, however, should not be seen as a substitute for academic biodiversity research, but rather as a valuable addition. Regarding the current quality debate, one must be aware of and accept the existing limitations of CS (Jäckel et al. 2023). Recognition of CS data could and should yet

be increased by establishing and communicating clear standards for data (quality), and encouraging collaboration between CS stakeholders and authorities.

In addition to the goal of contributing to research, our online questionnaire showed that CS projects name environmental education and awareness-raising as objectives. With regard to the acute and anthropogenically caused loss of biodiversity, there is an urgent need to educate the public. CS represents a promising approach to urban biodiversity monitoring and conservation that combines the power of scientific research with the passion and expertise of local communities. As cities continue to grow and urbanization intensifies, CS projects are likely to become even more important in efforts to protect urban biodiversity and create sustainable, resilient cities for future generations.

DATA ACCESSIBILITY STATEMENT

In order to protect the confidentiality of the responses of the Berlin citizen science project coordinators, the data analysed in this paper is not available.

ETHICS AND CONSENT

Ethical approval was not required at our institution for this study, as we worked closely with our data protection officer to provide all participants (i.e., project coordinators of Berlin citizen science projects) with detailed information about the conditions. They could take part in the surveys only if they agreed to these conditions. Specifically, we explained that participation was voluntary, that questions could be skipped, that participation in the study could be terminated at any time, and that information already stored could be completely deleted. Publication of the results does not allow any conclusions to be drawn about the project or individuals. The data were stored in a database at the Museum für Naturkunde Berlin for research purposes only.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Silke L. Voigt-Heucke orcid.org/0000-0002-0960-8069
Museum für Naturkunde Berlin, Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany

Moritz Müller orcid.org/0009-0001-4824-3912
Museum für Naturkunde Berlin, Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany

Julia Rostin orcid.org/0009-0008-9091-520X
Museum für Naturkunde Berlin, Leibniz Institute for Evolution and Biodiversity Science, Berlin, Germany

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