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RESEARCH ARTICLE

Community (citizen) science for assessing nature's benefits: A systematic review and survey

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Abstract

1. The undervaluation of nature in decision-making significantly contributes to the current global biodiversity crisis. However, assessing the benefits of nature for people is challenging, partly due to barriers in collecting relevant data. We therefore explore whether community (citizen) science could support holistic assessments of nature's benefits to inform national policies, using the UK as a case study.
2. We use a mixed methods approach, featuring a systematic review of UK community science programmes, a survey of UK community scientists and a comparison of UK national guidance on assessment of nature's benefits with national community science programmes and scientist experience. Our study is the first to: (a) combine a systematic review and survey to examine the relationship between UK community science and nature's benefits, (b) assess community scientists' opinions of the use of community science for assessing nature's benefits nationally and (c) evaluate links between national guidance on assessing nature's benefits, current community science programmes and community scientist experience.
3. Both the review and the survey found that while few UK community science programmes directly assess nature's benefits, many indirectly relate to nature's benefits, most often through the assessment of biodiversity, which underpins long-term benefit delivery. Community scientists supported further expanding and integrating community science as a supplementary approach to evaluating nature's benefits, with some caveats.
4. However, the review and survey also revealed divergences between national guidance on assessing nature's benefits, the academic literature on community science and the experiences and opinions of community scientists of nature's benefits, specifically for benefits from culture and recreation, soils and minerals and aquatic environments.
5. Our results suggest that community science is a valuable tool for engaging communities in assessing the benefits of nature to people, to strengthen the evidence base for decision-making and encourage pro-environmental behaviour; however, future research and policy should better integrate community science

into the evaluation of nature's benefits and vice versa. Addressing existing gaps in community science and expanding assessment methods to be more inclusive of pluralistic nature valuation approaches is crucial for a wider application of community science to assessing nature's benefits.

KEYWORDS
citizen science, community science, ecosystem services, nature's benefits, survey, systematic review, UK, United Kingdom

1 | INTRODUCTION

Protecting and restoring healthy ecosystems and the services they provide is vital to address the interconnected climate and biodiversity crises (Dee et al., 2017; Wamsler et al., 2016), but the values of nature are often neglected in policymaking that is dominated by political and economic values (Costanza et al., 2014). The concept that stocks of natural capital deliver flows of ecosystem services was developed to place the value of nature on the same footing as the value of other forms of capital including financial, social and manufactured (Daily et al., 2000). These links between nature and human welfare received global attention through the 2005 Millennium Ecosystem Assessment (MEA), which found that 60% of analysed global ecosystem services were 'degraded or used unsustainably' and that human actions were 'increasingly diminishing' nature's benefits for future generations (Millennium Ecosystem Assessment (MEA), 2005). Later, the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) adopted the term 'Nature's contributions to people' to include both the benefits and disbenefits of nature, and extend beyond the economic concepts of capital and services (Díaz et al., 2015). These concepts have been applied on numerous spatial scales (Fleming et al., 2022), in the public and private sector (Leach et al., 2019), and within a wide array of disciplines, including ecology, ecological economics and conservation science (Díaz et al., 2018). This paper uses the term 'nature's benefits' as a broad umbrella term to encompass the benefits of nature that contribute to people's well-being, spanning both the stocks of natural capital and the ecosystem services that they provide.

Assessing the value of nature's benefits can underpin conservation mechanisms such as payment for ecosystem services, which can deliver improved biodiversity and social outcomes (Grima et al., 2016; Hejnowicz et al., 2014). However, ecosystem service valuation can be limited by major information gaps (Barton et al., 2018) and may be poorly integrated into local decision-making (Primmer et al., 2018). Many monitoring and valuation methods for nature's benefits require extensive data, scientific and technological expertise and access to relevant tools (Kareiva et al., 2011), limiting their application by stakeholders and the public (UK National Ecosystem Assessment, 2011). Other problems include restricted availability and/or high cost of data, especially fine-scale local data (Costanza et al., 2014), and lack of guidance for certain ecosystems (Hooper et al., 2019). These challenges can impede efforts to utilize such assessments for biodiversity conservation efforts and restrict the ability to confirm the efficacy of such interventions.

Because evaluating nature's benefits involves a variety of stakeholders, landscapes and impact pathways, it requires a wide range of tools and methods (Bagstad et al., 2013). Therefore, recent studies have emphasized community-based approaches to facilitate awareness of and participation in nature's benefits assessments (Hinson et al., 2022), including community (citizen) science. The European Citizen Science Association (n.d.) currently defines citizen science, as 'the participation of the public in science and research' where 'citizens are actively involved in research' that produces 'a genuine science outcome'. Recent research has advocated for a transition from the term 'citizen science' to 'community science' as it is more politically and socially inclusive with respect to citizenship status (Finch et al., 2022).

Environmental community science empowers the public through monitoring aspects of environmental conditions, such as biodiversity or water quality, over short- and long-term periods. Technological advances have led to increased participation in community science (Freitag & Pfeffer, 2013), prompting increased data collection (Eitzel et al., 2017), increased scientific literacy (Bonney et al., 2009), the democratization of scientific processes (Strasser et al., 2018) and pro-conservation behaviours (Pocock et al., 2023). Importantly, community science has been noted as a mechanism for shaping policy, decision-making and planning on multiple governance levels (Kullenberg & Kasperowski, 2016).

However, there are crucial concerns surrounding the applicability of community science for assessing nature's benefits, including the potential for decreased data quality (Fritz et al., 2022) and the need for continuous engagement to deliver consistent monitoring, which demands nuanced design of community science (Gallagher et al., 2024). Furthermore, public and research interests within community science lead to biases that constrain its potential to assess the wide variety of nature's benefits (Fritz et al., 2022). However, it is widely recognized that community science, when conducted with high scientific and ethical standards, 'could benefit society greatly' (Wilkinson et al., 2016).

Prior studies have found increasing interest in using community science to analyse the state of ecosystems (Boakes et al., 2016). A global systematic review by Schröter et al. (2017) found that citizen

science has indirectly contributed to assessing regulating and cultural services, although direct assessment of ecosystem services was rare. Seymour et al. (2022) previously developed a multidimensional theoretical framework for utilizing community science to generate interdisciplinary natural capital knowledge and monitoring. However, to our knowledge, no research has examined the use of community science for assessing nature's benefits at the national level and in relation to national guidance, through the evaluation of real-world community science programmes and the experiences of community scientists.

This review explores the potential of community science to expand and diversify the assessment of nature's benefits, using the United Kingdom (UK) as a case study. The UK conducted one of the world's first national assessments of ecosystem services, showing that 30% of services were declining (UK National Ecosystem Assessment, 2011). In response, the UK developed national natural capital policies (Hein et al., 2020). These are supported by national guidance for government, public and private sector use, called *Enabling a Natural Capital Approach* (*ENCA*), which aims to increase services provided by nature in the UK (Defra, 2020). Despite these efforts, the UK remains in the bottom 10% of countries globally for biodiversity intactness (The Natural History Museum, London, 2021). The 2024 State of Natural Capital Report for England confirmed that all of England's ecosystem assets, and their benefits, are at high or medium-high risk of degradation, highlighting the continued need for better integration of the value of nature in decision-making (Natural England, 2024). While *ENCA* provides clear definitions and examples of nature's benefits, which serve as the guiding framework for this study, it does not currently reference the role of community science in assessing and monitoring nature's benefits, thus revealing a potential opportunity to align community science with this national guidance. For these reasons, the UK was selected for this case study.

Our study aims to understand the links between national guidance and community science with respect to assessing nature's benefits by answering three research questions: (1) how does UK community science relate to the assessment of nature's benefits as defined by the *ENCA* guidance; (2) what are the experiences of UK community scientists related to assessing nature's benefits; and, (3) what is the feasibility of using community science to assess nature's benefits and are there any gaps that need to be addressed?

2 | METHODS

2.1 | Overview of the two-part study design

A mixed methods sequential explanatory design was used, including two consecutive phases (Ivankova et al., 2006) to evaluate the feasibility of using community science to support assessments of nature's benefits in the UK. First, a systematic review of peer-reviewed literature and community science hubs was carried out to identify ongoing UK community science programmes and to determine whether they evaluated nature's benefits in line with *ENCA* guidance. This then informed a survey of UK community scientists evaluating their experience with assessing nature's benefits.

2.2 | Systematic review: How does UK community science relate to assessing nature's benefits as defined by the *ENCA* guidance?

2.2.1 | Overview

A systematic review was used to identify citizen science programmes active in the UK that address nature's benefits, as defined in the *ENCA* guidelines (Defra, 2020). We reviewed both academic literature databases and community science hubs, to increase the comprehensiveness and credibility of the conclusions (Bramer et al., 2017) and limit biases that could arise from insufficient data sources (Mayo-Wilson et al., 2018). Community science is often not reported in peer-reviewed literature (Theobald et al., 2015) due to the small size of some programmes (Wang et al., 2015) and the submission of program data to larger portals which masks specific programmes (Cooper et al., 2014). Furthermore, community science has numerous synonyms (e.g. citizen science, crowd-sourced science, volunteer data collection and community/volunteer monitoring; Finch et al., 2022), so that articles with divergent language, but similar community science approaches, may not appear in literature searches.

2.2.2 | Data sources

Two academic literature databases, Scopus and Web of Science, were searched; these are recognized for their quality and depth of coverage on scientific research (Norris & Oppenheim, 2007) (see *Data Sources* for a list of systematic review references). Additionally, four community science platforms ('hubs') were searched; these are considered to be 'the most formalized communication channels in the citizen science community' (Schröter et al., 2017). We selected CitSci.org, eu-citizen.science, SciStarter and Zooniverse because they have been used in previous systematic reviews on community science (Schröter et al., 2017; Storksdieck et al., 2016) and include UK-based community science programmes covering a range of research areas. This is particularly important as nature's benefits are interdisciplinary, thus necessitating multisubject platforms.

2.2.3 | Search and screening process

The review was carried out from June to July 2023 and adhered to the following replicable process. Peer-reviewed articles included in the review were identified from a search of article titles, abstracts

and keywords/topics. The selected search terms were chosen after a preliminary investigation of the literature in both databases to test the relevance of the results. As the research questions focus on the United Kingdom, place-based search terms were incorporated. The search phrase was: "'citizen science' OR 'community science' AND 'natural capital' OR 'ecosystem services' OR 'benefits' AND 'UK' OR 'United Kingdom'" without brackets. This returned more results than if parentheses or brackets were used (see Section 4.4 for more details). The literature search included only original published peer-reviewed research articles written in English in the last 3 years (2020–2022), to focus on programmes that were likely to be currently active.

Articles from the literature review were screened (based on titles and abstracts) to exclude studies if a specific community science programme was not explicitly identified by name. Community science programmes from the articles and hubs were then screened to ensure that they:

(i) were based in and primarily operated in the UK
(ii) were current and ongoing
(iii) conducted research directly related to nature's benefits as defined in the *ENCA* guidance OR
(iv) conducted research that was indirectly related to nature's benefits, or its related concepts, based on *ENCA* guidance (Sections 8.1–8.4, Defra, 2020).

The initial literature database search resulted in 162 articles and the search of hubs resulted in 1932 programmes. After screening, 41 articles were read in full and 536 programmes were retrieved through the community science hubs (Figure 1). Nineteen peer-reviewed journal articles met the criteria, as did 30 community science programmes from the hubs. After eliminating duplicates, 38 programmes were included in the review. Programme websites were then examined to answer the analysis questions (Table 1).

2.3 | Survey: What are the experiences and opinions of UK community scientists related to nature's benefits?

2.3.1 | Overview

To better understand the feasibility of UK-based community science to evaluate the benefits of nature, an online survey of UK community scientists was carried out. This aimed to (a) evaluate the experience of community scientists with community science related to nature's benefits and (b) evaluate the opinions of community scientists on the relationship between community science and nature's benefits. The survey expanded beyond definitions provided in the *ENCA* guidance to increase accessibility and clarity of the survey by providing more diverse and common terms and options.

2.3.2 | Participant recruitment

The survey questionnaire used Microsoft Forms and was open from July to August 2023. The length of time for survey collection was confined by the research project timescale, and rates of responses had plateaued by the end of the period. The survey was distributed to major conservation organizations and networks in the UK involved in a variety of community science programmes through a snowball sampling method. This method was chosen as UK community scientists form a small, local community with a close network of participants (Naderifar et al., 2017). The survey was spread through personal contacts, Facebook groups, LinkedIn posts and Twitter feeds of UK nature organizations and networks. Based on the sequential explanatory design of the mixed methods approach, these conservation organizations and networks were partially selected based on the organizations featured in the review.

The cover page of the questionnaire delineated the target audience: adults, aged 18+, who participate in or have participated in UK community science related to conservation and nature. It also stated the purpose of the investigation: 'to understand how community (citizen) science supports the evaluation and monitoring of local nature for its benefits and services to individuals and communities'. All levels of UK community science experience were accepted. All questions were optional, and potential participants were encouraged to provide as much or as little detail as they felt comfortable sharing. No personally identifiable information was collected and there was no financial reward for participation.

2.3.3 | Participants

We surveyed 22 respondents of which 90% were currently involved in UK community science and 10% had previous involvement. All respondents finished the survey, but not all questions were answered (see Results Section 3.2 for details on non-responses). All respondents were over the age of 25 years with 90% older than 35 years. The largest age groups were 35–44 years (36%) and 65 years and older (27%). Most of the respondents were female (59%), followed by male (36%) and other (3%). All respondents had a secondary education or higher, while 68% had a university degree or higher. The majority of respondents identified as professionals or retired ($n=21$). All identified as white or Caucasian. (see Section 4 for comparison of demographic data with wider UK community scientist demographics).

2.3.4 | Questionnaire design

The online questionnaire design drew on methods published in comparable studies on community science managers and participants (Finch et al., 2022; Stylinski et al., 2020) and online surveys for conservation research (Wardropper et al., 2021). It features self-reported responses about past and current experiences with community science programmes in the UK, along with opinions on the

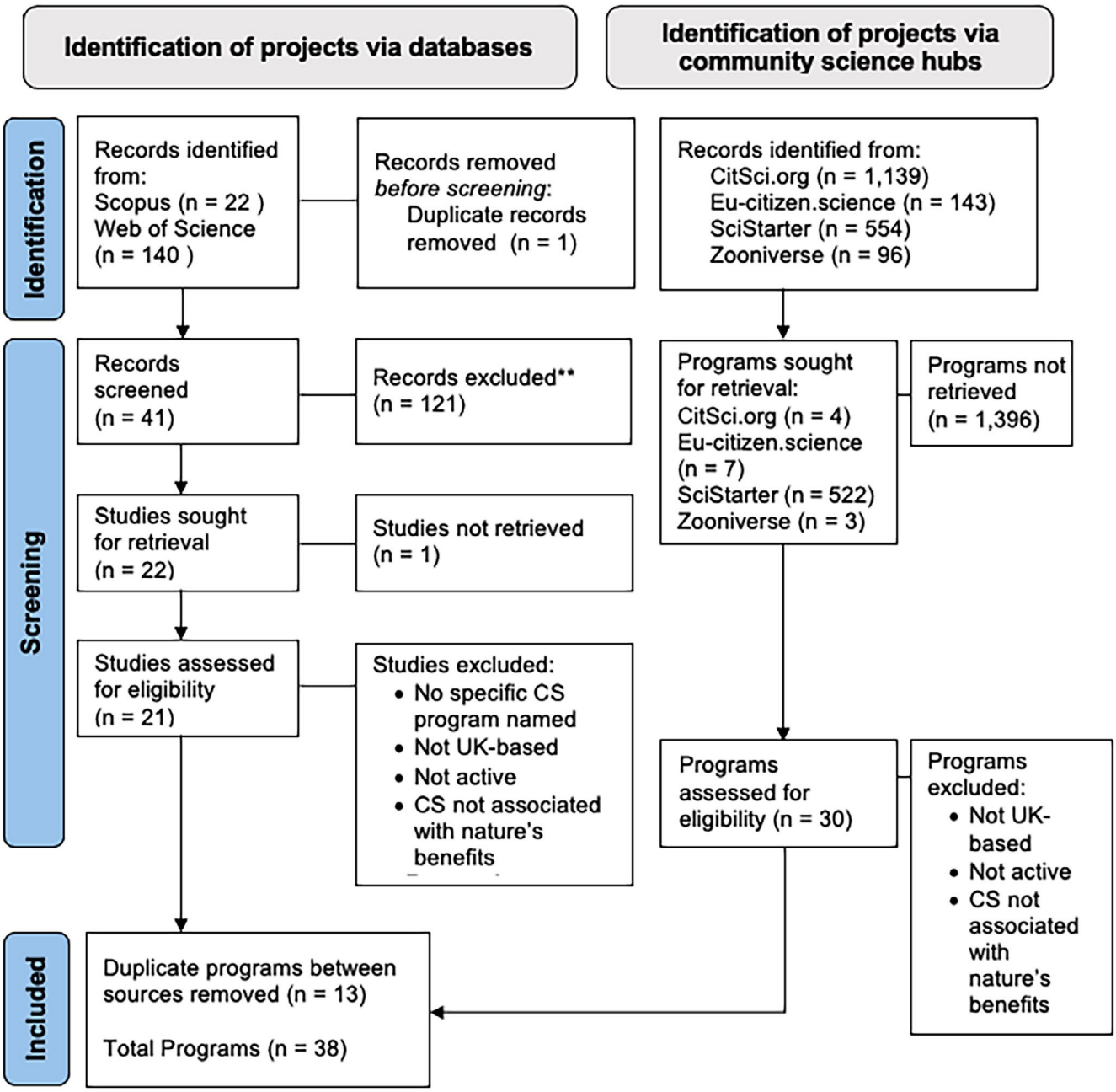

FIGURE 1 Systematic review results flow chart (adapted from the PRISMA flow chart Page et al., 2020).

TABLE 1 Review questions for the analysis of community science programmes featured in the peer-reviewed literature and hubs.

Systematic review questions for analysis
General information
• What is the community science programme's primary region of operation (specific country or nation) • What is the reach of the programme (regional, national or international)? • What organizations are involved in the programme? What types of organizations are they (e.g. non-profit, business, academic or governmental)? • What is the time scale of the programme? • What is the size of the community science programme? (Number of volunteers and number of total records collected in the programme's lifespan)
Relationship to nature's benefits (based on categories in the UK's Enabling a Natural Capital Approach)
• What is the subject of research conducted by the programme? • What is the natural capital asset(s) associated with the programme? • What are the ecosystem service(s) associated with the programme and what is the category of ecosystem service? • What are the benefits(s) from nature associated with the programme?

use of community science to assess nature's benefits (see Table S1 for the complete questionnaire).

The survey was split into two sections: demographic questions and questions about the experience and opinions of community science. Both parts collected quantitative data, through multiple-choice questions and qualitative data through short, write-in responses.

2.3.5 | Ethics

The questionnaire and all participant-facing materials were approved by the University of Oxford's Research Ethics Committee standards (CUREC reference: SOGE C1B 23 10) and adhered to strict ethical guidelines for internet-mediated research for online surveys. Informed consent was obtained before the start of the survey. Respondents confirmed that they were over the age of 18. To further adhere to ethical guidelines, the survey was anonymous with no identifiable data collected; all questions were optional, and participants were notified, in the recruitment email and survey instructions, that participation was voluntary.

2.4 | Data analysis

Data analysis followed a mixed methods explanatory design (Creswell, 1999) rather than a detailed data analysis. It used quantitative and qualitative exploratory data analysis; the quantitative analysis comprised descriptive statistics. All analyses and visualizations were performed in R Studio (v4.2.2) (RStudio Team, 2022). Packages used for data visualization include *ggplot* (Wickham, 2016) and *plotly* (Sievert, 2020) and featured *viridis* colour palettes for colour blindness (Garnier et al., 2024).

2.4.1 | Systematic review data analysis

The explicit subjects of the community science programmes were classified by the broad focus of the programme. If the focus of the programme was across multiple taxonomic classes or kingdoms, it was classified as 'biodiversity'. To understand the relationship between UK community science programmes and nature's benefits, data collected from the review was then coded according to the classification system used in the *ENCA* guidance (Defra, 2020; Table S2):

- Eight broad habitat types (ENCA Section 1.6)
- Four broad categories of benefits (provisioning, regulating, cultural and 'aggregated or bundled benefits', a catch-all category for benefits which did not fit within the first three; ENCA Section 8.4). Aligning with ENCA, supporting benefits are not included as their impact is captured in other categories (ENCA Section 1.8).
- Specific benefits (ENCA Sections 8.1 to 8.3). Abiotic flows ('flows which are not dependent upon functioning ecosystems') are also included, in line with the ENCA guidance.

If the research could be used to measure, support or inform assessments of specific benefits of nature, those benefits were listed even if the programme did not directly intend to measure them. Indirect coding is further supported by the *ENCA* Services Databook (Defra, 2023) and Smith et al.'s (2017) typology linking components of natural capital to ecosystem services. For example, forest habitat assessments were classified for potential ecosystem services such as carbon sequestration and timber production, even if they only directly aimed to measure ecological communities and species.

The exploratory quantitative analysis of the systematic review featured three primary variables: (i) count of community science programmes per related benefit and benefit category, (ii) length of time of programmes per related benefit and benefit category and (iii) count of related benefits per programme. Because all programmes involved volunteerism and provided educational training, we automatically assumed 'volunteerism' or 'education' as benefits for all programmes and did not include them in the analysis. The number of records/observations collected per programme and number of participants were not analysed due to lack of data, lack of standardization across data collection methods and heterogeneity of subjects (e.g. there will often be more observations for biodiversity than for water quality), potentially introducing significant bias.

Statistical analysis focused on understanding the underlying patterns between the numeric and categorical variables in relation to the number of benefits assessed per programme.

2.4.2 | Survey data analysis

Write-in responses were analysed through thematic analysis (Nowell et al., 2017). Some respondents did not answer all the questions, especially write-in questions. Due to the relatively small data set, the corresponding author conducted the theme identification and response coding manually. We calculated the count of respondents with community science experience per related benefit and benefit category.

3 | RESULTS

3.1 | How does UK community science relate to nature's benefits assessments as defined by UK's *ENCA* guidance?

3.1.1 | Overview of systematic review of peer-reviewed literature and community science hubs

The 38 programmes had been operating for 1–84 years (mean = ~19; SD = 18; median = 14) and covered all eight of the broad habitat types (Table S2) as defined by *ENCA*. Most programmes were associated with terrestrial habitats (76%), and 26% were in urban environments.

Most programmes had a geographic focus of the UK compared to a regional or international focus (Table 2).

The programmes were hosted or co-hosted through 46 organizations (Table S3), with the Joint Nature Conservation Committee (JNCC), the British Trust of Ornithology and UK Centre for Ecology and Hydrology hosting the most programmes (Table 3). Most host organizations were non-profits (56%) followed by government agencies (20%), academic institutions (20%) and businesses (4%).

The majority of community science programmes featured were hosted by organizations with missions for preserving nature and/or specific species. Their community science programmes primarily intended to monitor species population trends to support management for the protection of species and their habitats. The programmes also contributed species-specific data to monitor the state of biodiversity in the UK. The intended users of community science-collected data included land managers, researchers and policymakers. Motivations behind the studies featured in the review were numerous but included (1) informing management decisions for species and habitats, (2) assessing accuracy of data for monitoring broader population trends, (3) supporting improved environmental policy and guidance and (4) evaluating changes in ecosystem processes and/or functions.

3.1.2 | Subject focus of reviewed community science programmes

Birds were the most frequent subject ($n=8$), followed by insects, mammals and plants ($n=7$). Amphibians, fish, phenology and agriculture were the least represented subjects ($n=1$; Figure 2, Table S2).

3.1.3 | Benefits of nature associated with reviewed community science programmes

Most programmes assessed specific species or overall biodiversity ($n=36$; 95%) which falls within the *ENCA* 'aggregated & bundled benefit' category; few assessed cultural benefits ($n=2$) and none assessed abiotic flows (Figure 3, Table S2). The longest-running programmes were associated with the 'aggregated & bundled' category (average = 19.5 years), followed by provisioning and regulating services. Programmes involving cultural services had been running for the least time (average = 4.5 years; Figure 3).

The most common benefit was biodiversity ($n=35$), followed by carbon sequestration ($n=14$; 37%). Benefits not associated with the community science programmes reviewed were minerals, non-use values, renewable energy, soil health, waste

TABLE 2 Geographic focus of community science programmes featured in the systematic review.

Geographic focus	Community science programmes
Regional (7) Community science based in the UK with data collection occurring in a specific location or area in the UK, including individual countries (e.g. Wales, England, etc.)	Ecosystem Explorers, Our Outdoors, Project SIARC, Seabird Watch, Shorewatch, Southeast England Surface Water Project, Wild Watch
National (24) Community science based in the UK with data collection throughout the UK	Ancient Tree Inventory, Bat Tree Habitat Key Project, BeeWatch, Big Seaweed Search, Breeding Bird Survey, Garden BirdWatch, Garden Wildlife Health, Ladybird Survey, Marine Mammal Survey, MyHarvest, National Bat Monitoring Scheme, National Dormouse Monitoring Program, National Plant Monitoring Scheme, Nature's Calendar Survey, Nest Record Scheme, Nesting Neighbors, ObservATree, Riverfly Monitoring Initiative, Toads on Roads, Treezilla, UK Pollinator Monitoring, UK Butterfly Monitoring Scheme, Wetland Bird Survey, Wider Countryside Butterfly Survey
International (7) Community science based in the UK, with data collection both in the UK and other countries including Ireland	BeeWalk, Birdtrack, GreenHack, Herbaria@home, iSpot, MammalWeb, Sechhi Disk study

TABLE 3 The top three most frequent organizations hosting/co-hosting community science programmes featured in the systematic review.

Organizations	Community science programmes
Joint Nature Conservation Committee (8)	United Kingdom Pollinator Monitoring Scheme, United Kingdom Butterfly Monitoring Scheme, Wetland Bird Survey, Wider Countryside Butterfly Survey, Breeding Bird Survey, Ladybird Survey, National Bat Monitoring Scheme, National Plant Monitoring Scheme
British Trust for Ornithology (8)	Birdtrack, Breeding Bird Survey, Garden BirdWatch, Nest Record Scheme, Nesting Neighbours, United Kingdom Butterfly Monitoring Scheme, Wetland Bird Survey, Wider Countryside Butterfly Survey
UK Centre for Ecology and Hydrology (6)	Ladybird Survey, National Plant Monitoring Scheme, Nature's Calendar Survey, UK Pollinator Monitoring, United Kingdom Butterfly Monitoring, Wider Countryside Butterfly Survey

remediation and water supply (Figure 3). The longest-running programmes evaluated peat (average 30.5 years), followed by biodiversity (20 years) and benefits related to trees (e.g. timber, carbon sequestration, local climate regulation, etc.) (average 18–19 years). The shortest-running programmes related to cultural services (<~7 years).

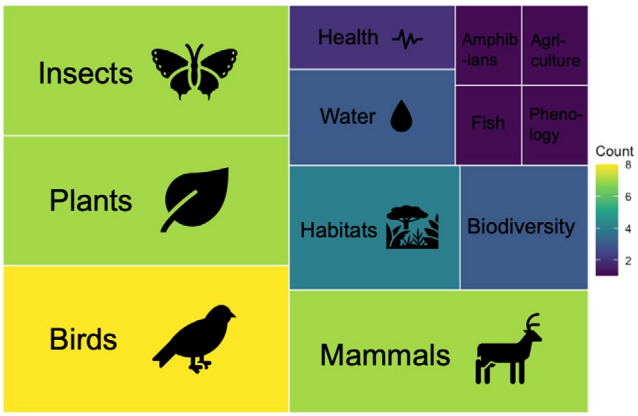

FIGURE 2 Count of subject focus across UK community science programmes featured in the systematic review of peer-reviewed literature and hubs.

3.1.4 | Multiple benefits

Most programmes ($n=25$; 61%) were associated with more than one benefit (Table S2). The maximum number of related benefits for a programme was 14; this occurred for two programmes associated with cultural benefits in greenspaces (GreenspaceHack and OurOutdoors). Sixteen programmes (39%) were related to only one benefit; these programmes focused on the following benefits: biodiversity ($n=13$), water quality ($n=2$) and food ($n=1$). A Pearson correlation analysis found no strong correlation between the number of benefits and the length of time for which the programme had been running ($r(36)=-0.062$).

3.2 | What are the experiences of UK community scientists related to nature's benefits?

3.2.1 | Overview of UK community science survey results

Most of the respondents (90%) had been involved with UK community science related to nature's benefits for more than 1 year, and 11 had been involved between 1 and 5 years. Fifteen identified themselves as community science participants/volunteers, while 2 identified as community science coordinators, and 5 identified as both.

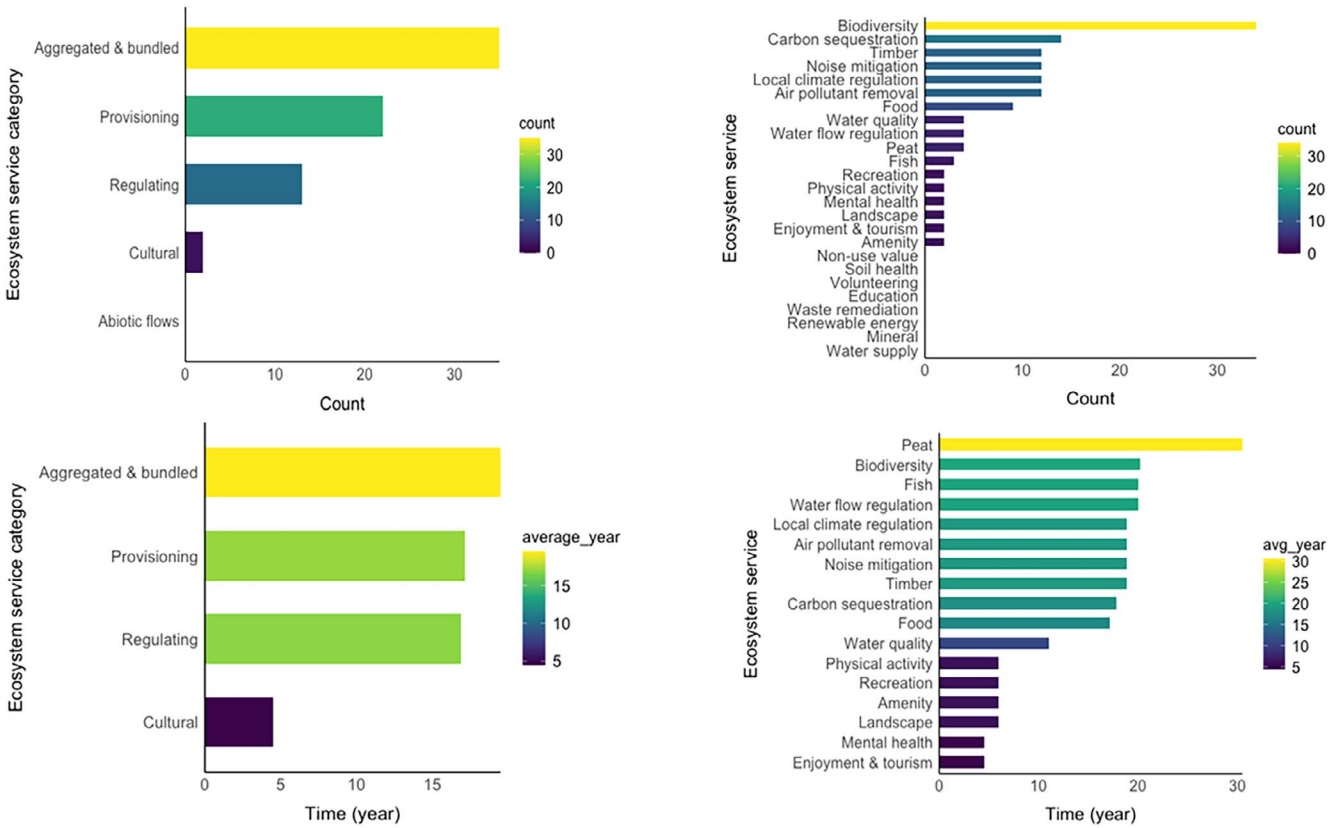

FIGURE 3 Top: Count of *ENCA*-defined benefit categories and specific benefits featured in community science programmes included in the systematic review. Bottom: Mean time (years) of community science program data collection associated with each *ENCA*-defined benefit category and benefit.

Most (73%) had been involved with 1–3 programmes, three with 4–6 programmes and three with 7 or more programmes. Respondents identified 38 current programmes in which they were previously or currently participating, of which 11 had been covered in the review (Table 4), that is 26 programmes mentioned by respondents were not covered in the review (Table S3). Most of the programmes were national scale (Table 4).

3.2.2 | Experience of UK community scientists with nature's benefits assessments

Most of the respondents (90%; $n = 20$) had heard of nature's benefits and ecosystem services before. When asked if they felt they had been involved with UK-based community science that was directly or indirectly related to nature's benefits broadly, 10 replied no, 8 replied yes, 3 replied maybe, and one did not respond.

However, the 22 respondents all identified benefits they felt were related to their current or previous community science experiences. Almost all respondents had experience with biodiversity (21), 14 had experience with pollinators, followed by water quality (9) and education and local knowledge of nature (9). Fewer participants identified experiences related to the benefits of timber, cooling and shading and fish (Figure 4).

Most respondents ($n = 12$) identified as participating in community science which was related to >1 benefit. Nine noted only one benefit and one did not respond. Pearson's correlation tests showed no significant relationship between the number of benefits participants felt they had evaluated and the number of programmes in which they were involved ($r(38) = 0.069$) or the length of community science participation time ($r(38) = -0.060$).

3.2.3 | Opinions of UK community scientists on assessing nature's benefits

Fourteen respondents (66%) supported evaluating nature's benefits through community science, and seven (33%) said 'maybe', with one not replying. However, it is critical to read this result with caution, as it could reflect acquiescence bias (Hinz et al., 2007).

Fourteen participants provided write-in responses to further describe their opinions. Eight themes were identified with several

TABLE 4 Geographic focus of the community science programmes mentioned in the survey (defined the same as Table 2).

Geographic focus	Community science programmes
Regional (3)	Evenlode Catchment Partnership Ecosystem Evolution Water Management Project*, Evenlode Catchment Partnership Waterwatch Community Water Quality Testing*, ObstacEELS
National (32)	**Ancient Tree Inventory**, Big Butterfly Count, Big Farmland Bird Count, **Big Garden Birdwatch**, **Big Seaweed Search**, Bird Ringing Scheme, **Breeding Bird Survey**, Churches Count on Nature, Dung Beetles for Farmers, Earthworm Watch*, Every Flower Counts, Freshwater Habitats Trust water quality monitoring, Freshwaterwatch, Garden Birdwatch, Grow Observatory, Health Bird Survey, Hedgeog Street, iRecord, Microverse*, Miniature Lives Magnified*, National Education Nature Park, National Plant Monitoring Scheme, Nature Overheard*, **Nature's Calendar**, Orchid Observers*, PTES Hedgerow Survey, PTES Stag Beetle Hunt, **Riverfly Monitoring Initiative**, Tiny Forest Monitoring Scheme*, **UK Butterfly Monitoring Scheme**, **UK Pollinator Monitoring Scheme, Wetland Bird Survey**
International (3)	**Beewalk**, Big Meadow Search, BSBI New Year's Plant Hunt

Note: Bolded programmes were identified in both the review and survey. Programmes with an asterisk (*) have since ended after the study's data collection.

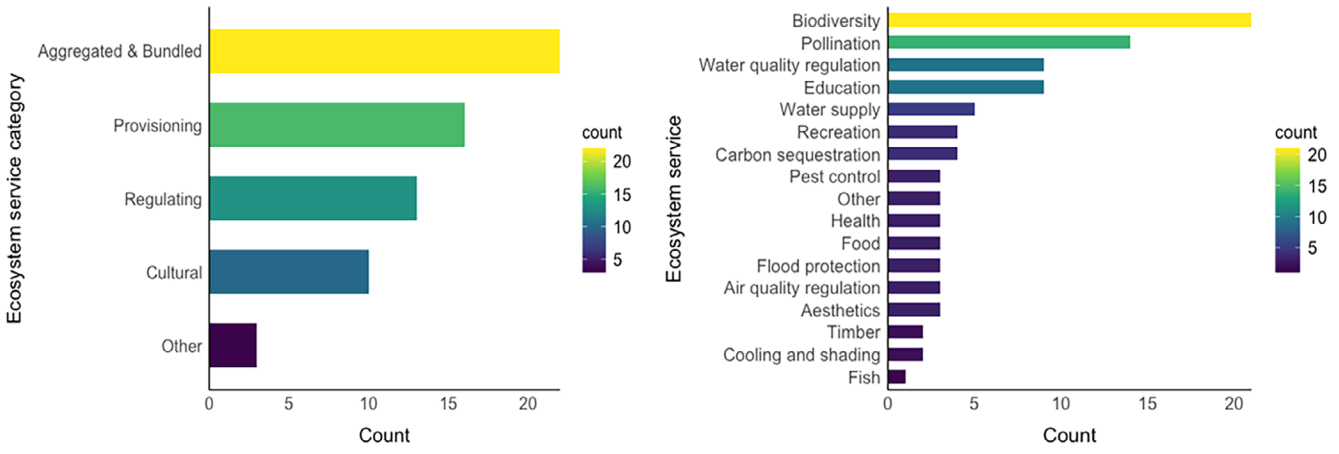

FIGURE 4 Number of survey respondents who self-identify as having experience with each benefit category and specific benefits.

TABLE 5 Summary of thematic analysis of community scientists' write-in response regarding UK community science's support of nature's benefits assessments.

Yes	Count	Maybe	Count	No	Count
Increased data collection	6	Data quality concerns	3	N/A	0
Benefits for humans	4	Community science alone is insufficient	1		
Benefits for nature	3	Consideration of community interests and place-based issues	1		
Benefits for humans & nature	3	Nature commodification concerns	1		
Benefits for communities	2				

responses covering more than one theme (Table 5). The most common opinion for supporting the inclusion of community science in nature's benefits assessments was increased data collection, followed by benefits for humans, such as increasing nature connection and mental health benefits.

Respondent primary concern on community science to support nature benefits assessments focused on data quality ($n=3$). One person each noted the following concerns: community scientists should not bear the burden of monitoring nature's benefits alone, community interest and place-based issues should guide community science efforts, and community science should not be used to commodify nature. The latter respondent noted that benefits less easily commodified through markets could be evaluated through community science.

4 | DISCUSSION

Here, we discuss our results in relation to the three research questions (Sections 4.1 to 4.3), discuss limitations and future research (Section 4.4) and consider policy and practice implications (Section 4.5).

4.1 | How does UK community science relate to nature's benefits assessments as defined by the systematic review and *ENCA* guidance?

Almost all reviewed community science programmes are related to the benefit of biodiversity (92%). Biodiversity was also associated with the longest-running programmes. Our findings mirror other studies that indicate that biodiversity is the most common focus of environmental community science (Schröter et al., 2017; Theobald et al., 2015). Furthermore, birds were the most common subject of the species observed in UK community science, a pattern acknowledged globally (Amano et al., 2016). With biodiversity declining in the UK and globally, filling in gaps for species rarely represented in community science (e.g. fish and amphibians) will be crucial to help understand both changes in biodiversity itself and how biodiversity underpins nature's benefits.

Only one programme, Treezilla, directly assessed nature's benefits using an ecosystem services framework. Indirect benefits associated with UK community science programmes included: (1) air pollutant removal, (2) amenity, (3) biodiversity, (4) carbon sequestration, (5) enjoyment and tourism, (6) fish, (7) food, (8) landscape, (9) local climate regulation, (10) mental health, (11) noise mitigation, (12) peat, (13) physical activity, (14) recreation, (15) timber and (16) water quality. This finding aligns with the global systematic review by Schröter et al. (2017) which found that most community science programmes evaluating ecosystem services did so through proxy indicators that 'implicitly provided information on ecosystem services' and that direct assessments of ecosystem services were rare.

The review reveals that over 60% of community science programmes associated with nature's benefits are associated with multiple benefits, with the highest number of potential benefits associated with programmes related to cultural services. Previous research has also stated that community science programmes have assessed or been associated with multiple ecosystem services (Schröter et al., 2017) as well as cultural services having association with multiple services (Ament et al., 2017). Multiple benefits frequently occur for programmes that assess vegetation also, mirroring research that evidences the numerous services delivered through plants and their functions (Quijas et al., 2019).

4.2 | What are the experiences and opinions of UK community scientists related to nature's benefits?

Although most of the UK community scientists surveyed knew about ecosystem services and nature's benefits, many did not feel that they had experience in collecting data on them when described using umbrella terms. Despite this, when asked about specific benefits with examples, they were able to identify benefits they felt they had experience with. This observation supports a previous analysis on public perceptions of urban park trees in London, UK, which found a lack of familiarity with the term 'ecosystem service' and examples

of tree-related services (Collins et al., 2019). Frameworks have been proposed to reduce this gap between scientific research, policy and the public by addressing different 'knowledge needs' for the public to better interpret scientific terminology (Carmen et al., 2018).

The survey revealed important nuances regarding the opinions of UK community scientists in using community science to assess nature's benefits. While most respondents were positive (considering the risk of agreement bias), noting the potential for improved data collection and benefits for both people and nature, respondents conveyed some reservations. The main concern was about data quality; this is widely noted in the scientific literature (Baker et al., 2021; Fritz et al., 2022), although further research has stated that community science data are useful due to their diversity and large extent (Wilkinson et al., 2016) and opportunities to employ quality controls in data collection (Brown & Williams, 2019). Only one respondent mentioned a concern about the commodification of nature, and suggested that benefits less easily commodified through markets should be evaluated through community science. Respondents also commented that community input within programmes was crucial if such assessments were to occur, in line with previous research showing that community input and recognition of local contexts are critical for the success of citizen programmes (McKinley et al., 2017).

4.3 | What is the feasibility of community science to assess nature's benefits and are there any gaps that need to be addressed?

Our research has shown that despite the lack of explicit targeting of nature's benefits in community science programmes, UK community science has been collecting nature's benefits associated data across numerous programmes for many years. This indicates a large potential to use these programmes to continue and expand relevant data collection, either directly or indirectly. However, this conclusion relies on our assumption that indirect benefits can be inferred from associated data on, for example, vegetation characteristics. In practice, additional data may need to be collected by community scientists. For example, tree size or age may be needed to fully assess carbon storage and flood regulation. This would therefore rely on the willingness of volunteers to collect additional data that cannot be gathered through other means (e.g. via satellite data) and the willingness of community science host organizations to include more variables within data collection protocols.

Additionally, the community scientist survey conveyed key concerns for utilizing community science to assess nature's benefits. When considering expanding community science data collection or developing new community science initiatives to support the assessment of nature's benefits, incorporating and evaluating the perspective of community scientists potentially further bolster the feasibility of such integration.

Our research revealed gaps that would need to be addressed to unlock the potential of community science for assessing nature's benefits. As noted, few programmes addressed nature's benefits directly. Cultural benefits were the least frequently associated benefits in both the review and survey, likely due to limited study (Cheng et al., 2019) and infrequent assessment or intervention (Gould et al., 2019). Although Schröter et al. (2017) found cultural and regulating services most prevalent in global community science, methodological differences in coding may explain the discrepancy. There were also gaps for aquatic benefits, echoing previous findings (Buytaert et al., 2014; Pocock et al., 2017). Sandahl and Tøttrup (2020) note that marine community science is significantly underrepresented in peer-reviewed literature, but that it has been steadily growing. Community science related to soils was not found in the review, but was identified through the survey. Soils have been less represented within community science literature (Mason et al., 2024).

These gaps could be areas for potential expansion within community science. Growing interest in the relationship between nature, human health and well-being indicates potential to support or create more cultural-service oriented community science in the UK (Silva et al., 2024). There is also growing interest in applying community science to benefits from marine ecosystems (Wehn et al., 2025) and for soils, especially in the UK (Head et al., 2020; Mason et al., 2024).

There are some differences between the findings of the review and the survey, which should be interpreted cautiously due to biases in sample size and response rate and varying methodologies between the review and survey. For instance, the review did not identify programmes assessing education but numerous survey respondents had experience with community science related to education and local knowledge of nature. Respondents reported having fewer experiences with climate regulation, timber and aesthetics of nature than the results from the review revealed.

4.4 | Limitations and future research

4.4.1 | Limitations

Our study encountered several limitations. The first relates to assumptions made while coding the relationship of the community science programmes with nature's benefits, as many benefits were inferred, rather than explicitly addressed by programmes. More information may therefore be required to fully assess nature's benefits, either through expanding data collection through community science or from other methods.

Other limitations surround the review's search terms and phrases. Firstly, the search phrase was originally designed for use in Scopus, where brackets or parentheses were not required, but Boolean operators are processed in a different order in Web of Science meaning that brackets or parentheses would have been advisable. Despite this, all results that would have met our criteria with brackets or parentheses were already included in our original search. Secondly, the literature search could have used a wider set

of terminologies including 'community scien*' (to include both community science and community scientist/s), 'crowd-sourced science', 'crowd science', 'participatory science' and 'volunteer monitoring'.

Limitations also arose from the choice of survey platform. Alternative platforms such as Qualtrics or SurveyMonkey could have addressed this problem. Future survey protocols should also separate key concepts into individual questions (e.g. indirect and direct experience with community science related to nature's benefits assessments) to reduce confounding questions.

The most significant limitation of the research approach was the small number of survey respondents, possibly attributed to the timing of the survey (summer) and the length of the survey (22 questions). This increases the likelihood of sampling bias, in which the sample of respondents does not accurately represent the larger population of UK community scientists (Wardropper et al., 2021). For example, the respondent profile for the survey was primarily female, differing from a study of thousands of UK community scientists by Pateman et al. (2021), which found most community scientists identified as male. Although, all survey respondents had a secondary education or higher and identified as white or Caucasian which did mirror Pateman et al.'s findings that community scientists in the UK tend to identify as white or Caucasian, middle-aged or older, and be more educated (2021).

4.4.2 | Future research

The study highlights the potential for future research to explore tailoring nature's benefits assessments to utilize existing community science methodologies and data. Analysing the potential for programmes to directly assess multiple benefits, rather than assuming the potential for benefits to be assessed by proxy, could direct future community science programme design to fill gaps in nature's benefits knowledge. If new community science programmes are created, it would be advisable to narrow the scope of research to limit redundancy within the nature's benefits community science landscape. Lastly, future research could evaluate the efficacy of community science design to support robust nature's benefits assessments. However, to address the concern about placing an undue burden on community science, it is important to frame community science as a potential additional approach to evaluate and monitor nature's benefits, alongside other methods (Bonney et al., 2009; Stuber et al., 2022).

Expanding on the findings of this study, research could examine additional nature's benefits frameworks, beyond the UK's *ENCA* guidance to further support real-world conservation decision-making and governance. For example, there is potential for a global synthesis of community science and its relationship to the IPBES framework of nature's contributions to people (Pascual et al., 2017). Such research would broaden the scope of inquiry to more diverse concepts and perspectives and include non-western values of nature (Díaz et al., 2018).

Additionally, one survey respondent expressed concern over the commodification of nature while also clarifying that benefits less easily commodified through markets should be assessed through community science. While concerns over the commodification of nature through neoliberal policies are widely addressed in literature on ecological economics and conservation (Smessaert et al., 2020), there are opportunities for research on whether the wider public, or a wider subset of community scientists, feels similarly or is familiar with this line of critique.

4.5 | Policy and management implications

To our knowledge, this is the first review and survey on the potential role of UK community science in assessing nature's benefits. We have identified specific community science programmes and datasets that could be useful for researchers, practitioners and the public to evaluate nature's benefits and to support wider participation in monitoring nature's benefits nationally. We also identify gaps where UK community science does not currently

TABLE 6 Summary of learnings, gaps and recommendations from the study.

Learnings	• Most community science programmes focus on biodiversity. • Few community science programmes focus on cultural benefits. • Survey participants supported expanding community science to include more benefits of nature but raised concerns about data quality primarily.
Gaps & future research	• Address gaps in cultural benefits, aquatic ecosystems, soils and underrepresented species groups by adapting current community science programmes or developing new community science initiatives. • Conduct a global synthesis of community science programmes using the IPBES framework, including more pluralistic values of nature (Díaz et al., 2015).
Recommendations	• Consider opportunities to assess one or more nature's benefits within community science data collection and design when possible. • Co-design programmes related to nature's benefits with community scientists, incorporating their interests, concerns and cultural values. • Monitor national nature benefits' data needs in alignment with existing community science efforts. Mobilize funding towards community science where gaps exist. • Promote community science as an additional, supplementary pathway for assessing nature's benefits in policy and guidance.

collect data on specific benefits of nature. Our study presents an example of how to apply a mixed methodology to evaluate the role of community science in nature's benefits assessments, which could be replicated within other countries or regions. To unlock the potential for community science to support wider evaluation of nature's benefits in the UK, policymakers or government agencies could provide direct policy or financial support for relevant programmes, targeting data gaps. Our key findings and recommendations are summarized in Table 6.

5 | CONCLUSIONS

This study has shown that there is significant potential for community science to inform the assessment of nature's benefits in line with UK guidance, but few programmes currently address this explicitly. Policy and funding support are needed to expand direct assessments of nature's benefits through community science programmes and address significant gaps for underrepresented benefits. There is also a need to expand current UK guidance on nature's benefits to explicitly include community science.

Through being the first study to analyse current initiatives and community scientist opinions on a national scale, this study offers an example pathway for similar assessments in other countries and regions. It is hoped that unlocking the potential of community science to contribute to evidence-led decision-making can help to empower communities, deliver more data-rich assessments and support improved policies and monitoring of the life-sustaining benefits from nature.

AUTHOR CONTRIBUTIONS

Raphaella Mascia conceived the ideas and designed the methodology with support from Alison Smith and Yadvinder Malhi; Raphaella Mascia collected the data, analysed the data, created the figures and led the writing of the manuscript; Alison Smith, Yadvinder Malhi and Martha Crockatt revised the draft for important intellectual content. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

No author associated with this paper declares any conflicts of interest.

DATA AVAILABILITY STATEMENT

Data are available through the Oxford University Research Archive (ORA): https://doi.org/10.5287/ora-o57bw7xgp (Mascia, 2025).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Questionnaire evaluating community scientist experience with assessing nature's benefits in the UK.

Table S2. Community science projects identified by the systematic review including benefit categories and benefit(s) associated with each project.

Table S3. Community science projects, featured in the systematic review, with associated host organizations.

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