CITIZEN SCIENCE:
THEORY AND PRACTICE

Human Well-Being Implications for Participants Involved in Animal-Related Citizen Science Projects Utilising Digital Technologies: A Scoping Review

SYNTHESIS ARTICLES

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ABSTRACT

Citizen science (CS) projects using technology such as mobile phones, apps, and social media play an increasingly important role in animal monitoring. These projects can support participant well-being through physical activity, social connection, and stress reduction, but may have unintended social consequences. Through a scoping review, we identified 153 technology-based CS studies, of which only 37 (24%) were from the Global South. Insects, mammals, and birds were the most frequently monitored taxonomic categories (comprising 60% of studies), and most studies (68%) focused on two essential biodiversity variables (EBVs): species populations and ecosystem functioning. Approximately half of the studies used social media and/or smartphone apps (52% and 48% of studies respectively), with slightly fewer (43%) using websites. Technologies were particularly important for creating a learning space and encouraging knowledge-sharing and social interaction among participants. Only 23 (15%) studies focused on human well-being considerations and associated impacts, although technology use can contribute to well-being through fostering a sense of cultural identity, and supporting empowerment and agency. Promoting human-nature interaction was a consistent benefit across studies, while improving internet connectivity, inclusivity, and usability were identified as challenges. The review highlights three priority areas for research: (1) enhance understanding of how technology-based CS projects can support well-being for participants, especially in the Global South; (2) create technology-driven CS projects that are equitable; and (3) improve knowledge and practice to increase opportunities and participation in CS.

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INTRODUCTION

Citizen science (CS) projects, which involve non-professionals and/or volunteers (Pocock et al. 2014), can make important contributions to monitoring changes in species distribution and abundance, and provide benefits to participants. They can facilitate nature connectedness and enable pro-conservation behaviours (Pocock et al. 2023), support physical and psychological health (Eichholtzer et al. 2024), increase knowledge of and self-efficacy for the environment (Peter et al. 2021), and foster community building and collective action (Von Gönner et al. 2024).

Technology is integral to many CS programmes (Hognogi et al. 2023). It is especially relevant for animal-related CS projects due to the popularity of animal-based CS projects overall and specific animal taxa such as insects, birds and Lepidoptera (Chandler et al. 2017). Technology can help overcome the specific challenges of recording and observing animals, which are mobile and frequently elusive in their behaviours (Sheard et al. 2024). Technology-enabled CS programmes widely use smartphone applications, web-based platforms, or social media (Pocock et al. 2017; Braz Sousa et al. 2022, Sheard et al. 2024). However, increasing technology use can have unintended social consequences due to digital divides caused by inequitable access, affordability, connectivity in rural and remote areas, and educational and literacy barriers (Andrachuk et al. 2019). These effects are especially pronounced in the Global South, where communities might be disadvantaged by high costs, lack of relevant content, and technological support (Ragnedda and Gladkova 2020a). This may limit access, usage, and the ability of people to turn online successes (e.g., building awareness) into favourable real-world outcomes (e.g., improving conservation) (Ragnedda and Gladkova 2020b). It is also possible that technology use could cause frustration amongst participants, hindering their ability to connect with nature, resulting in adverse effects on human well-being (Pocock et al. 2023). Here, we use a scoping review to synthesise evidence on how the adoption of technology in animal-related CS affects the human well-being of participants. The understanding gained will enhance inclusivity, engagement, and retention; inform better outcomes for participants; and potentially increase the value of the data produced by fostering community-building and action.

METHODOLOGY

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al. 2021) to evaluate and report the findings from the literature search. After defining the search protocol and strategy, we collected and screened the literature, including a secondary review. We then extracted relevant data from the selected papers, scoring each paper based on its consideration of human well-being using a scale derived from Hawker et al. (2002) (Table 1). Finally, we used thematic analysis to interpret the findings in the selected papers.

We defined human well-being using the five domains identified by Kaplan-Hallam and Bennett (2018): social (social capital and cohesion, safety and security, education and knowledge, infrastructure, adaptive capacity), health (physical, mental, emotional, food security, connection to nature), economic (employment, material wealth, economic wealth, equity, livelihoods), governance (transparency and accountability, local institutions, empowerment and agency, participation, rights and access), and cultural (identity, diversity, traditional knowledge, activities and practices).

SEARCH STRATEGY

Web of Science, Scopus, and Proquest were searched for peer-reviewed journal articles. These databases were selected for their broad combined coverage, their facility to filter by article types and publication dates, and their flexibility in terms of search term length.

Search terms were in English and included components for technology, citizen science and biodiversity/animal monitoring (Supplementary File 1: Table S1. Search Terms). These search terms were chosen to ensure broad coverage

SCORE	IMPORTANCE OF WELL-BEING DIMENSIONS IN THE CONTEXT OF THE STUDY	EXAMPLE
4	Focus or major part of the study	The aim of the study, or the primary research question, is focused on understanding human well-being impacts.
3	Minor part of the study	There is some mention of human well-being or social concepts in the results; there may be some questions dedicated to understanding this, but it is not one of the study's aims.
2	Mentioned in discussion	There is some mention of human well-being or social impacts in the discussion section.
1	Not mentioned	There is no mention of human well-being or social impacts in the study.

Table 1 Assessment scale for the extent of consideration of human well-being.

of technology-based, animal-related CS studies from across the world and tested across the databases to ensure relevant and consistent results were produced.

Searches were restricted to papers published between 2017 and 2023. This date range captures recent technological advancements and increasing adoption in Global South countries, where by 2017, about half of the adults surveyed by Poushter, Bishop, and Chwe (2018) had internet access, owned smartphones, or used social media. Grey literature and conference proceedings were excluded as the intention was to devise a conceptual and interpretive explanation rather than undertake an exhaustive search (Thomas and Harden 2008).

SCREENING AND SELECTION PROCESS

All results were uploaded into EndNote, and duplicates were automatically removed. The remaining articles were uploaded into Covidence, where abstracts and titles were first screened for relevance by the lead author, SG. Articles that passed this initial screening had their full texts retrieved and checked against the inclusion and exclusion criteria (Supplementary File 2: Table S2. Inclusion and Exclusion Criteria); this included a secondary review of a subset of the full texts by either of co-authors PW or AH, followed by a final validation by SG.

DATA EXTRACTION AND ANALYSIS

Data, consisting of segments from papers, were extracted by SG, by screening against a set of questions (Supplementary File 3: Table S3. Questions for Data Extraction) to identify basic information and details related to technology use, human well-being, and biodiversity. A mixed-methods approach was used to analyse the data. Percentages and trends were identified from questions that had short answers, multiple- or single-choice, and year/duration responses, and a thematic synthesis approach (Thomas and Harden 2008) was used for free-text questions. This preserves links between the text of the primary studies and the new hypothesis and conclusions that are formed. Given the volume of data, the approach was condensed into two stages: Descriptive themes were developed initially, and then analytical themes were generated to provide explanations or hypotheses. These themes were identified using an inductive approach based on the extracted free text, and were grouped and renamed as they emerged during the analysis.

RESULTS

In total, 3251 studies were identified on a search conducted on 6th March 2024, with 1986 screened for relevance through a title and abstract review. Within these, 346 were assessed for eligibility against the inclusion and exclusion criteria, and a subset of 43 underwent secondary review. A total of 153 studies (Supplementary File 4: Table S4. Full Citations of Articles Included in Scoping Review) were included in the data extraction and analysed (Figure 1).

Geographically, studies were distributed predominantly in Europe and North America (Figure 2). Only 37 (24%) studies were focused on the Global South, which we defined as countries that are members of the G77 (The Group of 77 at the United Nations 2026).

TAXONOMIC FOCUS

The animals being studied were classified into taxonomic categories following the classification system used within the Catalogue of Life (Table 2; Ruggiero et al. 2015).

Most studies were in the taxonomic category of insects (Table 2), with mosquitos (Culicidae) being the most studied single insect family (10 studies). Insects, mammals, and birds were the most frequently monitored taxonomic categories. A marginally higher proportion of vertebrates were monitored through technology-based CS studies than invertebrates.

The studies were also classified based on the essential biodiversity variables (EBVs) (GEOBON 2023), using the main aim of the study rather than secondary focus areas, to understand what biodiversity data were being collected (Table 3).

Studies that focused on species populations considered distribution and abundance. Most studies concerned with ecosystem functioning focused on disease control and management of invasive species. Studies that did not consider a biodiversity variable explored engagement, awareness, and behaviours of participants.

TECHNOLOGY USE

The most frequently used technology was social media (Table 4), with the most popular CS platform being iNaturalist, which was used in 13 of the 19 studies using online CS platforms. Intended users of the technology were predominantly citizen scientists or the public (Table 5).

Technology was used as often as participants liked in 99 (65%) studies and during specific study periods or seasons in 26 (17%) studies. Three (2%) studies involved just one-time use of technology, and 25 (16%) studies provided no explicit indication of usage frequency. Twenty (13%) projects provided support to participants through in-app guides, training sessions (Baumbach et al. 2019; Zhang et al. 2021; Potsikas et al. 2023), or telephonic support (Boyce and Corrigan 2017).

ADVANTAGES AND DISADVANTAGES OF TECHNOLOGY USE FOR PARTICIPANTS

Ten descriptive themes were identified relating to the advantages or disadvantages for participants that result from using technology (Table 6).

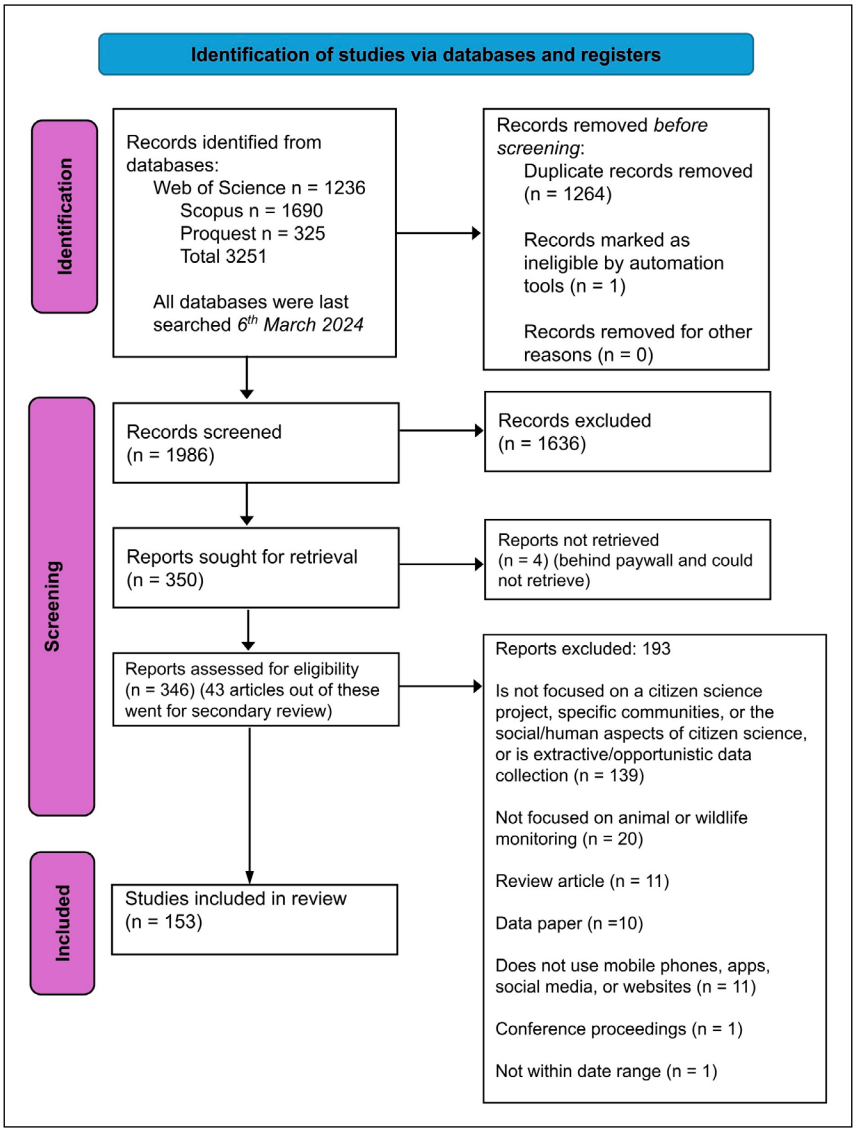

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Diagram for selection and screening of studies.

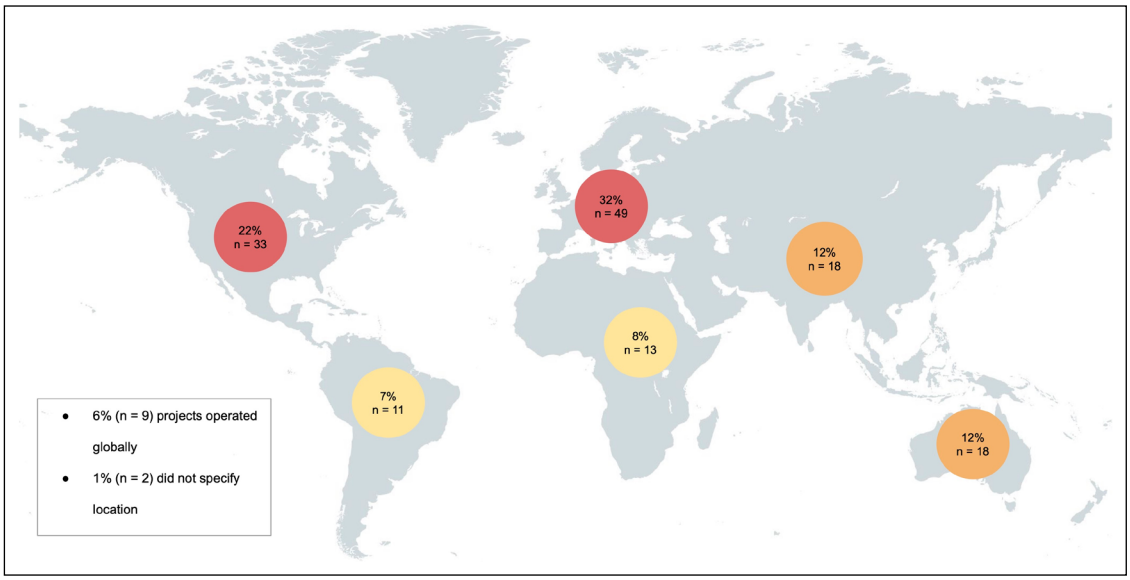

Figure 2 Map of the distribution of studies. Map template downloaded from mapchart.net/Licensed under CC BY-SA 4.0. Modifications were made to indicate study numbers.

TAXONOMIC CATEGORY	SIMPLIFIED TAXONOMIC RANK	NUMBER OF STUDIES (%)
Insects	Phyl. Arthropoda, Subphyl. Hexapoda, Cl. Insecta	40 (26)
Mammals	Phyl. Chordata, Subphyl. Vertebrata, Cl. Mammalia	34 (22)
Birds	Phyl. Chordata, Subphyl. Vertebrata, Cl. Reptilia, Subcl. Aves	18 (12)
Bony fish	Phyl. Chordata, Subphyl. Vertebrata, Cl. Teleostei	9 (6)
Amphibians	Phyl. Chordata, Subphyl. Vertebrata, Cl. Amphibia	5 (3)
Jellyfish	Phyl. Cnidaria, Subphyl. Medusozoa	5 (3)
Spiders	Phyl. Arthropoda, Subphyl. Chelicerata, Cl. Arachnida, Ord. Araneae	5 (3)
Snails	Phyl. Mollusca, Cl. Gastropoda	4 (3)
Reptiles	Phyl. Cordata, Subphyl. Vertebrata, Cl. Reptilia	3 (2)
Crabs, lobster, shrimp	Phyl. Arthropoda, Subphyl. Crustacea, Cl. Malacostraca, Ord. Decapoda	3 (2)
Coral	Phyl. Cnidaria, Subphyl. Anthozoa	2 (1)
Cartilaginous fish	Phyl. Chordata, Subphyl. Vertebrata, Cl. Elasmobranchii	2 (1)
Birds and insects	Both as above	1 (1)
Mammals and birds	Both as above	1 (1)
Clams	Phyl. Mollusca, Cl. Bivalvia	1 (1)
Slugs	Phyl. Mollusca, Cl. Gastropoda	1 (1)
Snails and Platyhelminthes	As above; Phyl. Platyhelminthes	1 (1)
Several (across categories)	n/a	9 (6)
Marine life (category not mentioned)	n/a	4 (3)
Fish (category not mentioned)	n/a	2 (1)
Not mentioned	n/a	3 (2)

Table 2 Taxonomic categories of animals monitored by the studies, defined according to Ruggiero et al. (2015). Only the most appropriate of the 14 ranks used by Ruggiero et al. in their hierarchy are used here for simplicity in defining the taxonomic rank for each category. Ranks used are: Phyl.: Phylum, Subphyl.: Subphylum, Cl.: Class, Subcl.: Subclass, Ord.: Order. The system is hierarchical, although evolutionary history means that not all levels of the hierarchy are applicable for each taxonomic category. Where more than one taxonomic category is grouped together, they are defined as earlier in the table unless appearing for the first time. Note: Percentages are higher due to rounding.

EBV	NUMBER OF STUDIES (%)
Species population	60 (39)
Ecosystem functioning	45 (29)
Species traits	14 (9)
Community composition	13 (9)
Not focused on a specific biodiversity variable	21 (14)

Table 3 Essential biodiversity variables (EBVs) addressed by the studies.

TECHNOLOGY	NUMBER OF STUDIES USING THE TECHNOLOGY (%)
Social media	80 (52)
Smartphone apps	73 (48)
Project websites	66 (43)
Citizen science or nature-specific platforms	19 (12)
Other	25 (16)

Table 4 Types of technologies used in studies. Note: The number exceeds the total as some studies used multiple technologies.

Technology benefits and advantages

One of the greatest opportunities technology provided for participants was creating a learning space and helping them identify various species (Grigoletto et al. 2023). Additionally, technology motivates knowledge-sharing (Liebenberg et al. 2017), helps participants pursue research questions (Wood et al. 2022), and enhances perceptive abilities (Sharma et al. 2019; Low et al. 2022), thus contributing to the social domain of well-being (Kaplan-Hallam and Bennett 2018). Research indicates that ease of use, non-requirement of specialised skills, and convenience offered by mobile apps have made them necessary for

INTENDED USERS	NUMBER OF STUDIES (%)
Citizen scientists/general public	110 (72)
Specific interest groups or stakeholders (e.g., scuba divers)	26 (17)
Particular geographic communities (e.g., members of a locality)	13 (9)
Citizen scientists and specific interest groups	2 (1)
Not mentioned	2 (1)

Table 5 Intended users of the technology.

ANALYTICAL THEMES	DESCRIPTIVE THEMES
Technology benefits and advantages	Learning
	Data collection and management
	Ease of use and accessibility
	Access to information
	Privacy and security
	Social Interaction and community-building
	Socio-economic impacts
Technology challenges and disadvantages	Ease of use and accessibility
	Inequalities
	Data management

Table 6 Analytical and descriptive themes for the question "Are there any advantages or disadvantages of using the technology for participants?"

projects that include participants over diverse spatial and temporal scales (Martin and Greig 2019). Furthermore, in relation to improving participation and access, within the well-being domain of governance, multi-language support (Johnson et al. 2021) and removing registration and login requirements (Páll-Gergely et al. 2019) all contribute to positive experiences. Icon user interfaces or voice reporting and offline data capture are particularly useful for participants who cannot read or write, are situated in rural areas where the cost of internet is high, or may not be able to afford high-end smartphones (Liebenberg et al. 2017; Baumbach et al. 2019; Thumbi et al. 2019).

Enabling better safety and security in projects to make participants feel more comfortable in providing data (Liebenberg et al. 2017; Oviedo and Bursztyn 2017; Jäckel et al. 2023) can contribute to improving the social domain of well-being. This can be achieved through real-time feedback (Davis et al. 2017; Davis, Taylor, and Martin 2019), connecting with practitioners (Chepkwony, Van Bommel, and Van Langevelde 2018), reducing information search times (Forrester, Dzilenski, and Gleeson 2021), obscuring GPS locations (Braz Sousa et al. 2022), removing voice activity from recordings (Sinka et al. 2021), and seeking permission to use publicly available information (Gibson et al., 2020).

Technology facilitates social capital and cohesion through efficient social interaction between citizen scientists and scientists (Grigoletto et al. 2023). Consistent data sharing sustains curiosity and links participants to research in real-time virtual spaces. This fosters community-driven discussions that include marginalised groups, promotes a sense of teamwork through shared experiences (Turnbull, Searle, and Lorimer 2023), and encourages friendly competition, which can increase submission rates (Wood et al. 2022).

Technology can improve participants' socioeconomic status, acting as a tool for local empowerment in low-resource communities (Wamwenje et al. 2019; Low et al. 2022). It has also been found to increase users' prestige, give more meaning and recognition to community members' environmental work, and help retain traditional skills (Liebenberg et al. 2017). This may contribute to well-being through fostering a sense of cultural identity, building activities and practices, and supporting empowerment and agency.

Technology challenges and disadvantages

Accessibility and usability are two key challenges for participants. Contributory factors include cumbersome data entry procedures (Skelton et al. 2018), with participants unwilling to invest more than eight minutes for reporting (Ostermann-Miyashita et al. 2023), limited access to connectivity and training (Dwivedi 2021), concerns around smartphone theft and damage (Vliet et al. 2017), poor integration into everyday lives (unlike social apps) (Zhang et al. 2021), difficulties for older generations handling tactile smartphones (Vliet et al. 2017; Zhang et al. 2021), and insufficient language options (Johnson et al. 2021). These factors can all affect several domains of well-being, including participation, infrastructure limitations, safety, empowerment and agency, and rights and access.

In the Global South, technology can exacerbate existing inequalities, particularly between classes and genders (Chepkwony, Van Bommel, and Van Langevelde 2018), owing to illiteracy in app use (Wamwenje et al. 2019) and financial constraints (Dam et al. 2023). Furthermore, it is necessary to be mindful of capturing and sharing traditional knowledge and managing sensitive data (Vattakaven et al. 2022).

PARTICIPATION BY COMMUNITY MEMBERS

We identified four analytical themes and thirteen descriptive themes relating to factors affecting participation (Table 7).

ANALYTICAL THEMES	DESCRIPTIVE THEMES
Propensity for citizen science participation	Interest in and associations with nature
	Project and species type
	Gender
Limitations and enabling factors for participation	Time
	Wealth
	Privilege
	Information and support
Digital inclusion	Age
	Accessibility and connectivity
	Literacy
Political, economic, and cultural dimensions	Insecurity
	Institutional design
	Beliefs and practices

Table 7 Analytical and descriptive themes related to factors influencing participation

Propensity for citizen science participation

The nature of the project and the focal animal(s) influence involvement. Studies that focus on species that affect participants' health, such as mosquitoes (Culicidae), have diversity in the species that can be observed (Martin and Greig 2019), or focus on charismatic species such as wombats and ladybirds (Skelton et al. 2018; Weyman, Butler, and Mckeown 2022), may have a higher likelihood of participation. Research on bird-related citizen science projects from Sydney and Bali indicates that men are more likely to make simple opportunistic sightings, rather than complex observations such as taking measurements (Davis, Taylor, and Martin 2019), and females visit fewer places than average (Squires et al. 2021). People with scientific backgrounds or environmental knowledge tend to contribute more to CS overall (Thomaes et al. 2021; Lodi, Maricato and Mathias 2023; Ostermann-Miyashita et al. 2023). The high frequency of technology use in bird- and mammal-focused studies is likely to reflect their popularity as species, level of conspicuousness, and charismatic nature (Lundquist et al. 2025; Forti and Szabo 2025), and hence, interest in such species can be leveraged through technology to enhance recruitment and data in studies. Easily accessible technologies such as mobile phones can be used to allow participants to submit incidental observations for elusive species (Stenhouse et al. 2021). Additionally, technology can provide a means of reducing some key barriers to engagement, such as the expertise gap, by facilitating information sharing and exchange between participants (Ganesh, White, and Haque 2026; Truong and Van der Wal 2024).

Limitations and enabling factors for participation

Availability of free time is a key enabler for involvement in voluntary activities. Studies suggest that people with older children and more stable employment, or who have retired, have more time to volunteer (Martin and Greig 2019). However, misconceptions about time required can hinder participation, potentially impacting data scalability (Martin and Greig 2019). The participation of some age groups such as younger adults may be affected by financial constraints (Martin and Greig 2019). In the Global South, many marginalised communities may have high levels of expertise but face severe poverty; thus, creating employment opportunities or initiating payments for environmental services may be more effective for participation than relying on volunteers (Liebenberg et al. 2017). Privilege plays a central role in affording participation, especially when people have "the means to pause, the technologies to connect, the social capital to deploy the information they gathered, and access to (often private) greenspace" (Turnbull, Searle, and Lorimer 2023, p.243). Other factors that enable participation include sufficient provision of information about the programme, feedback and guidance (Thomaes et al. 2021), and support from family and other community members (Martin and Greig 2019). Thus, participation is influenced by several economic and social domains of well-being, including wealth, access to infrastructure, social capital, and cohesion.

Digital inclusion

Scientists note that digital platforms attract specific demographics, raising questions about whether these are the best volunteers for CS (Sharma et al. 2019). Age is frequently associated with technology adoption. Use of social media, smartphones and online tools are more likely to attract young adults (Davis, Taylor, and Martin 2019; Zhang et al. 2021) due to their familiarity with technology, exposure to a globalised world, and greater commitment towards conservation (Lodi, Maricato and Mathias 2023). Older people are less interested in technology but often have more time to engage in CS (Sharma et al. 2019), so this presents a potential dilemma for organisers of CS projects, with a possible trade-off between levels of participation and the amount or quality of data.

Limited access to the internet and mobile connectivity hampers CS programmes (Chepkwony, Van Bommel, and Van Langevelde 2018; Johnson et al. 2021; Gasparic et al. 2022), biasing reports towards accessible urban sites (Mohd Rameli et al. 2020). In the Global South, lack of communication networks, poor electricity connections, and unaffordable pricing affect inclusion (Chepkwony, Van Bommel, and Van Langevelde 2018; Grigoletto et al. 2023). Local data storage, installing wi-fi in community

halls, advocating for collaboration with neighbourhood organisations (Grigoletto et al. 2023; Tréhin 2023), and encouraging local development through open access to assets (Low et al. 2022) can offer a solution. Furthermore, poor literacy can limit activities such as texting and impede inclusion (Chepkwony, Van Bommel, and Van Langevelde 2018; Wamwenje et al. 2019).

Political, economic, and cultural dimensions of participation

CS projects often compete for focus with pressing local animal-related issues such as property damage, human-wildlife conflicts, cattle raiding, and spread of zoonotic diseases (Chepkwony, Van Bommel, and Van Langevelde 2018; Mwango'Mbe et al. 2021), especially in Global South countries. Thus, institutional linkages between government agencies and local communities can enhance participatory processes by improving information sharing and enabling communities to provide inputs on environmental regulation (Oviedo and Bursztyn 2017; Chepkwony, Van Bommel, and Van Langevelde 2018), consequently benefiting well-being through the domain of governance.

Belief systems can also challenge the effectiveness of CS, for example, cultural practices of maintaining high livestock numbers without investment in improved health measures can impede disease-control-related CS (Chepkwony, Van Bommel, and Van Langevelde 2018). Additionally, the reputation of the institute conducting the project, such as NASA's credibility, strongly motivates involvement (Low et al. 2022).

BENEFITS OF PARTICIPATION

Two analytical and nine descriptive themes were identified relating to the benefits and effects of participating in CS (Table 8).

ANALYTICAL THEMES	DESCRIPTIVE THEMES
Participant benefits	Knowledge-building
	Interest in research
	Interest and attention to nature
	Knowledge sharing
	Monetary benefits
	Social interaction and community-building
Effects on participants' feelings and self-perception	Joy and relaxation
	Nature connectedness
	Identity-building and pride

Table 8 Analytical and descriptive themes for the question "Does the study discuss any benefits or effects on participants by taking part in the CS project?"

Participant benefits

Several studies noted enhanced skills and knowledge in participants (Williams et al. 2017; Caputo et al. 2020). These positive educational outcomes can contribute to people's appreciation of nature and sensitivity to environmental issues (Mohd Rameli et al. 2020; Pardee, Wiley, and Fendrick 2023; Potsikas et al. 2023; Tréhin 2023), encouraging participation in conservation acts (Garcia-Cegarra, Toro, and Gonzalez-Borasca 2021). Furthermore, they can impact people's perceptions, with participants forming relationships with non-humans (Sharma et al. 2019), increasing awareness of natural resources that are important to animals (Zapponi et al. 2017), and gaining interest in issues of environmental health (Martin and Greig 2019).

These changes in perception and awareness have also been heightened by technology, specifically the ability of social media to reach a much wider audience than traditional science-communication channels (Mohd Rameli et al. 2020). This can enhance connection to nature, education and knowledge, and empowerment and agency within the health, social, and governance domains of well-being. There may be further knock-on effects, including encouraging adoption of real-world sustainable behaviours (Tréhin 2023), reinforcing traditional management practices (Pardee, Wiley, and Fendrick 2023), building community groups to implement management measures (Englefield et al. 2020), and potentially creating new models of governance and innovation (Oviedo and Bursztyn 2017; Caputo et al. 2020).

Other positive outcomes include increased interest in research (Cho et al. 2021), motivation to share knowledge (Etter et al. 2023), receiving monetary benefits (Thumbi et al. 2019; Pardee, Wiley, and Fendrick 2023), and opportunities to share information and have bi-directional interactions (Martin and Greig 2019; Forrester, Dzilenski, and Gleeson 2021). This can create an inclusive community where people can ask for advice or information without fear of judgment (Turnbull, Searle, and Lorimer 2023).

Effects on feelings and self-perception

Gasparic et al. (2022, p.118) noted that citizen scientists "felt better, [were able to] be active in fresh air and be useful" by participating in the activity. However, few studies have reported specific benefits to participant well-being, such as joy, relaxation, and purpose, as a result of interacting with wildlife through observations or listening (Martin and Greig 2019). One study found a statistically significant positive shift in participants' nature connectedness scores after taking part in a CS project (Potsikas et al. 2023). These authors suggested that factors such as experience and wisdom, format of the activity, and levels of motivation and engagement may also contribute to higher nature connectedness scores.

SCORE	IMPORTANCE OF HUMAN WELL-BEING DIMENSIONS IN THE CONTEXT OF THE STUDY	NUMBER OF STUDIES (%)	EXAMPLES
4	Focus or major part of the study	23 (15)	• Community-building and empowerment (Grigoletto et al. 2023; Turnbull, Searle, and Lorimer 2023) • Motivations and incentives for participation (Dam et al. 2023; Etter et al. 2023; Jäckel et al. 2023) • Participant outcomes (e.g., understanding changes in learning, values or attitudes [Sharma et al. 2019; Cho et al. 2021]) • Technology-related impacts such as human-nature relations or its social and cultural benefits (Liebenberg et al. 2017)
3	Minor part of the study	29 (19)	• Capturing demographic information (Braz Sousa et al. 2022; Gasparic et al. 2022) • Ethics, privacy, and data management (Vattakaven et al. 2022) • Measuring participant outcomes (Williams et al. 2017) • Collecting information on technology usability (Vliet et al. 2017).
2	Mentioned in discussion	40 (26)	Discussions related to participation, motivation, engagement, and retention of citizen scientists within the project in the discussion section.
1	Not mentioned	61 (40)	

Table 9 Relevance scoring and examples of human well-being dimensions discussed in studies, following the scoring criteria in Table 1. Total number of studies: 153.

There is a brief mention in the literature of the effects of technology use on people. Wood et al. (2022) suggest that greater accessibility to technology gives more people the opportunity to interact closely with nature, improving physical and mental health. However, Potsikas et al. (2023) call for more research to understand how technology fosters a complementary relationship with nature. Particularly in the Global South, it has been noted that involving participants in the development of the technology (e.g., through enabling knowledge-sharing and in pilot testing) gives a sense of identity and pride (Liebenberg et al. 2017).

RELEVANCE AND CONSIDERATION OF HUMAN WELL-BEING

Only 15% of studies received the highest human well-being relevance score, meaning they had an aim or primary research objective of understanding human well-being impacts (Table 9).

The limited discussions on human well-being spanned several domains of the Kaplan-Hallam and Bennett (2018) framework. The predominant foci were on social capital and cohesion within the social domain of well-being, and empowerment and agency, and participation, within the domain of governance. Other aspects of well-being that were discussed included: education and knowledge, safety and security, infrastructure, adaptive capacity (social); rights and access, local institutions (governance); identity, activities, and practices (cultural); wealth (economic); nature connection, mental, physical (health). There was limited discussion on cultural diversity, traditional knowledge (cultural), transparency and accountability (governance), employment, livelihoods, and equity (economic), and food security and emotional (health).

DISCUSSION

The results of our scoping review highlight key findings on the use of technology in animal-related CS, the implications for human well-being and social inequalities, and the potential biases of technology-enabled CS data.

1. FEWER REPORTED TECHNOLOGY-BASED ANIMAL-RELATED CITIZEN SCIENCE STUDIES IN THE GLOBAL SOUTH

Only 37 (24%) studies on technology-based animal monitoring were focused on Global South countries. There may be fewer CS initiatives in the Global South than the Global North, but this figure may also represent lower levels of reporting of Global South projects in the scientific literature. The Global South contains some of the most mega-diverse regions in the world (Purton 2024); yet, only 24% of the 220 million observations on iNaturalist were made in the Global South (Oliveira 2025). Other elements potentially affecting these disparities include socio-economic factors (e.g., wealth [GDP per capita], internet connectivity, and school enrolment), a greater emphasis on scientific development and activities in the Global North, resource constraints, and cultural and political barriers (Pocock et al. 2019; Ibrahim, Khodursky, and Yasseri 2021).

2. LACK OF FOCUS ON HUMAN WELL-BEING

Many studies did not seek to understand their participants beyond their role as a source for data. However, recent studies have shown that considering the well-being of participants can not only inform better scientific outputs, but can also provide learning opportunities for communities (Hall et al. 2024), and help to motivate, recruit and retain participants (Land-Zandstra et al. 2021), in turn helping to achieve programme success.

3. OPPORTUNITIES TO EMPHASISE TECHNOLOGY'S CONTRIBUTION TO ANIMAL-RELATED CS

The review highlighted how digital technology can promote community experiences (Turnbull, Searle, and Lorimer 2023) and foster increased understanding and engagement with nature. For example, platforms such as iNaturalist can encourage in-app group formation and data sharing to enable the collection of observations and support species identification (Truong and Van der Wal 2024), although this functionality to promote community interaction is not a common feature of CS studies (Ganesh, White, and Haque 2026).

Some challenges were also highlighted, such as the potential for technology to create inequality (Chepkwony, Van Bommel, and Van Langevelde 2018), and with usability and data entry (Zhang et al. 2021; Ostermann-Miyashita et al. 2023). It was noted that response rates could be boosted by options for anonymous data submission (Jäckel et al. 2023) and that removing registration and login requirements facilitated ease of use (Páll-Gergely et al. 2019). However, there is a trade-off in the latter as registrations and logins are designed to enhance the security of the projects and their participants.

It is important to ensure that the inclusion of technology in CS projects is beneficial to participants (Sheard et al. 2024). This is particularly important in low- and middle-income countries, where internet access and technology uptake have increased significantly (Twining-Ward et al. 2022), enabling ease of communication and collection of information in low-resource settings (Wamwenje et al. 2019; Twining-Ward et al. 2022). Failing to consider the social and human well-being impacts of technology in these situations may unintentionally exclude participants who have limited familiarity with technology (Benyei et al. 2023).

4. NEED TO ADDRESS REPRESENTATION AND BIASES WITHIN COMMUNITIES AND DATA IN TECHNOLOGY-BASED CS PROJECTS ON ANIMALS

The focus of animal monitoring was largely on insects, mammals, and birds, and on biodiversity variables related to species populations and ecosystem functioning. Although there are several citizen science studies on marine life (Kelly et al. 2020), these have relatively lower representation in relation to technology use and well-being. Wider application of technology has the greatest potential value for animal-related CS projects focusing on species groups that are less well known and present greater barriers in terms of expertise, but are ecologically significant in terms of ecosystem functioning and also amenable to study by citizen scientists.

Several studies mentioned age and gender-related constraints to participation (Davis, Taylor, and Martin 2019; Squires et al. 2021) which may have implications for technology uptake and effectiveness (Martellos, Seggi, and Conti 2022). There is a tendency for programmes to include more older participants (50+), and there are also gendered differences in the way people engage in CS (Davis, Taylor, and Martin 2019). In the UK, women are also less likely to participate in CS than men, with participation from ethnic minority groups being particularly low (Pateman, Dyke, and West 2021). It is important to understand whether such differences occur in other regions of the world, and how projects are attempting to improve inclusivity.

CONCLUSIONS AND FUTURE DIRECTIONS

There is a need for more research to inform the design of technology-based CS programmes that monitor animals, so that their value to participant well-being can be enhanced. We have identified three priority areas for research to advance knowledge and practice in this area:

1. Enhance understanding of how CS initiatives that monitor animals can support well-being in the Global South. These communities may have different perspectives towards human well-being and technology than the Global North, and future research could consider the extent of community representation, benefits for participants, and factors hindering positive project experiences.
2. Create technology-driven CS projects that are equitable. The role of technology in projects should be evaluated and designed to ensure that participants benefit from, and are not adversely impacted by, its use. Further research should explore technology use and adoption within CS projects to improve understanding of its effects on communities, and how the benefits can be optimised.
3. Improve knowledge and practice to increase opportunities and participation in CS. Targeted research is required to enhance the application of technology use in CS projects for all species,

especially those that are less understood, to understand the constraints faced by different demographic groups engaging in CS (Ganesh, White, and Haque 2026), and to determine how programs can be designed optimally to encourage participation and enhance well-being.

Incorporating participant well-being more formally into CS projects across both the Global North and South will foster a greater connection and understanding of nature and ensure a more equitable distribution of the human well-being benefits of participation.

DATA ACCESSIBILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

SUPPLEMENTARY FILES

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

- **Supplementary File 1.** Table S1: Search Terms. DOI: https://doi.org/10.5334/cstp.1001.s1
- **Supplementary File 2.** Table S2: Inclusion and Exclusion Criteria. DOI: https://doi.org/10.5334/cstp.1001.s2
- **Supplementary File 3.** Table S3: Questions for Data Extraction. DOI: https://doi.org/10.5334/cstp.1001.s3
- **Supplementary File 4.** Table S4: Full Citations of Articles Included in Scoping Review. DOI: https://doi.org/10.5334/cstp.1001.s4

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Sangita Ganesh, Piran White, and Anika Nasra Haque conceived the idea and designed the methodology. Sangita Ganesh collected and analysed the data and Piran White and Anika Nasra Haque did a secondary review of a subset of the data; Sangita Ganesh led the writing of the manuscript, with inputs from Piran White and Pinaki Nandan Pattnaik. All authors contributed critically to the drafts and gave final approval for publication.

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