CITIZEN SCIENCE:
THEORY AND PRACTICE

Does Citizen Science Foster Conservation? Evidence from Wildlife Monitoring Programmes

SYNTHESIS ARTICLES

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ABSTRACT

Citizen science is increasingly used to engage the public in biodiversity monitoring and conservation, yet its effects on participants' conservation-related awareness, attitudes, and behaviours remain poorly understood. We conducted a systematic review of 56 wildlife monitoring case studies published between 1995 and 2023, spanning 16 countries and four vertebrate groups (birds, mammals, reptiles, and fish). We examined whether and how participation in citizen science programmes was associated with changes in these outcomes. Overall, the reviewed studies reported predominantly positive changes in conservation awareness, attitudes and behaviours, particularly in studies using pre- and post-participation assessments. Reported outcomes were described in the context of different types of support provided to participants, including training, materials, and financial incentives. However, the evidence base was dominated by bird monitoring and studies of population trends, limiting our understanding of outcomes across other taxa and monitoring contexts. Future studies should use well-designed and rigorously assessed evaluation approaches to determine how participation in citizen science programmes may influence conservation-related learning outcomes and whether such changes are sustained over time, particularly across different programme contexts. Most evaluations in this review relied on post-participation qualitative assessments, limiting causal inference. Strengthening evaluation designs is therefore critical to better understand the potential of citizen science for conservation.

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INTRODUCTION

Citizen science has emerged as an effective strategy to address the cost and sustainability issues in wildlife monitoring while promoting public involvement in biodiversity conservation (Danielsen et al. 2003; Danielsen, Burgess, and Balmford 2005). The term "citizen science" (CS) generally refers to volunteer participants being involved in scientific research (Bonney et al. 2009; Gray et al. 2017). It is broadly used in environmental science and in biodiversity-related issues (Peter et al. 2021).

CS provides opportunities for non-professionals to contribute to scientific research through activities such as data collection, analysis, and dissemination (Bonney et al. 2009; Dickinson, Zuckerberg, and Bonter 2010). Although public participation can occur at any stage of the scientific process, volunteers are most commonly involved in data collection (Dickinson, Zuckerberg, and Bonter 2010; Gray et al. 2017). Technological developments, including online platforms, spatial web applications, and smartphone apps, have further expanded opportunities for citizen participation and wildlife monitoring, facilitating data gathering across spatial scales (Cohn 2008; Walker, Smigaj, and Tani 2020). However, reliance on such technologies may also create barriers for people with limited digital skills (Sheard et al. 2024). More broadly, CS initiatives have attracted increasing attention for their potential to engage volunteers in wildlife monitoring from local to global scales (Conrad and Hilchey 2011; Bonter and Cooper 2012; Kobori et al. 2016; Ballard, Dixon, and Harris 2017). Involving local people in monitoring programmes can therefore broaden the geographical and temporal scope of data collection and generate valuable information that might otherwise be difficult for researchers and conservation practitioners to obtain (Sharma et al. 2019).

Beyond data collection, CS provides several benefits for individual participants (Santori et al. 2021), including access to education, technical skill development (e.g., data management and project design), and livelihood benefits (Walker, Smigaj, and Tani 2020). At the same time, CS can advance conservation literacy by enhancing knowledge and scientific reasoning, as well as promoting involvement in policymaking and decision processes (Cooper et al. 2007; Jordan et al. 2011; Bonney et al. 2016; Sharma et al. 2019).

Nevertheless, several CS projects face challenges related to programme management, volunteer retention, and data quality (Ortega-Álvarez et al. 2012; Peters et al. 2016). Specifically, persistent staff turnover, sampling bias, and lack of sustained funding can undermine the continuity and long-term success of monitoring programmes (Conrad and Hilchey 2011).

The CS engagement model has been conceptualized through several frameworks that are based on the degree and nature of public involvement in monitoring schemes. (Haklay 2013). One widely used framework categorizes CS projects into contributory, collaborative, and co-created models (Bonney et al. 2009; Shirk et al. 2012). Although contributory CS remains the most common approach in biodiversity monitoring, collaborative and co-created models are increasingly recognized for their potential to strengthen community involvement, knowledge exchange, and governance outcomes (Shirk et al. 2012; Suškevičs et al. 2024).

In addition, involving local stakeholders in monitoring programmes is thought to support environmental conservation, as it can increase the coverage of data collection, facilitate the early detection of environmental changes, and foster environmental awareness and stewardship (Sharma et al. 2019; Tengö et al. 2021). These benefits have led conservation organizations, researchers, and government institutions to increasingly engage volunteers in monitoring initiatives (Newman, Buesching, and Macdonald 2003; Lehtiniemi, Outinen, and Puntila-Dodd 2020). Locally based monitoring may also be more sustainable over time (Danielsen, Burgess, and Balmford 2005). In this context, participation of local people in research and monitoring agendas can enhance conservation decision-making while generating scientific knowledge and strengthening participants' skills and environmental awareness (Couvet et al. 2008; Conrad and Hilchey 2011; Bonney et al. 2016).

However, despite the many arguments pointing toward the benefits of CS in monitoring programmes, the actual impact of CS projects on conservation-related attitudes and behaviours remains insufficiently synthesised (Chase and Levine 2017). In particular, changing behaviour through CS initiatives remains relatively understudied (Jordan et al. 2011). Most existing studies rely on self-reported changes rather than directly observed behavioural measures (Santori et al. 2021), which may be influenced by social desirability or recall bias.

Participation in CS projects can affect the knowledge, attitudes, or behaviours of participants (Shirk et al. 2012). Moreover, sustained engagement in CS projects influences participants' attitudes and translates into conservation action (Peter, Diekötter, and Kremer 2019). Direct engagement with nature can foster environmental awareness and strengthen pro-conservation values and behaviours (Akintunde 2017). The value-belief-norm theory (Stern 2000) and research on emotional affinity toward nature (Kals, Schumacher, and Montada 1999) propose that increased personal values and beliefs, and

emotional connection to nature, can enhance moral commitment and motivate conservation-oriented action. In addition, the theory of planned behaviour (Ajzen 1991) highlights the role of knowledge and attitudes in shaping behavioural intentions. Wildlife monitoring may provide these forms of engagement by facilitating experiential learning and direct interaction with biodiversity (Mitchell et al. 2017; Santori et al. 2021). This framework connects cognitive and behavioural changes to expected societal and personal benefits, such as community empowerment and engagement in decision-making (Bela et al. 2016).

Given these considerations, we aimed to systematically review the reported conservation outcomes of involving citizen scientists in wildlife monitoring programmes, focusing on changes in conservation awareness, values, attitudes, and behaviours. We hypothesised that engagement in wildlife monitoring is associated with reported positive changes in awareness, attitudes, and behaviours. We further examined whether different forms of volunteer support, such as training, materials, and incentives, influence these outcomes. In addition, we assessed major problems of CS projects that hinder the success of wildlife monitoring programmes. The review includes 56 case studies from 1995 to 2023, covering 16 countries and five vertebrate groups (birds, mammals, reptiles, amphibians, and fish), although no studies involving amphibian monitoring met our inclusion criteria.

METHODS

LITERATURE SEARCH

We systematically searched articles from the Web of Science database published from January 1995 to December 2023 using the following word combination in the Topic field: [(Attitude* OR perception* OR behaviour* OR willing* OR engage*) AND (conservation OR protection) AND (Wildlife OR mammal OR fish OR reptile OR amphibian OR bird OR animal) AND (survey OR sampling OR monitoring) AND ("local communit*" OR "Indigenous people*" OR "Citizen* science")]. This search generated 433 related articles written in English.

Our search strategy had some limitations: restricting the search to a single database and English-language publications may have excluded relevant studies, as may the selection of keywords. Furthermore, the resulting sample contained relatively few survey-based quantitative studies, with most articles reporting qualitative findings on participants' experiences, perceptions, and observations of conservation outcomes.

LITERATURE DATA EXTRACTION AND ANALYSIS

We screened the titles and abstracts of 433 search results and selected papers for in-depth review based on the following criteria: 1) peer-reviewed research articles; 2) articles describing at least one wildlife monitoring initiative; and 3) articles measuring changes in conservation awareness, values, attitudes, or behaviours (Akintunde 2017; Milfont, Duckitt, and Wagner 2010), including methods used to measure these aspects (e.g., interviews, discussions, questionnaires). Articles not meeting these criteria were excluded. We focused only on studies dealing with vertebrate groups (i.e., birds, mammals, reptiles, amphibians, and fish), which cover a higher proportion of CS observations in biodiversity monitoring (Fraixedas et al. 2020; Yadav and Phartyal 2026). We excluded studies focusing on all other taxonomic groups.

In addition, we employed the PRISMA guidelines to ensure transparent and comprehensive reporting of the systematic review.

We finally reviewed a total of 33 research articles. However, given that some articles reported more than one case study, as a result, the final sample size increased to 56 case studies from 16 countries across the world (Figure 1). For each study, we extracted information about different variables that we categorised into the following groups:

1) General information about the monitoring scheme, including the following variables: study ID, study site, and taxa (birds, mammals, reptiles, amphibians, and fish). However, we found no monitoring programmes involving amphibians. Metrics assessed include species diversity, species abundance, and population trends.
2) We classified into four main categories the type of support provided, following Shirk et al. (2012): training, material support, incentives (i.e., financial or in-kind incentives), and supervision (i.e., coordination, communication, and guidance support). We categorised volunteers' levels of engagement into three categories: high (consistent and active participation), medium (moderate dedication and effort), and low (limited or occasional participation) based on the level and the duration of participation in the scientific process (Haklay 2013).
3) Information on conservation outcomes. The conservation outcomes measured were arranged into four categories: (awareness, values, attitudes, and behaviours (Phillips et al. 2018; Peter, Diekötter, and Kremer, 2019). Awareness: knowledge and understanding of biodiversity and conservation issues (Waylen et al., 2009; Peter, Diekötter, and Kremer, 2019). Values: beliefs or goals that guide

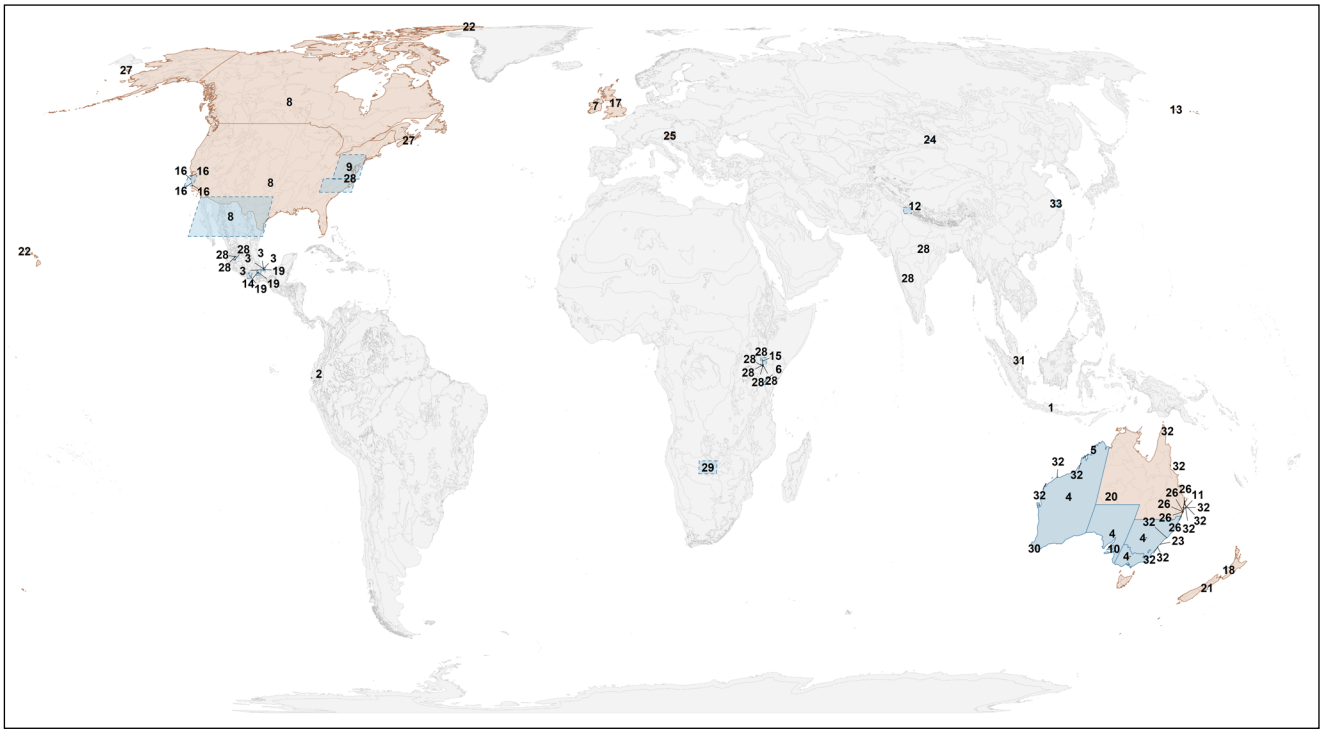


Figure 1 Geographic distribution of the wildlife monitoring studies included in the review, represented by 67 geolocations associated with 33 source articles, overlaid on the WWF Terrestrial Ecoregions of the World (TEOW; Olson et al., 2001). Numbers identify the source articles (1–33), as listed in Supplementary File 2: Table S1; individual articles may be represented by multiple geographic locations. Where labels have been displaced to avoid overlap, black lines and dots indicate their corresponding geographic reference locations. Shaded areas represent the geographic coverage of studies: beige indicates country-wide coverage, whereas blue indicates regional study areas or multi-state coverage. Regional study-area extents are approximate and illustrate the general geographic coverage rather than precise sampling boundaries. Country and state boundary data used for coverage shading were obtained from Natural Earth (naturalearthdata.com). Geographic coordinates, locality references, spatial representations, and geographic data sources for each study are documented in Supplementary File 2: Table S1.

individuals' attitudes and behaviours toward biodiversity conservation. Attitudes: individuals' evaluative position of conservation, shaped by personal experiences, norms, and values. Behaviours: conservation-related actions or intentions, including participation in conservation activities and knowledge sharing (Waylen et al. 2009; Steg et al. 2014). We recorded the evaluation design (before-and-after or post-participation), the evaluation method used to collect information (i.e., discussion, interview, or questionnaire), the type of data generated and analyzed (i.e., qualitative or quantitative), and the reported effect (i.e., positive, negative, or no change). We distinguished between evaluation method and type of data because the use of a particular evaluation method did not necessarily determine whether the resulting data were qualitative or quantitative. For example, questionnaires were classified as quantitative when analysed numerically or using standardized measures, and qualitative when based on open-ended responses. In cases where studies evaluated more than one outcome (e.g., behaviours and attitudes simultaneously), we treated each outcome as a separate unit of analysis and counted it as a distinct monitoring scheme within the same study, while acknowledging potential non-independence among cases within the same study.

4) Challenges and recommendations reported by the study authors, including methodological constraints (i.e., limitations related to the design, data collection, and validation procedures), participant-related problems (i.e., limitations related to participants' skills, motivation, and availability to participate effectively in a CS project), data quality problems, inadequate funding and governance problems (coordination and management of CS projects) during the monitoring programmes, as well as suggestions for improving project design, volunteer engagement, or data quality. These qualitative insights were systematically recorded to complement the quantitative outcomes of the monitoring programmes.

DESCRIPTION OF CONSERVATION OUTCOMES

In this study, we focused on four types of conservation outcomes: awareness, values, attitudes, and behaviours that together represent key dimensions through which

people engage with conservation issues (Thomas, Barth, and Leiserowitz 2019). These elements are often conceptualized as related but not strictly linear constructs, including more abstract cognitive dimensions (awareness and values), mid-level evaluative components (attitudes), and more concrete manifestations in behaviour (Milfont, Duckitt, and Wagner 2010; Akintunde 2017). Nevertheless, relationships among these components are complex and not necessarily hierarchical. Behaviours may be influenced by values, norms, awareness, and attitudes, while behavioural experiences can also reshape attitudes (Milfont, Duckitt, and Wagner 2010; Akintunde 2017). Pro-environmental behaviour is therefore shaped by multiple interacting social, cultural, personal, and contextual factors (Kollmuss and Agyeman 2002; Stern 2000; Krasny 2020).

RESULTS

We present our results in three subsections: (1) the characteristics of wildlife monitoring programmes, (2) conservation-related outcomes for participants, and (3) reported challenges and recommendations.

CITIZEN SCIENCE IN WILDLIFE MONITORING PROGRAMMES

The study covered a total of 16 countries across the globe, with Australia having the highest number of studies (n = 9), followed by the United States (n = 7) and Mexico (n = 5). Nine countries were represented by only one case study each (Figure 1).

Although we searched for studies covering all five vertebrate groups, we found no monitoring scheme related to amphibians. Among the four taxonomic groups monitored across various wildlife initiatives, birds were the most frequently monitored (43%), followed by mammals (32%), fish (16%), and reptiles (9%). Species diversity was the most commonly measured metric in wildlife monitoring programmes, accounting for 27% of cases (n = 20), sometimes measured alongside other metrics. This was closely followed by abundance and population trends, measured in 17% (n = 13) and 16% (n = 12) of studies, respectively.

Regarding the level of involvement of local stakeholders, our review indicated that most monitoring programmes, 55% (n = 31) were externally driven, with local data collectors (category two). Additionally, others were done with collaborative monitoring, either with external data interpretation (32%, category three), or local data interpretation (13%, category four). Articles driven and executed exclusively by professional researchers (category one) were excluded from our review (see Table 1 and Supplementary File 1: Appendix S1 for more details about each of the categories used).

Furthermore, the majority of monitoring programmes, 52% (n = 35) provided training ranging from basic to extensive for participants, while 24% (n = 16) benefited from field materials and equipment, and 16% (n = 11) received incentives such as recognition certificates, financial incentives, and feedback. The remaining 7% (n = 5) were supported through supervision, including consistent guidance, connection, and organizational support (see Supplementary File 1: Appendix S1 for more details on the types of support). Importantly, 71.4% (n = 40) of cases in which monitoring programmes were reported received at least one type of support for participants (e.g., training, financial support, or materials and equipment), whereas 14.3% (n = 8) did not receive any support. For another 14.3% (n = 8) of cases, it was unknown whether support was provided. The level of engagement was high in the majority of cases (59%, n = 33), while only 11% of cases (n = 6) were classified as medium engagement. No cases exhibited a low level of engagement. Importantly, the level of engagement could not be determined for 30% of the cases (n = 17) (see Supplementary File 1: Appendix S1).

EFFECTS OF ENGAGING CITIZEN SCIENTISTS IN MONITORING PROGRAMMES

Our findings suggest that all wildlife monitoring programmes reported a positive effect on changing conservation awareness, values, attitudes, and behaviours

MONITORING CLASSIFICATION	DATA COLLECTION	DATA ANALYSIS AND INTERPRETATION	LOCAL PARTICIPATION IN DECISIONS
Category one	Professional data collectors	Professionals	No direct participation (we excluded from the final analysis, as this study focused on volunteer-based initiatives).
Category two	Local collectors and/or professionals	Professionals	Limited or indirect
Category three	Local stakeholders	External scientists	Participatory
Category four	Local stakeholders	Local stakeholders, with possible external support	Substantial participation

Table 1 Types of monitoring schemes categorised according to the level of involvement of local stakeholders, following Danielsen et al. (2008).

through the participation of citizen scientists. Attitudes were the most frequently examined outcome, reported in 38% of the studies (n = 21), followed by awareness (36%, n = 20), behaviour (23%, n = 13), and values (4%, n = 2) (Figure 2). Reported changes included increased appreciation of biodiversity and greater support for conservation activities, improved knowledge of wildlife species and environmental change, and the adoption of wildlife-friendly practices and the sharing of knowledge with others. Beyond these general patterns, it is also instructive to consider the variety of outcomes documented across different programmes, illustrating how CS participation translates into conservation engagement. In some programmes, such as local community biodiversity monitoring in Indonesia, volunteers increased their knowledge of species and ecosystems, reflecting clear cognitive gains (Ashuri, Haryadi, and Santosa 2017). Other initiatives, including collaborative fisheries research, led to shifts in conservation attitudes, with participants expressing stronger support for marine protected areas and sustainable practices (Mason et al. 2020). Participation in programmes focused on large mammal monitoring, for instance African lion conservation by Maasai community members, directly engaged volunteers in pro-conservation behaviours, such as anti-poaching activities and systematic species monitoring (Dolrenry, Hazzah, and Frank 2016). Finally, comprehensive mammal monitoring programmes demonstrated combined effects, fostering knowledge, promoting positive conservation attitudes, and motivating advocacy behaviours among participants (Forrester, Freeman, and Morley 2017). Together, these studies illustrate that CS participation can simultaneously foster awareness, encourage stewardship, and support tangible conservation actions, highlighting the multifaceted impact of well-designed monitoring programmes.

Most monitoring programmes (82%, n = 46) evaluated changes only after participation, with the remaining 18% (n = 10) applying a before-and-after evaluation design. Before-and-after designs were more common for studies examining behavioural change (44%) compared with attitude (24%) and awareness (11%) (see also Figure 2). For instance, Frigerio et al. (2023) measured both attitudes and intended behavioural changes before and after participation in a CS programme focused on birds in Australia, while Beltrán, Pacheco, and Rivera (2020) focused on post-participation evaluation of conservation awareness, values, and attitudes in Tuxtla Quail-Dove (*Zentrygon carrikeri*) monitoring.

Regarding evaluation methods (i.e., tools used to evaluate cognitive changes), 41% (n = 23) of the schemes used discussions, which typically involved facilitated group conversations or debriefing sessions where participants reflected on their experiences, shared observations, and expressed changes in their awareness, attitudes, or intended behaviours. In addition, 39% (n = 22) employed questionnaires, and 20% (n = 11) conducted interviews to assess cognitive and behavioural outcomes. Of the 22 questionnaire studies, 18 were qualitative and 4 were quantitative; among the 11 interview studies, 10 were qualitative and 1 was quantitative. Overall, 91% (n = 51) of the reviewed studies relied on qualitative approaches, while 9% (n = 5) used quantitative methods. Examples include Gupta, Kumar, and Singh (2019), who applied quantitative questionnaires to assess awareness and values regarding

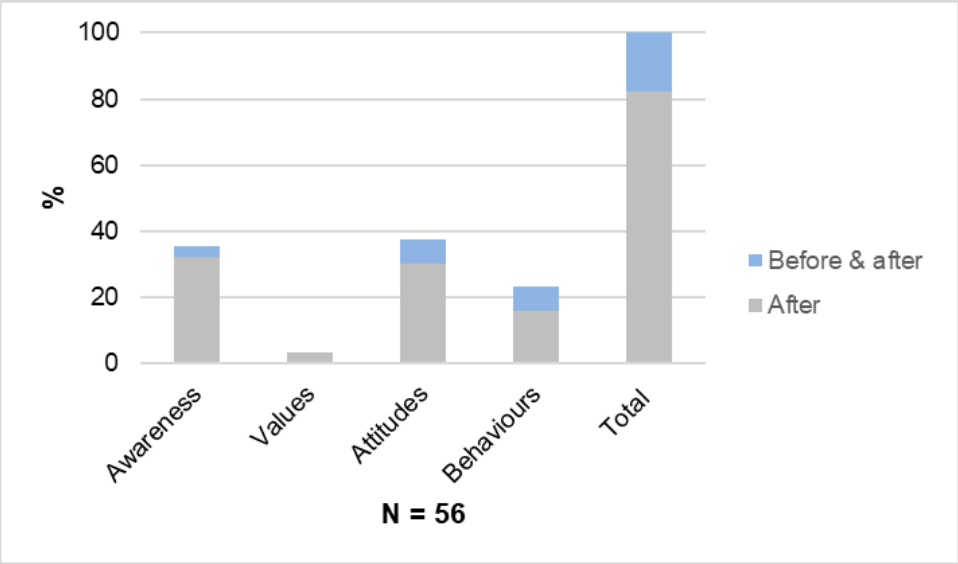


Figure 2 Number of studies reporting changes in conservation-related outcomes (awareness, values, attitudes, and behaviours), comparing post-participation evaluations with before-and-after evaluation designs.

otter conservation in India, and Peters et al. (2016), who measured attitude and behavioural outcomes in New Zealand bird, mammal, and reptile monitoring programmes (see our dataset in the Zenodo repository: https://doi.org/10.5281/zenodo.19709259).

CHALLENGES AND RECOMMENDATIONS

Our results indicate that methodological issues such as lack of standardized sampling protocols and sampling bias were the most frequently reported challenge (23%, n = 13) in implementing CS wildlife monitoring programmes. Additionally, participant-related constraints, including participants' motivation, availability, and effort, were identified in 21% (n = 12) of the schemes (Table 2). To address these challenges, several key solutions were reported, including evaluating data quality, applying standardized monitoring guidelines and protocols, ensuring continuous recruitment and retention of volunteers, and providing training and financial support (Table 2). These challenges may also limit participants' learning, engagement, and sustained conservation involvement.

DISCUSSION

OUTCOMES OF PARTICIPATION IN CITIZEN SCIENCE MONITORING PROGRAMMES

Across the 56 cases reviewed, participation in CS wildlife monitoring was predominantly associated with increases in conservation awareness and attitudes and in pro-conservation behaviours, including improved knowledge, increased valuing of biodiversity and understanding of the environment, and commitment to participate in conservation measures (e.g., Dolrenry, Hazzah, and Frank 2016; Forrester, Freeman, and Morley 2017; Mason et al. 2020; Ražen et al. 2020). These findings reinforce a growing body of evidence positioning CS not only as a data-generation strategy but also as a socially embedded process capable of shaping how individuals engage

TYPE OF CHALLENGE	CHALLENGES IN DETAIL	RECOMMENDATIONS
Methodological limitations (23%)	• Sampling bias (e.g., Mason et al. 2020). • Lack of standardized protocols, data collection guidelines, and incomplete survey designs (e.g., Ashuri, Haryadi, and Santosa 2017).	• Employ standardized data recording procedures (e.g., Zhou et al. 2020). • Improve sampling design, use monitoring checklists, and ensure sufficient sampling effort (e.g., Dolrenry, Hazzah and Frank 2016).
Participant-related constraints (21%)	• Low motivation and participation (e.g., Beltrán, Pacheco, and Rivera 2020). • Inadequate time and effort spent by volunteers (e.g., Lavariega et al. 2020).	• Empower local participants through equitable benefit-sharing (Frigerio et al. 2023). • Provide incentives and foster a sense of stewardship (e.g., Forrester, Freeman, and Morley 2017).
Data quality problems (14%)	• Biased reports (e.g., Wee 2011). • Incomplete data, bias, inconsistency, deviations from protocol, and substandard quality (e.g., Roelfsema et al. 2016). • Lack of data quality control and management systems (e.g., Pirotta et al. 2020).	• Use clear protocols and guidelines for data collection and reporting (e.g., Pirotta et al. 2020). • Conduct regular evaluation of monitoring data and activities (e.g., Peters et al. 2016). • Implement data entry validation systems (e.g., Mason et al. 2020).
Inadequate funding (14%)	• Limited financial support and logistical resources from governments and donors (e.g., Dolrenry, Hazzah and Frank 2016).	• Secure funding through collaboration with multiple donor organizations to support volunteer participation and logistics (e.g., Peters et al. 2016).
Governance problems (4%)	• Low recruitment and high volunteer turnover (e.g., Forrester, Freeman, and Morley 2017). • Inadequate training and capacity building (e.g., Peters et al. 2016). • Lack of incentives (e.g., Frigerio et al., 2023). • Scheduling conflicts and technological limitations (e.g., Williams, Holmes, and Pepperell 2015).	• Sustained recruitment and retention of volunteers (e.g., Mason et al. 2020). • Careful planning and execution of schemes (e.g., Williams, Holmes, and Pepperell 2015). • Address ethical concerns in volunteer engagement (e.g., Ražen et al. 2020). • Regular training and capacity building (e.g., Peters et al. 2016). • Consider programme expansion and structured implementation (Peters et al. 2016). • Integrate government and community-based monitoring programmes (Forrester, Freeman, and Morley 2017).

Table 2 Major challenges of citizen science monitoring programmes and corresponding recommendations proposed by the original authors of the studies. Challenges are presented in order of decreasing frequency, from the most commonly reported to the least. All references correspond to studies included in our review datasets.

Note: Out of n = 56 study cases, n = 13 (23%) reported unknown problems, meaning the specific challenges were not clearly indicated in the studies.

with biodiversity (Conrad and Hilchey 2011; Jordan et al. 2011; Bonney et al. 2016). However, these outcomes may vary with differences in participants' prior knowledge, experience, and capacity to engage in monitoring activities (Ortega-Álvarez et al. 2012; Pirotta et al. 2020).

Most monitoring schemes were initiated by professional researchers but actively involved local volunteers in data collection (Ortega-Álvarez et al. 2012; Pirotta et al. 2020; Ražen et al. 2020).

Evidence from before-and-after evaluations suggests that engagement in CS monitoring activities can enhance ecological knowledge and foster more favourable attitudes toward conservation (Chase and Levine 2017; Jordan et al. 2011; Santori et al. 2021), as also observed in community-based programmes such as Dolrenry, Hazzah, and Frank (2016) and Forrester, Freeman, and Morley (2017), where participation was linked to stronger conservation advocacy and engagement.

However, the reviewed studies reported outcomes across different forms of support, including training, supervision, material assistance, and financial incentives. Although our review did not quantitatively assess whether specific types or levels of support were associated with stronger outcomes, some studies reported positive outcomes where sustained support was provided (Low et al. 2009; Perry et al. 2022). Thus, the reviewed literature suggests that how participation is structured and supported may influence participant learning and engagement, although this pattern should not be interpreted as evidence of a causal or statistical relationship.

Beyond cognitive outcomes, CS participation enhanced environmental literacy and empowered communities in conservation decision-making (Ortega-Álvarez et al. 2012; Peters et al. 2016). Participants frequently reported greater appreciation for monitored species and more positive perceptions toward conservation. Some studies associated these outcomes with programmes that provided tangible benefits, such as training or access to equipment (Dolrenry, Hazzah, and Frank 2016; Roelfsema et al. 2016; Pirotta et al. 2020). Participation in wildlife monitoring may therefore create conditions conducive to behavioural change, although the extent to which such changes are sustained over time remains uncertain.

These findings are consistent with established theories of pro-environmental behaviour, which emphasize that direct engagement with nature and environmental activities influence conservation-related personal values and beliefs, emotional connection, knowledge, and skills, ultimately promoting pro-conservation attitudes and behaviours (Kals, Schumacher, and Montada 1999; Stern 2000).

Overall, CS monitoring can support conservation-related learning, including changes in awareness, attitudes, and behaviours. However, outcomes varied across programmes and evaluation approaches, and our review did not test whether programme structure, support, or participant engagement explained these differences. CS monitoring may also contribute to natural resource management, particularly in long-term community-based monitoring systems, which highlight improvements in coordination, governance, and conservation capacity (Peters et al. 2016; Ražen et al. 2020).

The involvement of local stakeholders can further enhance understanding of environmental change and support biodiversity protection efforts (Becker et al. 2005; Peters et al. 2016). Partnerships that bridge local and national actors appear particularly effective in improving data quality, facilitating knowledge exchange, and increasing the likelihood of conservation impact (Kainer et al. 2009). Active participation often led to greater involvement in environmental issues, advocacy, and policy engagement, demonstrating the dual role of CS as a tool for both data collection and conservation empowerment.

CHALLENGES AND BEST PRACTICES

Despite these benefits, CS monitoring schemes face a range of persistent challenges. Methodological limitations, such as sampling bias, variable data quality, and absence of standardized protocols, remain central concerns (Roelfsema et al. 2016; Massimino, Harris, and Gillings 2018). Other reported constraints include low volunteer recruitment, high turnover, insufficient training, funding shortages, and limited human resources (Perry et al. 2022).

Volunteer support is essential. Structured training, continuous supervision, provision of field materials, and incentives were reported to improve data quality, engagement, and conservation responsiveness (Ortega-Álvarez et al. 2012; Dolrenry, Hazzah, and Frank 2016; Perry et al. 2022). Programmes that responded to community needs and provided support achieved higher engagement and more reliable outcomes (Low et al. 2009; Peters et al. 2016; Lavariega et al. 2020). Accessible digital platforms, simplified monitoring protocols, and involvement of local stakeholders further improved efficiency, data quality, and long-term sustainability (Roelfsema et al. 2016).

CS schemes also faced governance and organizational constraints, including inconsistent management, limited coordination, and gaps in data utilization (Ortega-Álvarez et al. 2012; Peters et al. 2016; Ražen et al. 2020). High staff turnover, participant attrition, and fluctuations in funding were repeatedly identified as barriers to programme success (Dolrenry, Hazzah, and Frank 2016; Lavariega et al. 2020; Perry et al. 2022; Thompson et al. 2023). Overcoming these challenges requires clear data quality control techniques, regular recruitment and retention strategies,

ongoing training, and stakeholder engagement throughout programme design and implementation (Danielsen et al. 2014; Bonney et al. 2016; Johnson et al. 2021).

One of the main causes of failure in many conservation programmes is inadequate consideration of social dimensions such as people's needs, opinions, experiences, and knowledge (Berdej and Armitage 2016). This highlights the importance of designing conservation and CS initiatives that align with community priorities and interests, particularly in more participatory or co-designed approaches (e.g., category four initiatives). Such approaches were associated in several reviewed studies with high participation and meaningful conservation outcomes (Ortega-Álvarez et al. 2012; Forrester, Freeman, and Morley 2017; Peters et al. 2016).

LIMITATIONS AND FURTHER RESEARCH

Several limitations warrant careful consideration: First, relying on a single database (Web of Science) and predefined search keywords may have resulted in the omission of relevant studies. Restricting inclusion to peer-reviewed publications may have excluded studies documented in reports, project websites, or other grey literature. In addition, reliance on self-reported outcomes may have introduced social desirability and recall biases. The predominance of positive findings may also reflect publication or reporting bias, as studies finding no or limited changes may be less likely to be published or reported. Lack of a counterfactual or longitudinal design limited causal inference. Variation of participant characteristics, programme design, and context may have affected the magnitude and generalisability of the observed outcomes.

Future research should emphasize rigorous, comparable, and longitudinal methods, expand geographic and taxonomic coverage, and integrate quantitative and qualitative approaches to better understand how CS participation influences conservation outcomes. A future meta-analysis could further quantify the magnitude of reported changes where sufficient comparable quantitative data are available across studies.

CONCLUSIONS

This systematic review suggests that participation in CS wildlife monitoring schemes can be associated with positive changes in participants' conservation awareness and attitudes, and behaviours. Across the 56 case studies reviewed, positive outcomes were reported particularly in studies using pre- and post-participation assessments. However, the predominance of post hoc qualitative evaluations and self-reported measures limits causal inference and makes it difficult to determine whether observed changes can be attributed to participation itself. The reviewed studies also described different forms of volunteer support and levels of engagement in the context of reported conservation outcomes, but the evidence available did not allow us to assess systematically whether these programme characteristics were associated with stronger or more consistent outcomes.

Taken together, these findings suggest that wildlife monitoring through CS can contribute not only to biodiversity data collection but also to participants' conservation-related attitudes and engagement. Realizing this potential requires more robust evaluation designs, including mixed-methods and longitudinal approaches, to investigate how participation shapes conservation-related awareness, attitudes, and behaviours, and whether these changes persist over time. At the same time, effective programmes need to address practical challenges such as data quality, volunteer retention, and sustained participant engagement through appropriate monitoring protocols, quality-control procedures, ongoing support, and programme designs that respond to participants' needs and local contexts.

DATA ACCESSIBILITY STATEMENT

The supplementary file of this study is available in the Zenodo repository (https://doi.org/10.5281/zenodo.19709259).

SUPPLEMENTARY FILES

The Supplementary files for this article can be found as follows:

- **Supplementary File 1.** Appendix S1. DOI: https://doi.org/10.5334/cstp.1039.s1
- **Supplementary File 2.** Table S1. DOI: https://doi.org/10.5334/cstp.1039.s2

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Belete Tilahun Tefera led the conceptualization, data curation, formal analysis, and visualization, and wrote the original draft of the manuscript. Sara Fraixedas and Daniel Burgas contributed to the conceptualization and methodology, supervised the project, supported data curation and visualization, contributed to writing and editing the manuscript, and secured funding for Belete Tilahun Tefera's research. Aina Brias Guinart and Álvaro Fernández-Llamazares contributed to data collection and assisted with reviewing and editing the manuscript.

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