A mixed methods approach to evaluate community (citizen) science as a tool to support nature's benefits assessments in the UK: a systematic review and survey of community scientists

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Abstract

1) Developing methods for valuing nature aim to address biodiversity and environmental crises caused by nature's undervaluation in decision-making. However, implementing methods to assess nature's benefits is challenging for a myriad of reasons.
2) We explored whether community science (CS) could support a more holistic assessment of nature's benefits on a national scale using a mixed-methods approach, featuring a systematic review of UK CS and a survey of UK community scientists, comparing UK national guidance on nature's benefits with national CS projects and scientist experience. Our study is the first to: (a) combine a systematic review and survey to examine the relationship between UK CS and nature's benefits, (b) assess community scientists' perceptions of CS and nature's benefits nationally, and (c) evaluate links between national nature's benefits guidance, current CS programs, and community scientist experience.
3) Both the systematic review and the survey found that while few UK CS projects directly assess nature's benefits, numerous programs indirectly relate to nature's benefits, most often through assessing biodiversity. Furthermore, community scientists supported further expanding and integrating CS as a supplementary approach for assessing nature's benefits, albeit with some caveats.
4) However, both the review and the survey also revealed substantial dissonance between national guidance on nature's benefits, the CS academic literature, and community scientist experiences and perceptions of nature's benefits, specifically for benefits from culture and recreation, soils and minerals, and aquatic environments.

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5) In light of the highlighted discrepancies, our results suggest CS is a valuable tool for engaging local communities in assessing benefits of nature to people, nevertheless, future research and policy should better integrate CS into nature benefit's assessments and vice versa. Addressing existing gaps in CS and widening CS methods to be more inclusive of pluralistic nature valuation methods and concepts is also crucial for wider application of CS related to nature's benefits assessments.

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Keywords

Key words: citizen science, community science, ecosystem services, nature’s benefits, survey, systematic review

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1 Introduction

Protecting and restoring healthy ecosystems is vital to address the interconnected climate and biodiversity crises (Dee et al., 2017; Wamsler et al., 2016), but the broad values of nature are often neglected in decision-making which is dominated by economic and political factors (Costanza et al., 2014). The concepts ecosystem services and natural capital were developed to place the value of nature on the same footing as the value of human, social, financial and manufactured capital (Daily et al., 2000). These measures of value linking nature and human welfare received global attention through the 2005 Millennium Ecosystem Assessment (MEA)), which found that around 60% of analyzed ecosystem services were “degraded or used unsustainably” and that human actions were “increasingly diminishing” the benefits of nature for future generations (MEA, 2005). This paper uses the term ‘nature’s benefits’ to encompass the concepts related to the benefits of nature which contribute to people’s well-being. This concept has been applied on numerous spatial scales (Austen et al., 2019; 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 (Dìaz et al., 2011; McHale et al., 2018).

The United Kingdom was an early pioneer of measuring nature’s benefits to people, conducting one of the first global national ecosystem services assessments from 2009-2011 (UK National Ecosystem Assessment, 2011). The UK Government then established the Natural Capital Committee (UK NCC, 2022), which developed a resource hub called *Enabling a Natural Capital Approach* (ENCA) lead by the UK Department of Environment, Food, and Rural Affairs (UK Defra, 2020), which provides guidance on natural capital assessment for use by the government, public sector, and private individuals. These initiatives aim to halt the ongoing degeneration of biodiversity in the UK (Blumgart et al., 2022; Salido et al., 2012) and augment

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the social welfare advantages provided by nature (Jones et al., 2019). However, the guidance currently does not make direct reference to the role of community (citizen) science in nature's benefits assessments and monitoring (Defra, 2020).

Assessing the value of nature's benefits can underpin conservation mechanisms such as payment for ecosystem services, which has delivered improved biodiversity and social outcomes in some cases (Grima et al., 2016; Hejnowicz et al., 2014). Nevertheless, ecosystem service valuation can have large 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 (Daily et al., 2011, Karieva 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), knowledge gaps (Schröter, et al., 2014), and lack of guidance for certain ecosystems (Hooper et al., 2019). The challenges limit the assessment of nature's benefits in numerous fields and restrict the ability to confirm the efficacy of nature-based interventions.

Because assessing nature's benefits involves a variety of stakeholders and landscapes, it necessitates an array of tools and methods to allow for implementation (Bagstad et al., 2013). Therefore, recent scholarship has emphasized bottom-up approaches to facilitate awareness of and participation in nature's benefits assessments (Petit-Boix & Apul, 2018) like participatory mapping (Hinson et al., 2022) and community surveys (Okada et al., 2021). Such community involvement increases data collection capacity, potentially increases support towards and implementation of such valuations, and better attunes management and policy to suit communities, thereby improving the likelihood of positive nature outcomes (Seymour et al.,

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2022). Another significant avenue to evaluate nature's benefits is through community science (CS) (Bonney, 2021).

Community science is the practice of involving the public in conducting scientific research (Heigl et al., 2019). Recent scholarship has advocated a transition from the term "citizen science" to "CS" as it is more politically and socially inclusive regarding citizenship status (Finch et al., 2022). CS engages the public with a range of environmental issues, especially biodiversity, water quality, and habitat monitoring (Finch et al., 2022) over both short-term and long-term periods. Moreover, CS involves varying degrees of collaboration through diverse methods including field monitoring (Conrad & Hilchey, 2011), archival translation (Hill et al., 2012), and online video and photo identification (Green et al., 2023).

Participation in such initiatives has grown along with technological advances which expand access to CS (Freitag & Pfeffer, 2013). Through increased reach and participation, successful CS has many advantages including increasing the capacity to collect large data sets (Eitzel et al., 2017), increased scientific literacy and awareness (Bonney et al., 2009), the democratization and diversification of scientific processes (Strasser et al., 2018), and prompting pro-conservation (Pocock et al., 2023) and pro-environmental behaviors (Pierinni et al., 2021). Importantly, CS has been noted as a mechanism for shaping policy, decision-making, and planning on many levels (Pearse, 2020), and has been specifically analyzed within the context of ecosystem services and natural capital (Schröter et al., 2017; Seymour et al., 2022).

Nevertheless, there are crucial concerns surrounding CS which could impact its applicability to assess nature's benefits. A central critique is the possibility of diminished data quality (Fritz et al., 2022)—although there are proven steps to enhance CS data quality such as through data source comparison (See et al., 2013). Continued CS engagement is also a concern,

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as activities such as biodiversity monitoring require consistency, which may not be ensured through volunteerism. Furthermore, not all areas of science are of public interest, thus prompting bias in the subjects covered by CS (Fritz et al., 2022). Important ethical ramifications for CS include the sharing and use of CS-collected data and ensuring reciprocity between research and volunteer scientists (Resnik et al., 2015). However, it is widely recognized that CS, when conducted along high scientific and ethical standards, "could benefit society greatly" (Wilkinson et al., 2016).

Prior studies have emphasized that CS and natural capital/ecosystem services are complementary as they both connect natural science concepts with social science (Seymour et al. 2022). Boakes et al. (2016) found increasing interest in employing CS to analyze the state of ecosystems, and a systematic review by Schröter et al. (2017) found that globally citizen science has indirectly contributed to assessing regulating and cultural services, although direct assessment of ecosystem services was rare. Previous research by Seymour et al. (2022) provided a theoretical framework for linking CS to the UK's ENCA guidance. Yet no research—to the best of our knowledge—has examined CS on a national level and in relation to national guidance, through the evaluation of real-world CS projects and local community scientists' experience.

This review explores the potential of CS for expanding and diversifying assessment of nature's benefits, especially on local levels, in the United Kingdom. The study seeks to answer the following questions: how does UK community science relate to nature's benefits assessments and what are the experiences of UK community scientists with CS related to nature's benefits? We investigate which nature's benefits are currently measured by CS and community scientists in the UK. The UK was chosen because the UK government has established some of the most

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advanced natural capital and ecosystem service policy globally (Guerry et. al., 2015; Hein et al., 2020) which features definitions and examples of nature's benefits (UK Defra, 2020), thus narrowing the classification of nature's benefits amidst a surfeit of research (Missemer, 2018) and enabling this paper to build on relevant scholarship on real-world implementation of UK natural capital policy (Hooper et al., 2019). Moreover, the UK has a lengthy history of CS based in natural science (Tweddle et al., 2012). Thus, our research aligns UK CS projects with the assessment framework presented in the *ENCA* guidance and the experience of community scientists from around the UK. This research addresses the need to examine pathways for increasing public awareness and engagement towards valuing nature in response to the causes of biodiversity and nature decline. Our assessment identifies potential evidence gaps in current UK CS and UK community scientist's experience where nature's benefits are currently being underassessed or ignored. It also offers an example of national-level evaluation to understand the links between national policy, local community science, and the experiences of community scientists towards supporting nature's benefits assessments.

2 Methods

2.1 Overview of 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 CS to support assessments of nature's benefits in the UK. First, systematic review of peer-reviewed literature and CS hubs was carried out to identify ongoing UK CS programs and whether they assessed benefits from nature in light of ENCA guidance. This then informed a survey of local UK community scientists about their experience with CS and nature's benefits.

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2.2 Systematic Review of UK Community Science

2.2.1 Overview

A multiple data sources (MUD) systematic review featuring a review of scientific databases and CS hubs was utilized to increase the comprehensiveness and credibility of conclusions (Bramer et al., 2017), and limit biases which could arise from insufficient data sources (Mayo-Wilson et al., 2018). CS is often not reported in peer-reviewed literature (Theobald et al., 2015) due to the small size of some projects (Wang et al., 2015), programs submit data to larger portals which mask specific programs (Cooper et al., 2014), and some are only identified in the literature as a methodology but not by a program name (Schröter et al., 2017). Additionally, CS has numerous synonyms (e.g., citizen science, crowd-sourced science, volunteer data collection, and community/volunteer monitoring (Heigl et al., 2019)), which entails articles with divergent language, but similar CS methodologies, may not appear in literature searches.

Two scientific databases were searched, SCOPUS and Web of Science, which are recognized for their quality and depth of coverage on scientific research (Norris & Oppenheim, 2007). In addition, four CS platforms or "hubs", were searched; these are considered to be "the most formalized communication channels in the citizen science community" (Schröter et al., 2017).

~~2.2.1~~2.2.2 Data selection

Four international hubs—CitSci.org, eu-citizen.science, SciStarter, and Zooniverse—were selected as they have been utilized in previous systematic reviews on CS programs (Schröter et al., 2017; Storksdieck et al., 2016) and include UK-based CS projects covering a range of research areas. This is particularly important as nature's benefits are interdisciplinary

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thus necessitating multi-subject platforms. A description of the selected CS hubs can be found in the supplementary material (Table S1).

~~2.2.2~~2.2.3 Search of peer-reviewed literature and CS hubs

The aim of the literature search was to identify citizen science projects active in the UK that address nature's benefits, as defined in the ENCA guidance. The systematic review was carried out from June to July 2023 and adhered to the following replicable process. Peer-reviewed papers included in the systematic review were identified from a search of articles' titles, abstracts, and keywords/topics. The selected search terms were chosen after a preliminary investigation of the literature in both databases to test relevance of results. As the research questions focus on the UK, place-based search terms were incorporated. The search phrase was: "'citizen science' OR 'CS' AND 'natural capital' OR 'ecosystem services' OR 'benefits' AND 'UK' OR 'United Kingdom'" with no parentheses or brackets. The literature search consisted of only published, peer-reviewed original research articles written in English. Additionally, years were restricted to 2022-2020 to focus on community projects that are more likely to be currently active.

Initial screenings of titles and abstracts and CS hubs focused on the presence of specific CS projects and the location of the studies. Studies were excluded if a specific CS program was not explicitly identified by name. Peer-reviewed papers and projects were excluded if the project was not UK-based. Each article and project included in the review met the following criteria: the CS project (defined as an initiative which engages members of the public in the scientific research process (Heigl et al., 2019)):

(i) was based in and primarily operated in the UK

(ii) was current and ongoing

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(iii) conducted research that 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 the ENCA guidance (Section 8.1-8.4, UK Defra 2020). (For example, species and biodiversity are core components of the natural capital approach as described in the ENCA guidance, and thus programs collecting data on a distinct species were included as well as those collecting broad biodiversity data.)

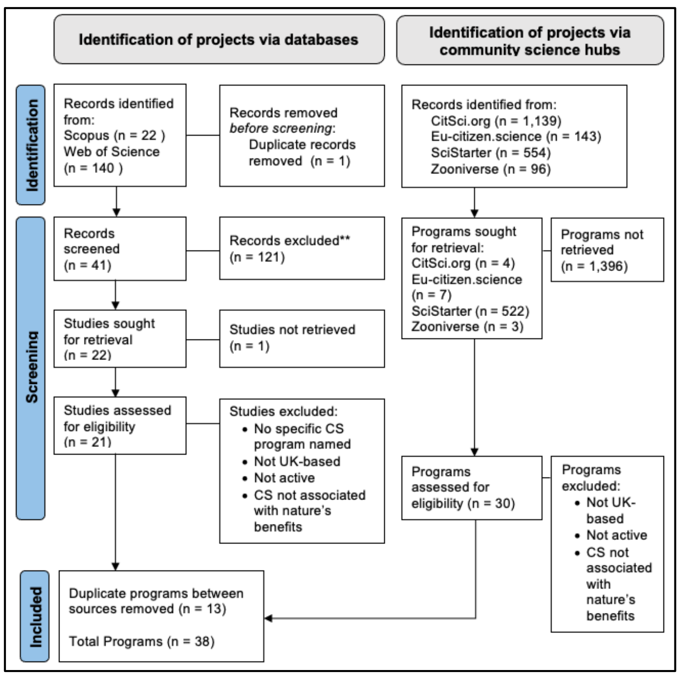

Figure 2. MUD systematic review results flowchart (adapted from the PRISMA flow diagram (Page et al., 2020))

The initial database search resulted in 162 articles, and the CS hubs search resulted in 1,932 projects. After screening titles and abstracts and hub project descriptions, 41 articles were read in

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full, and 536 projects were retrieved via CS hubs (Figure 2). Twenty-one peer-reviewed journal articles met the criteria as did 30 CS projects found on CS platforms. After eliminating duplicates, 38 projects were included in the MUD systematic review. For the 38 CS projects included, project websites were examined to answer the analysis questions (Table 1).

Systematic Review Questions for Analysis
General Information • What is the CS project's primary region of operation (specific country or nation) and what is the project's reach (local, regional, national, international, or global)? • What organizations are involved in the project? What type of organizations are they (e.g., non-profit, business, academic, or governmental)? • What is the time scale of the project? • What is the size of the CS project? (Number of volunteers and number of total records collected in the project'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 project? • What is the natural capital asset(s) associated with the project? • What is the ecosystem service(s) associated with the project and what is the category of ecosystem service? • What is are the benefit(s) from nature associated with the project?

Table 1. Review questions for analysis of CS projects featured in peer-reviewed literature and CS hubs.

2.3 UK Community Scientist Survey (Phase 2)

2.3.1 Overview

To further understand the feasibility of UK-based CS to evaluate nature's benefits as outlined in national guidance, a survey was carried out consisting of an online questionnaire aimed at UK community scientists. This aimed to a) evaluate community scientists' experience

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with CS related to nature's benefits and b) evaluate the perceptions of community scientists on the relationship between CS and nature's benefits.

2.3.2 Participant recruitment

The questionnaire used Microsoft Forms and was open from July to August 2023. It was disseminated to major conservation organizations and networks in the UK involved in a variety of CS projects via a snowball sampling method. This method was chosen as this study examined local UK community scientists which is a small, local community extant within a close network of participants (Naderifar et al., 2017). The survey was disseminated through personal contacts, Facebook groups, Linkedin posts, and Twitter feeds of local nature organizations and networks. Based on the mixed methods sequential explanatory design, these conservation organizations and networks were selected partially based on the organizations featured in the systematic review.

The cover page of the questionnaire delineated the target audience—adults, aged 18+, who participate in or have participated in UK CS related to conservation and nature. It also stated the purpose of the research—"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 CS 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 identifying information was collected, and there was no financial reward for participation.

2.3.3 Participants

The survey featured 22 respondents with 90% currently involved in UK CS and 10% with previous, but not current, involvement. All respondents were above the age of 25 with 90% over 35. The largest age groups were 35-44 (36%) and 65 and over (27%). Most respondents were

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female (59%), followed by male (36%), and other (3%). This differed from a study of thousands of UK community scientists by Pateman et al. which found most CS participants identified as male (2021). All respondents had a secondary education or higher while 68% had a university degree or higher. The master's degree had the largest number of respondents for an educational group (n=5) followed by professional or retired (n=21). All identified as white or Caucasian. This respondent profile, excluding gender identity, mirrored Pateman et al.'s findings (2021) that community scientists in the UK tend to identify as white or Caucasian, middle-aged or older, and more educated. The most significant limitation of the research approach was the small number of respondents, possibly attributed to the timing of the survey (summer) and length of the survey (22 questions), which increases the likelihood of introducing sampling bias, in which the sample of respondents does not accurately represent the larger population of UK community scientists (Wardhopper et al., 2021).

2.3.4 Questionnaire design

The online questionnaire was designed by drawing from methods published in comparable peer-reviewed studies on CS managers and participants (Stylinski et al., 2020, Finch et al., 2022) and scholarship on online surveys for conservation research (Wardropper et al., 2021; Fogle & Herkenhoff's, 2018). It features self-reported responses about past and current experiences with CS programs in the UK, along with opinions on CS's relationship in measuring nature's benefits assessments (See Table S4 in Supplementary Material for the complete questionnaire).

The survey was split into two sections: respondent demographic questions and questions on CS experience and perceptions. Both parts collected both quantitative data, via the multiple-

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choice questions, and qualitative data via short-form, write-in responses to capture more in-depth reflections of community scientist's experiences and perceptions.

2.3.5 Ethics

The questionnaire and all participant-facing materials were approved by the University of Oxford's Research Ethics Committee standards and adhered to strict ethical guidelines for internet-mediated research, specifically for online surveys. Informed consent was gathered before the start of the survey, and respondents confirmed that they were over the age of 18. To further assure the adherence of strict ethical guidelines, the survey was anonymous with no identifiable data collected, all questions were optional, and participants were notified frequently, in the recruitment email and the survey's instructions, that participation and all questions were voluntary.

2.4 Data Analysis

The data analysis featured quantitative and qualitative analysis aligning with the mixed methods sequential explanatory design approach (Creswell, 1999). All analysis and visualizations were completed in R Studio (v4.2.2) (R Core Team, 2022). Packages utilized for data visualization include *ggplot* (Wickham, 2016) and *plotly* (Sievert, 2020) and featured *viridis* color palettes for color blindness (Garnier et al., 2024). Following the mixed methods sequential explanatory design, data analysis, results, and discussion are conveyed in a sequential pattern.

2.4.1 Systematic review data analysis

To understand the relationship between UK CS projects and nature's benefits, data collected from the systematic review was coded based on the classification system used in the ENCA guidance: eight broad habitat types (ENCA Section 1.6), ecosystem service categories

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(provisioning, regulating, cultural) and ecosystem services (ENCA Sections 8.1 to 8.3), and 'aggregated or bundled benefits', a catch-all category used in ENCA for other concepts related to natural capital such as biodiversity, soil health and amenity (ENCA Section 8.4) (UK Defra, 2020). The subjects of the CS projects were also classified by the broad focus of the project; all subjects involving species were classified by class, but if the focus of the project was across multiple classes, and assessed biodiversity broadly, it was classified under "biodiversity". If the project's research could be utilized to measure, support, or inform specific natural capital (NC), ecosystem service (ES), or nature's benefit (NB) assessments, then they were included in those classifications even if the project did not directly or intend to measure them. For instance, habitat assessments of forests were categorized for potential ecosystem services such as carbon sequestration and timber production although they only directly aimed to measure the asset of "ecological communities" and "species". This was done to comprehensively include all projects associated with nature's benefits in the review. (See Supplementary Material (Table S2) for complete categorizations of CS projects and associated benefits.)

Quantitative analysis of the systematic review featured a multidimensional assessment of three primary variables: (i) frequency of coding for ES categories, ES, and 'aggregated or bundled benefits' within projects included in the review, (ii) length of time for which CS projects have conducted research related to specific services (indicator of a project's success or continued interest in and support of the project's research focus, (Finch et al., 2022)), and (iii) the number of potential benefits/services which could be measured through the data collected by the program (Table 3).

CS program	Ecosystem service/benefit category	Ecosystem services

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Ancient Tree Inventory	Provisioning, Regulating, Aggregated & bundled	Timber, Carbon sequestration, Air pollutant removal, Noise mitigation, Local climate regulation, Biodiversity
Big Seaweed Search	Provisioning, Regulating, Aggregated & bundled	Food, Carbon sequestration, Biodiversity
Breeding Bird Survey	Aggregated & bundled	Timber, Carbon sequestration, Air pollutant removal, Noise mitigation, Local climate regulation, Biodiversity, Water flow regulation, Peat
Greenspace Hack	Provisioning, Regulating, Aggregated & bundled, Cultural	Water quality, Amenity, Landscape, Recreation, Physical activity, Enjoyment & tourism, Mental health, Carbon sequestration, Timber, Air pollutant removal, Noise mitigation, Local climate regulation, Peat, Biodiversity
Marine Mammal Survey	Aggregated & bundled	Biodiversity
National Plant Monitoring Scheme	Provisioning, Aggregated & bundled	Timber, Carbon sequestration, Air pollutant removal, Water flow regulation, Noise mitigation, Local climate regulation, Biodiversity
Nature's Calendar Survey	Provisioning, Regulating, Aggregated & bundled	Timber, Carbon sequestration, Air pollutant removal, Noise mitigation, Local climate regulation, Waterflow regulation, Biodiversity
Our Outdoors	Provisioning, Regulating, Aggregated & bundled, Cultural	Water quality, Amenity, Landscape, Recreation, Physical activity, Enjoyment & tourism, Mental health, Carbon sequestration, Timber, Air pollutant removal, Noise mitigation, Local climate regulation, Peat, Biodiversity
Pollinator Monitoring Program	Provisioning, Aggregated & bundled	Biodiversity, Food
Treezilla	Provisioning, Regulating,	Timber, Carbon sequestration, Air pollutant removal, Noise mitigation,

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	Aggregated & bundled	Local climate regulation, Biodiversity

Table 3. Representative examples of a variety of CS projects associated with various nature's benefits which could be assessed using data collected through the projects. (See S1 for a complete list).

Because all programs involved volunteerism or non-paid participation, and provided educational training to participate, we automatically assumed "volunteerism" or "education" as benefits within the review and therefore did not include them in analysis. The number of records/observations collected by each project and the number of participants were not analyzed due to lack of data (only half of the projects had such information available), lack of standardization across data collection methods, and heterogeneity of subjects (e.g., there will often be more observations for biodiversity than for water or air quality), which alone or combined could introduce significant bias.

Statistical analysis centered on understanding underlying patterns between numeric and categorical variables in relation to number benefits assessed per project, i.e., did patterns arise to predict which programs gathered data for multiple benefits.

2.4.2 Survey data analysis

The write-in opinion responses were analyzed through thematic analysis (Nowell et al.'s, 2017). Some respondents did not answer all questions, especially for write-in questions. Due to the relatively small data set and the small number of write-in questions, theme identification and response coding were conducted by the corresponding author. The frequency of respondent's CS experience related to nature's benefits was calculated as well as the number of benefits that could be assessed per CS program through the CS project's data collection.

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3 Results

3.1 Overview of systematic review of peer-reviewed literature and CS platforms

The systematic review consisted of 38 projects which had a range of 1-84 years (avg= ~19; sd=18; median=14), with the oldest program, the British Trust for Ornithology's Nest Record Scheme, founded in 1939 and the newest program, Project SIARC from the Zoological Society of London, and Natural Resources Wales, created in 2022. Most programs had a nationwide geographic focus (operated throughout the whole UK), 6 had a country/regional (England, Guernsey, Scotland, or Wales), 4 had an international (covering the UK and Ireland), and 4 had a global focus. CS projects covered all 8 habitat types as defined by the UK's National Ecosystem Assessment (2011). Many covered multiple habitats and the most habitats covered in one project was 8 (avg=6). Most programs were associated with terrestrial habitats (76%), and 26% occurred in urban environments.

The programs were hosted by 46 unique organizations, and 55% were hosted by multiple organizations. The UK's Joint Nature Conservation Committee (JNCC) and the British Trust of Ornithology hosted or co-hosted the most programs (n=8), followed by the UK Centre for Ecology and Hydrology (UK CEH) (6) (Table 2). Most host organizations were non-profits (56%) followed by government agencies (20%), academic institutions (20%), and businesses (4%).

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Organizations	CS projects featured in review
Joint Nature Conservation Committee	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	Birdtrack, Breeding Bird Survey, Garden BirdWatch, Nest Record Scheme, Nesting Neighbours, United Kingdom Butterfly Monitoring Scheme, Wetland Bird Survey, Wider Countryside Butterfly Survey
UK Center for Ecology and Hydrology	Ladybird Survey, National Plant Monitoring Scheme, Nature's Calendar Survey, UK Pollinator Monitoring, United Kingdom Butterfly Monitoring, Wider Countryside Butterfly Survey
Royal Society for the Protection of Birds (RSPB)	BirdTrack, Breeding Bird Survey, Wetland Bird Survey
Botanical Society of Britain and Ireland	Herbarium at Home, National Plant Monitoring Scheme

Table 2. Top five most frequent organizations hosting CS projects featured in the systematic review including the CS projects the organizations either host or co-host

3.2 UK CS and nature's benefits

3.2.1 Subject of CS projects

Birds were the most frequent subject of focus (n=8), followed by insects, mammals, and plants (7 each). Amphibians, fish, phenology, and agriculture were the least represented subjects (n=1) (Figure 3).

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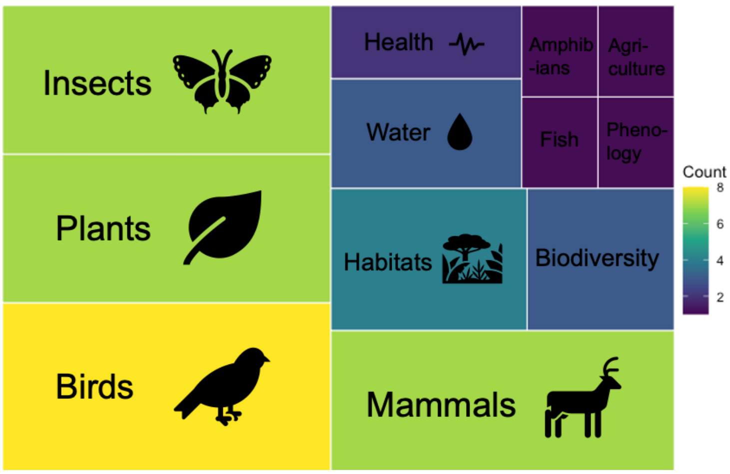

Figure 3. Frequency of subject focus across UK CS programs featured in the systematic review of peer-reviewed literature

3.2.2 Ecosystem service categories and ecosystem services

Most programs (n=35; 92%) within the ENCA category of "aggregated & bundled" benefits as they assessed species, i.e., biodiversity. Provisioning services were the second most frequently assessed (n=22; 58%), followed by regulating services (n=13; 34%). Very few (n=2) CS programs assessed cultural services, and none assessed abiotic flows (Figure 4). The longest-running programs were associated with the "aggregated & bundled" benefit category (average 19.5 years), followed by provisioning and regulating services (both averaging 17 years). CS projects involving cultural services had been running for only 4.5 years on average (Figure 4).

It is significant to note that only one project in the review (Treezilla) explicitly framed its research around and directly measured ecosystem services. For the remainder, we recorded the potential ES that we assumed could be evaluated from the information gathered by the CS project (see section 2.4.1).

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The most common service or effect was biodiversity (n=35; 92%), followed by carbon sequestration (n=14; 37%). Cultural services only appeared in 5% of the projects (n=2 each). Services not associated with any of the CS projects reviewed were minerals, non-use values, renewable energy, soil health, waste remediation, and water supply (Figure 4). The longest-running CS projects were those assessing peat (average 30.5 years), followed by biodiversity (20 years) and then ES related to trees (e.g., timber, carbon sequestration, local climate regulation, etc.) with an average age of ~18-19 years. Programs related to cultural services were the shortest running programs (<~ 7 years).

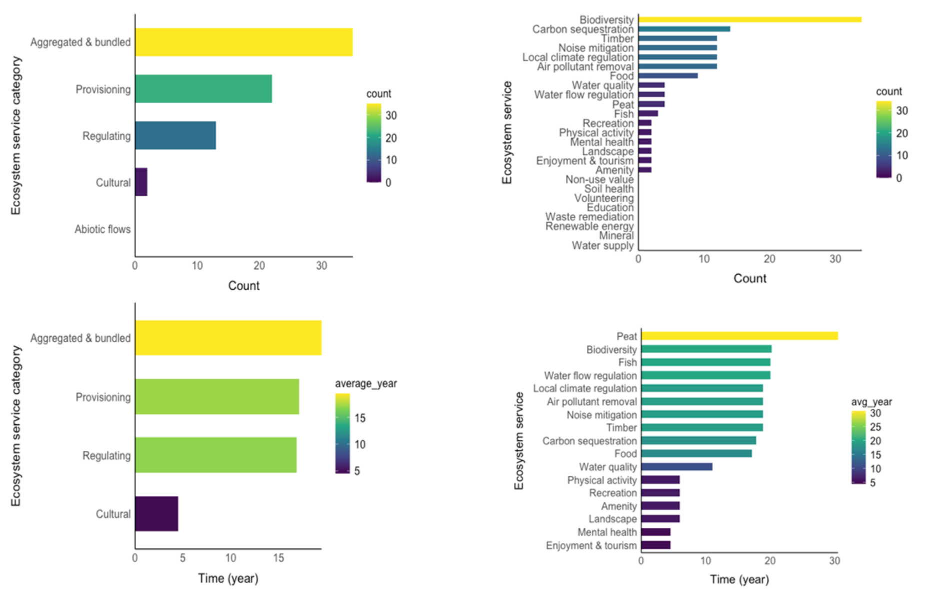

Figure 4. Frequency of 4 ecosystem service categories and ecosystem services, as defined by ENCA, featured in CS programs included in the systematic review (Numerous programs related to multiple ecosystem service categories), and average time (years) of CS project data collection

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associated with each ecosystem service category and CS data collection associated with each ecosystem service.

3.2.3 Multiple benefits

Most programs (n=25; 61%) were associated with more than one benefit per individual CS project. The average number of benefits per program was four (avg=3.54; sd=3.42; median=2). Fifteen projects evaluated only one effect/benefit, which was most frequently biodiversity. The greatest number of benefits associated with an individual project was 14 ecosystem services (e.g., GreenspaceHack and OurOutdoors); the two projects with 14 benefits centered on cultural services provided by greenspaces. The least number of benefits were associated with biodiversity projects (n=1), specifically for non-vegetation classes of species. A Pearson correlation was performed to assess the relationship between the lifetime of the CS project and the number of benefits. According to the Pearson correlation analyses there was not a strong correlation between multiple benefits and time (r(36)=-.062) (i.e., longer running projects did predict number of benefits associated with CS).

3.3 Overview of results of UK CS survey

Most respondents (90%) had been involved with UK CS which related to NB for more than one year, and 11 had been involved between 1-5 years. All participants in the survey had either been a volunteer or participant in local CS (n=15) or managed CS programs (n=2) and some in both (n=5). Most (73%) of survey participants had been involved with 1-3 projects, 3 with 4-6 projects, and 3 with 7 or more. Respondents were asked to describe the current projects in which they were previously or currently participating (Table 5). In total, 44 specific projects were identified by respondents, and of those 11 had been covered in the review (See Table S3 in

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Supplementary Material for further information). Thirty-three identifiable projects were mentioned by respondents but not covered in the review (Table S3).

CS program	Ecosystem service/ benefit category	Ecosystem services
Big Butterfly Count	Aggregated & bundled; provisioning	Biodiversity, pollination
BeeWalk	Aggregated & bundled, provisioning, cultural	Biodiversity, pollination, education and local nature knowledge
Dung Beetle for Farmers	Aggregated & bundled, provisioning, cultural	Biodiversity, food production, pollination, education and local nature knowledge
Earthwatch Europe Tiny Forest Monitoring Scheme	Aggregated & bundled, regulating, provisioning, cultural	Carbon sequestration, cooling and shading, education and local nature knowledge, biological pest and disease control, flood protection, health & well-being
Every Flower Counts	Aggregated & bundled; provisioning	Biodiversity, pollination
FreshwaterWatch	Regulating	Water quality regulation
Nature's calendar	Aggregated & bundled, regulating, provisioning, cultural	Biodiversity, pollination, carbon sequestration, air quality regulation, biological pest and disease control, recreation and leisure in nature, education and local nature knowledge, health & well-being
Nature Overheard,	Cultural	Education and local nature knowledge
ObstacEELS with Action for the River Kennet	Provisioning	Biodiversity, water supply water quality regulation, fish production
PTES Hedgerow Survey	Aggregated & bundled, regulating, provisioning, cultural	Biodiversity, food production, timber/Wood production, flood protection, pollination, air quality regulation, cooling and shading, biological pest and disease control, recreation and leisure in nature, aesthetics of nature,

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		education and local nature knowledge, health & well-being

Table 5. Representative examples of CS projects identified by community scientists and the associated ecosystem services aligning with participants responses based on whether projects collected data which could be used in specific ecosystem service assessments.

3.3.1 UK community scientists' experience with nature's benefits assessments

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

However, all 22 respondents identified services which they felt related to their current or previous CS experiences. All 22 had experience with biodiversity, and 14 had previous experience with pollinators, followed by water quality (9) and education & local nature knowledge (9). Fewer participants identified CS experience related to the benefits of fish production (n=7), biological pest & disease control (7), local climate regulation (6), timber (5), and the aesthetics of nature (5) (Figure 5).

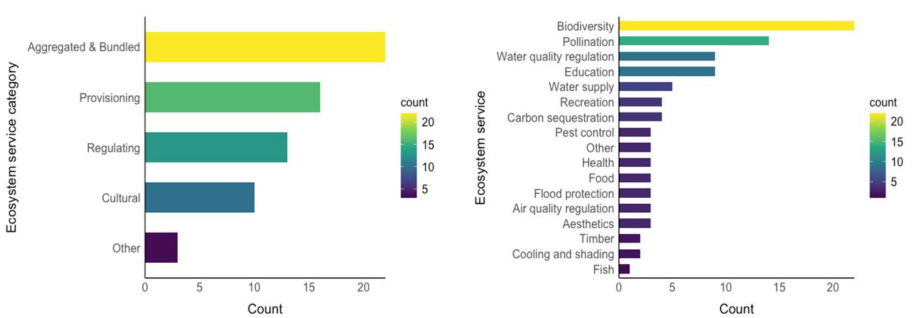

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Figure 5. Number of survey respondents who self-identify as having experience with each ecosystem service category and frequency of services/benefits appearing in responses to the CS survey.

3.3.2 UK community scientists' experiences and benefits bundling

Due to the structure of the survey, it was not possible to attribute the number of potential benefits associated with each individual project identified by respondents. Instead, the number of overall benefits associated with each respondent's CS experience was assessed. The majority of respondents (n=12) identified with participating in CS which was related to >1 benefits with 9 respondents noting only one benefit. One respondent did not respond

Through Pearson' correlations, the relationship between respondent's length of time participating in CS and number of benefits with which they reported having experience was analyzed. The number of projects they participated in and the number of benefits with which they reported experience was assessed. Both analyses were aimed at understanding what factors may correlate to more experience associated with NB assessment. According to the results of the Pearson correlation tests, there is no significant relationship between the number of benefits participants felt they had assessed and either the number of CS projects they were involved in ($r(38)=0.069$) or the length of time of they had been participating in CS ($r(38)=-0.060$).

3.3.3 UK community scientists' opinions on CS and nature's benefits

When asked about whether respondents supported nature's benefits being assessed by or associated with CS, 21 people responded and no respondent replied that nature's benefits should not be associated with CS. Fourteen people (66%) said "yes", and 7 people (33%) said "maybe". However, it is critical to read this result with caution as it could reflect agreement bias, and the write-in responses reveal concerns about nature's benefits being incorporated into UK CS.

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Through thematic analysis, the responses of 14 survey participants were coded for their opinions on CS for NB assessments. Their reasonings fell into 8 themes, and several responses covered more than one theme (Table 6). The two most frequent reasons for including CS in NB were the benefits for individuals such as increasing one's nature connection, mental health benefits, and increased awareness of individuals' impact on nature. Two respondents stressed the importance of community benefits and community-focus when utilizing CS in NB measures. The benefits to nature alone and the benefits to the human-nature relationship were also mentioned, and data collection advantages repeatedly appeared in respondent's opinions.

There were three main concerns surrounding incorporation of CS into ES/NB assessment, the primary one surrounding data quality. The other concern was that community scientists should not bear the burden of monitoring key ecosystem services alone. Only one person included a concern about the commodification of nature.

Yes	**Count**	**Maybe**	**Count**	**No**	**Count**
Increased data collection	6	Concerns over data quality	3	N/A	0
Benefits for humans/individuals	4	CS alone is insufficient	1		
Benefits for nature	3	Fear of the commodification of nature	1		
Benefits for humans & nature	3				
Benefits for communities	2				

Table 6. Summary of thematic analysis of community scientist's write-in opinions regarding UK CS's inclusion in nature's benefits assessments, split between "Yes" and "Maybe" responses.

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4 Discussion

4.1 UK CS and Nature's Benefits Assessments

To our knowledge, this is the first review and survey on the relationship between UK CS and nature's benefits assessments. This paper indicates specific projects and datasets which could be useful for researchers, practitioners, and the public to evaluate local nature's benefits and to support participation in the monitoring of nature's benefits. It also identifies gaps in UK CS which do not currently involve communities or collect data on specific nature's benefits. In doing this, we lay out an example of national and local-level analysis on how to apply a mixed methodology to evaluate citizen science and nature's benefits assessments, which could be modeled within other countries or regions.

Only one CS program, Treezilla, directly assessed nature's benefits using an ecosystem services framework. All other projects collected data which was assumed to be possibly utilized in assessing nature's benefits indirectly. This aligns with research conducted by Schröter et al., which found that most CS programs assessing ecosystem services did so through proxy indicators that "implicitly provided information on ecosystem services" and that direct assessments of ecosystem services through CS did not occur often (2014).

In both the systematic review and the survey, biodiversity was the most frequently occurring benefit assessed by the CS programs, and this was also associated with the longest-running CS programs. Our findings mirror other studies indicating that species and biodiversity are one of the most common focuses of CS (Schröter et al., 2017; Theobald et la., 2015). Moreover, birds were the most common subject of the species observed through UK CS, a pattern acknowledged more globally (Amano et al., 2016). For instance, Amano et al. (2016), found that rates of non-bird species data collection have not increased, especially in data-poor,

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biodiversity-rich regions, thereby also noting a gap in CS biodiversity data collection. With biodiversity declining globally and, in the UK, filling in gaps with regards to species represented in CS will be crucial to understand both changes in biodiversity itself and how biodiversity underpins nature's benefits broadly.

In both the systematic review and the community scientist survey, the least frequently associated benefits were cultural services. We also discovered that CS projects have been conducting research related to cultural services for the shortest amount of time, possibly arising from the fact that cultural services are a relatively newer service to be conceptualized in research (Chan et al., 2011), the least studied (Cheng et al., 2019), and are less frequently assessed and targeted for interventions in practice (Gould et al., 2019). In a review of global citizen science and ecosystem services, Schröter et al. (2017) stated that cultural services and regulating services were most present in global CS. However, this difference could be the result of different approaches for coding CS programs for cultural services, particularly for programs which implicitly, but not directly, assess them

Aquatic benefits were also less frequently assessed in the systematic review compared to terrestrial environments, another trend noted in previous research (Buytaert et al., 2014; Pocock et al., 2017). Sandahl & Tøttrup note that marine citizen science is significantly underrepresented in peer-reviewed literature, but that it has been steadily growing over the last decades (2020). For water science in general, CS has been noted as a new and emerging data collection format for monitoring flood risk and management, water quality, and species distributions (Ioana-Toroimac et al., 2020; Njue et al., 2019).

Soils and mineral CS projects were not accounted for in the results of the systematic review but were identified through the community scientist survey. Soil assessments are less

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present in the scientific literature on CS (Mason et al., 2024); yet recent research has evaluated the potential for CS to monitor and evaluate various characteristics of soils, especially in the UK (Head et al., 2020; Mason et al., 2024). The large gaps in CS's association with nature's benefits remains evident in underground components (i.e., minerals and soils), aquatic environments, and cultural assessments, and could be areas for potential expansion of CS and data collection.

The systematic review reveals that over 60% of CS projects associated with nature's benefits are associated with numerous benefits, showing how a single project could potentially collect data related to numerous nature's benefits assessments. The greatest number of multiple potential benefits occurred for cultural services-related projects. Previous research has mapped the additive bundling effects for cultural services and other types of services more generally (Ament et al., 2017), and similar occurrences of CS, cultural ecosystem services, and bundling effects has previously been affirmed in specific projects (Schröter et al., 2017). Multiple benefits also frequently occur for projects assessing vegetation, mirroring research which supports the numerous services delivered through plants and their functions (Quijas et al., 2019). There was no significant relationship between project lifetime and the number of benefits. Yet, the number of benefits was inferred within the analysis, not explicitly outlined by projects themselves, which is a limitation of the research as more information, from non-CS sources may be required to conduct real-world nature's benefits assessments.

Future CS could consider expanding data collection to encompass information necessary for assessment of nature's benefits. Analyzing the potential for programs to directly assess multiple benefits, rather than assuming a potential for benefits to be assessed by proxy, could direct future CS design and allocation of efforts to fill gaps in understanding of nature's benefits.

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4.2 Experience and opinions of UK community scientists

The experiences and opinions of UK community scientists reveal important nuances surrounding local CS and the feasibility of utilizing nature's benefits assessments/frameworks amongst UK community scientists. Our survey follows in line with previous studies examining UK community scientist's experiences related to nature's benefits like biodiversity data collection (Gardiner et al., 2012; West et al., 2021) and water science (McGoff et al., 2017; Walker et al., 2021). However, to the best of our knowledge, this is the first survey of local community scientists to examine the relationship between nature's benefits and ecosystem services as a framework to apply or expand via CS.

While most UK community scientists surveyed had known about ecosystem services and nature's benefits, many did not feel that they had experience related to assessing or collecting data on them. Even though this was their self-reported experience, they were able to identify nature's benefits—most frequently biodiversity, pollination, education, and water quality—with which they felt they had CS experience. This observation supports previous analysis revealing a divide between public knowledge about nature's benefits (Jordan & Russel, 2014). A case study of public perception of urban park trees in London, UK uncovered a lack of familiarity with the term "ecosystem service" and examples of services provided by such trees (Collins et al., 2019). Frameworks have been proposed to improve upon this divide between scientific research, policy, and the public by addressing distinct "knowledge needs" for the public to better interpret ecosystem science (Carmen et al., 2018). But based on our research, there has been minimal surveying of the citizen scientists' knowledge of ecosystem services and nature's benefits.

Our survey also evaluated interest in integrating nature's benefits assessments within local CS. While no respondent was fully against CS for assessing nature's benefits, possibly a result of

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agreement bias, there was not complete support either. Respondents also commented that community input within programs was crucial if such assessments were to occur. Prior research has also affirmed that community input and recognition of local contexts are critical for the success of citizen programs (McKinley et al., 2017). For the respondents against having CS involved in NB assessments, the main concern was over data quality. Concerns over data quality in CS are widely noted in scientific literature (Fritz et al. 2022), although further research has stated that citizen science data is useful due to its diversity and large extent (Wilkinson et al., 2016).

Only one respondent mentioned a concern over the commodification of nature as a consideration against integrating CS with nature's benefits assessments. The same respondent still noted that benefits less easily commodified through markets should be assessed through CS. While the scientific literature in the fields of ecological economics and conservation are replete with concerns over the commodification of nature through neoliberal policies (Gomez-Baggethun et al., 2010; Smessaert et al., 2020), minimal research has been conducted about whether the wider public, or community scientists, feel similarly or are familiar with this line of critique.

4.3 Comparing systematic review and survey

Some of results from the systematic review differed from the experiences of surveyed community scientists. Aligning with the mixed methods sequential explanatory design, several of the projects listed by respondents were present in the systematic review, but the survey revealed numerous projects which were missed by the review. The systematic review revealed 38 UK CS programs while the survey of community scientists revealed 44 programs. Only 10 of the 44 programs mentioned in the community scientist surveys were mentioned in the systematic review

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(S3). This finding reflects wider patterns in CS and academic research; often, smaller, more local CS efforts do not have the resources or expertise to publish in academic journals, resulting in their absence in the scientific literature (Primmer et al., 2018; Roche et al., 2020). Our survey of local community scientists thus revealed a fuller picture of relevant local CS, complementing the systematic review, which should be taken into consideration when evaluating CS at various scales.

The systematic review and the survey differed regarding frequency of nature's benefits associated with CS. For example, community scientists felt they had the least experience with timber, aesthetics, and fish, which partially aligned with the results of the review which showed a lack of cultural services and aquatic services represented in UK CS. The discrepancies between the systematic review and scientist experience could also be a result of sampling bias, geographical bias of respondents, or could be construed as a disconnect between bottom-up and top-down approaches to measuring nature's benefits (Primmer et al., 2018). Ideally, CS and policy would connect, in that policy considers terminology and frameworks that are easily implemented by community scientists while retaining scientific integrity. In turn, community scientists, could communicate their projects and methodologies to wider audiences like policymakers (Guerrini et al., 2018). For CS to effectively support policy, both sides must engage in various formats and communication channels that are more suitable to those projects and communities (Hecker et al., 2018).

4.4 Future of nature's benefits assessment and CS

Our study has numerous limitations, primarily related to the assumptions made while coding for CS project's relationship to nature's benefits, as only one project directly measured nature's benefits. However, this limitation also points to future research and science possibilities:

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creating CS specifically to measure nature's benefits or tailoring nature's benefits methods to extant CS programs. If new CS projects are created, it would be advised to narrow the scope of the research to limit redundancy because extant CS already addresses some of nature's benefits assessments. Lastly, future avenues of research could look at the efficacy of CS design/approaches to support NB assessments rather than the feasibility of integration. Yet, all future efforts should understand CS as one, additional approach (Bonney et al., 2009; Stuber et al., 2022), out of many, to evaluate and monitor nature's benefits.

Expanding on the findings of this study, future research could go beyond UK guidance on nature's benefits via a global synthesis and survey of CS and its relation to nature's contributions to people (Pascual et al., 2017). Such research would widen the scope and definition from "nature's benefits" to more diverse concepts and communities, including non-western valuations of nature (Díaz et al., 2018).

5 Conclusions

This study is the first of its kind to examine the relationship between national guidance and evaluation of nature's benefits through an analysis of specific, real-world CS initiatives on a national scale. Therefore, the study offers an example pathway for similar nation-wide studies to expand and diversify valuation methods, potentially facilitating improved implementation strategies of such assessments aimed at nature recovery and pro-biodiversity outcomes.

However, the study also indicates further efforts should be directed towards direct assessments of nature's benefits through CS projects, and there are significant gaps to the extent in which UK CS currently assesses nature's benefits. There was a division between community scientists' understanding of nature's benefits and UK guidance, hinting that the two areas could improve communication and that policymakers may need to further adjust policy to suit such

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localized community science efforts. Currently, UK guidance on nature's benefits does not explicitly include community (citizen) science; it only refers to 'volunteering' within key cultural services (Defra, 2020). Further consideration should be dedicated to filling in gaps in CS efforts while adjusting both communication efforts in policy and CS to accurately translate the plurality of nature's benefits concepts into practice.

More research should be done to expand upon these conclusions, by examining additional nature's benefits frameworks with other geographic areas and additional assessment methods for such integration, to implement these findings for real-world conservation decision-making and governance. Through such potential efforts, CS could increase engagement with the public regarding nature's benefits, empowering communities to participate and inform policies and management of life-sustaining ecosystem functions.

References

Ament, J. M., Moore, C. A., Herbst, M., & Cumming, G. S. (2017). Cultural Ecosystem Services in Protected Areas: Understanding Bundles, Trade-Offs, and Synergies. *Conservation Letters*, *10*(4), 440–450. https://doi.org/10.1111/conl.12283

Austen, M., Andersen, P., Armstrong, C., Döring, R., Hynes, S., Levrel, H., Oinonen, S., Ressurreição, A., & Coopman, J. (2019). *Valuing Marine Ecosystems - Taking into account the value of ecosystem benefits in the Blue Economy* [Preprint]. MarXiv. https://doi.org/10.31230/osf.io/vy3kp

Bagstad, K. J., Semmens, D. J., Waage, S., & Winthrop, R. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services*, *5*, 27–39. https://doi.org/10.1016/j.ecoser.2013.07.004

Barton, D. N., Kelemen, E., Dick, J., Martin-Lopez, B., Gómez-Baggethun, E., Jacobs, S., Hendriks, C. M. A., Termansen, M., García- Llorente, M., Primmer, E., Dunford, R., Harrison, P. A., Turkelboom, F.,

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Saarikoski, H., Van Dijk, J., Rusch, G. M., Palomo, I., Yli-Pelkonen, V. J., Carvalho, L., … Lapola, D. M. (2018). (Dis) integrated valuation – Assessing the information gaps in ecosystem service appraisals for governance support. *Ecosystem Services*, *29*, 529–541. https://doi.org/10.1016/j.ecoser.2017.10.021

Blumgart, D., Botham, M. S., Menéndez, R., & Bell, J. R. (2022). Moth declines are most severe in broadleaf woodlands despite a net gain in habitat availability. *Insect Conservation and Diversity*, *15*(5), 496–509. https://doi.org/10.1111/icad.12578

Boakes, E. H., Gliozzo, G., Seymour, V., Harvey, M., Smith, C., Roy, D. B., & Haklay, M. (2016). Patterns of contribution to citizen science biodiversity projects increase understanding of volunteers' recording behaviour. *Scientific Reports*, *6*(1), 33051. https://doi.org/10.1038/srep33051

Bonney, R. (2021). Expanding the Impact of Citizen Science. *BioScience*, *71*(5), 448–451. https://doi.org/10.1093/biosci/biab041

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen Science: A Developing Tool for Expanding Science Knowledge and Scientific Literacy. *BioScience*, *59*(11), 977–984. https://doi.org/10.1525/bio.2009.59.11.9

Bramer, W. M., Rethlefsen, M. L., Kleijnen, J., & Franco, O. H. (2017). Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. *Systematic Reviews*, *6*(1), 245. https://doi.org/10.1186/s13643-017-0644-y

Buytaert, W., Zulkafli, Z., Grainger, S., Acosta, L., Alemie, T. C., Bastiaensen, J., De BiÃ¨vre, B., Bhusal, J., Clark, J., Dewulf, A., Foggin, M., Hannah, D. M., Hergarten, C., Isaeva, A., Karpouzoglou, T., Pandeya, B., Paudel, D., Sharma, K., Steenhuis, T., … Zhumanova, M. (2014). Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Science*, *2*. https://doi.org/10.3389/feart.2014.00026

Carmen, E., Watt, A., Carvalho, L., Dick, J., Fazey, I., Garcia-Blanco, G., Grizzetti, B., Hauck, J., Izakovicova, Z., Kopperoinen, L., Liquete, C., Odee, D., Steingröver, E., & Young, J. (2018). Knowledge needs for the operationalisation of the concept of ecosystem services. *Ecosystem Services*, *29*, 441–451. https://doi.org/10.1016/j.ecoser.2017.10.012

Chan, K. M. A., Goldstein, J., Satterfield, T., Hannahs, N., Kikiloi, K., Naidoo, R., Vadeboncoeur, N., & Woodside, U. (2011). Cultural services and non-use values. In P. Kareiva, H. Tallis, T. H. Ricketts, G. C.

Formatted: Centered

Daily, & S. Polasky (Eds.), *Natural Capital* (pp. 206–228). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199588992.003.0012

Cheng, X., Van Damme, S., Li, L., & Uyttenhove, P. (2019). Evaluation of cultural ecosystem services: A review of methods. *Ecosystem Services*, *37*, 100925. https://doi.org/10.1016/j.ecoser.2019.100925

Collins, C. M. T., Cook-Monie, I., & Raum, S. (2019). What do people know? Ecosystem services, public perception and sustainable management of urban park trees in London, U.K. *Urban Forestry & Urban Greening*, *43*, 126362. https://doi.org/10.1016/j.ufug.2019.06.005

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment*, *176*(1–4), 273–291. https://doi.org/10.1007/s10661-010-1582-5

Cooper, C. B., Shirk, J., & Zuckerberg, B. (2014). The Invisible Prevalence of Citizen Science in Global Research: Migratory Birds and Climate Change. *PLoS ONE*, *9*(9), e106508. https://doi.org/10.1371/journal.pone.0106508

Costanza, R., De Groot, R., Sutton, P., Van Der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, *26*, 152–158. https://doi.org/10.1016/j.gloenvcha.2014.04.002

Creswell, J. W. (1999). Mixed-Method Research. In *Handbook of Educational Policy* (pp. 455–472). Elsevier. https://doi.org/10.1016/B978-012174698-8/50045-X

Daily, G. C., Kareiva, P. M., Polasky, S., Ricketts, T. H., & Tallis, H. (2011). Mainstreaming natural capital into decisions. In P. Kareiva, H. Tallis, T. H. Ricketts, G. C. Daily, & S. Polasky (Eds.), *Natural Capital* (pp. 2–14). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199588992.003.0001

Daily, G. C., Söderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P. R., Folke, C., Jansson, A., Jansson, B.-O., Kautsky, N., Levin, S., Lubchenco, J., Mäler, K.-G., Simpson, D., Starrett, D., Tilman, D., & Walker, B. (2000). The Valu of Nature and the Nature of Value. *Science*, *289*(5478), 395–396. https://doi.org/10.1126/science.289.5478.395

Dee, L. E., De Lara, M., Costello, C., & Gaines, S. D. (2017). To what extent can ecosystem services motivate protecting biodiversity? *Ecology Letters*, *20*(8), 935–946. https://doi.org/10.1111/ele.12790

Formatted: Centered

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M. A., Baste, I. A., Brauman, K. A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., Van Oudenhoven, A. P. E., Van Der Plaat, F., Schröter, M., Lavorel, S., … Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359* (6373), 270–272. https://doi.org/10.1126/science.aap8826

Eitzel, M. V., Cappadonna, J. L., Santos-Lang, C., Duerr, R. E., Virapongse, A., West, S. E., Kyba, C. C. M., Bowser, A., Cooper, C. B., Sforzi, A., Metcalfe, A. N., Harris, E. S., Thiel, M., Haklay, M., Ponciano, L., Roche, J., Ceccaroni, L., Shilling, F. M., Dörler, D., … Jiang, Q. (2017). Citizen Science Terminology Matters: Exploring Key Terms. *Citizen Science: Theory and Practice*, *2*(1), 1. https://doi.org/10.5334/cstp.96

Fleming, A., O'Grady, A. P., Stitzlein, C., Ogilvy, S., Mendham, D., & Harrison, M. T. (2022). Improving acceptance of natural capital accounting in land use decision making: Barriers and opportunities. *Ecological Economics*, *200*, 107510. https://doi.org/10.1016/j.ecolecon.2022.107510

Freitag, A., & Pfeffer, M. J. (2013). Process, Not Product: Investigating Recommendations for Improving Citizen Science "Success." *PLoS ONE*, *8*(5), e64079. https://doi.org/10.1371/journal.pone.0064079

Fritz, S., See, L., & Grey, F. (2022). The grand challenges facing environmental citizen science. *Frontiers in Environmental Science*, *10*, 1019628. https://doi.org/10.3389/fenvs.2022.1019628

Garnier, Simon, Ross, Noam, Rudis, Robert, Camargo, Pedro A, Sciaini, Marco, Scherer, Cédric (2024). *viridis(Lite) - Colorblind-Friendly Color Maps for R*. doi:10.5281/zenodo.4679423, viridis package version 0.6.5, https://sjmgarnier.github.io/viridis/

Grima, N., Singh, S. J., Smetschka, B., & Ringhofer, L. (2016). Payment for Ecosystem Services (PES) in Latin America: Analysing the performance of 40 case studies. *Ecosystem Services*, *17*, 24–32. https://doi.org/10.1016/j.ecoser.2015.11.010

Gould, R. K., Morse, J. W., & Adams, A. B. (2019). Cultural ecosystem services and decision-making: How researchers describe the applications of their work. *People and Nature*, *1*(4), 457–475. https://doi.org/10.1002/pan3.10044

Green, S. E., Stephens, P. A., Whittingham, M. J., & Hill, R. A. (2023). Camera trapping with photos and videos: implications for ecology and citizen science. *Remote Sensing in Ecology and Conservation*, *9*(2), 268–283. https://doi.org/10.1002/rse2.309

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Guerrini, C. J., Majumder, M. A., Lewellyn, M. J., & McGuire, A. L. (2018). Citizen science, public policy. *Science*, *361*(6398), 134–136. https://doi.org/10.1126/science.aar8379

Guerry, A. D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G. C., Griffin, R., Ruckelshaus, M., Bateman, I. J., Duraiappah, A., Elmqvist, T., Feldman, M. W., Folke, C., Hoekstra, J., Kareiva, P. M., Keeler, B. L., Li, S., McKenzie, E., Ouyang, Z., Reyers, B., … Vira, B. (2015). Natural capital and ecosystem services informing decisions: From promise to practice. *Proceedings of the National Academy of Sciences*, *112*(24), 7348–7355. https://doi.org/10.1073/pnas.1503751112

Head, J. S., Crockatt, M. E., Didarali, Z., Woodward, M.-J., & Emmett, B. A. (2020). The Role of Citizen Science in Meeting SDG Targets around Soil Health. *Sustainability*, *12*(24), 10254. https://doi.org/10.3390/su122410254

Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J., & Bonn, A. (Eds.). (2018). *Citizen science: innovation in open science, society and policy*. UCL Press.

Heigl, F., Kieslinger, B., Paul, K. T., Uhlik, J., & Dörler, D. (2019). Toward an international definition of citizen science. *Proceedings of the National Academy of Sciences*, *116*(17), 8089–8092. https://doi.org/10.1073/pnas.1903393116

Hein, L., Bagstad, K. J., Obst, C., Edens, B., Schenau, S., Castillo, G., Soulard, F., Brown, C., Driver, A., Bordt, M., Steurer, A., Harris, R., & Caparrós, A. (2020). Progress in natural capital accounting for ecosystems. *Science*, *367*(6477), 514–515. https://doi.org/10.1126/science.aaz8901

Hejnowicz, A. P., Raffaelli, D. G., Rudd, M. A., & White, P. C. L. (2014). Evaluating the outcomes of payments for ecosystem services programmes using a capital asset framework. *Ecosystem Services*, *9*, 83–97. https://doi.org/10.1016/j.ecoser.2014.05.001

Hill, A., Guralnick, R., Smith, A., Sallans, A., Gillespie, R., Denslow, M., Gross, J., Murrell, Z., Conyers, T., Oboyski, P., Ball, J., Thomer, A., Prys-Jones, R., De La Torre, J., Kociolek, P., & Fortson, L. (2012). The notes from nature tool for unlocking biodiversity records from museum records through citizen science. *ZooKeys*, *209*, 219–233. https://doi.org/10.3897/zookeys.209.3472

Hinson, C., O'Keeffe, J., Mijic, A., Bryden, J., Van Grootveld, J., & Collins, A. M. (2022). Using natural capital and ecosystem services to facilitate participatory environmental decision making: Results from a systematic map. *People and Nature*, *4*(3), 652–668. https://doi.org/10.1002/pan3.10317

Formatted: Centered

Hooper, T., Börger, T., Langmead, O., Marcone, O., Rees, S. E., Rendon, O., Beaumont, N., Attrill, M. J., & Austen, M. (2019). Applying the natural capital approach to decision making for the marine environment. *Ecosystem Services*, *38*, 100947. https://doi.org/10.1016/j.ecoser.2019.100947

Ioana-Toroimac, G., Zaharia, L., Neculau, G., Constantin, D. M., & Stan, F. I. (2020). Translating a river's ecological quality in ecosystem services: An example of public perception in Romania. *Ecohydrology & Hydrobiology*, *20*(1), 31–37. https://doi.org/10.1016/j.ecohyd.2019.10.005

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods*, *18*(1), 3–20. https://doi.org/10.1177/1525822X05282260

Jones, L., Vieno, M., Fitch, A., Carnell, E., Steadman, C., Cryle, P., Holland, M., Nemitz, E., Morton, D., Hall, J., Mills, G., Dickie, I., & Reis, S. (2019). Urban natural capital accounts: developing a novel approach to quantify air pollution removal by vegetation. *Journal of Environmental Economics and Policy*, *8*(4), 413–428. https://doi.org/10.1080/21606544.2019.1597772

Jordan, A., & Russel, D. (2014). Embedding the Concept of Ecosystem Services? The Utilisation of Ecological Knowledge in Different Policy Venues. *Environment and Planning C: Government and Policy*, *32*(2), 192–207. https://doi.org/10.1068/c3202ed

Leach, K., Grigg, A., O'Connor, B., Brown, C., Vause, J., Gheyssens, J., Weatherdon, L., Halle, M., Burgess, N. D., Fletcher, R., Bekker, S., King, S., & Jones, M. (2019). A common framework of natural capital assets for use in public and private sector decision making. *Ecosystem Services*, *36*, 100899. https://doi.org/10.1016/j.ecoser.2019.100899

Mason, E., Gascuel-Odoux, C., Aldrian, U., Sun, H., Miloczki, J., Götzinger, S., Burton, V. J., Rienks, F., Di Lonardo, S., & Sandén, T. (2024). Participatory soil citizen science: An unexploited resource for European soil research. *European Journal of Soil Science*, *75*(2), e13470. https://doi.org/10.1111/ejss.13470

Mayo-Wilson, E., Li, T., Fusco, N., Dickersin, K., & for the MUDS investigators. (2018). Practical guidance for using multiple data sources in systematic reviews and meta-analyses (with examples from the MUDS study). *Research Synthesis Methods*, *9*(1), 2–12. https://doi.org/10.1002/jrsm.1277

McHale, M. R., Beck, S. M., Pickett, S. T. A., Childers, D. L., Cadenasso, M. L., Rivers, L., Swemmer, L., Ebersohn, L., Twine, W., & Bunn, D. N. (2018). Democratization of ecosystem services—a radical

Formatted: Centered

approach for assessing nature's benefits in the face of urbanization. *Ecosystem Health and Sustainability*, *4*(5), 115–131. https://doi.org/10.1080/20964129.2018.1480905

McKinley, D. C., Miller-Rushing, A. J., Ballard, H. L., Bonney, R., Brown, H., Cook-Patton, S. C., Evans, D. M., French, R. A., Parrish, J. K., Phillips, T. B., Ryan, S. F., Shanley, L. A., Shirk, J. L., Stepenuck, K. F., Weltzin, J. F., Wiggins, A., Boyle, O. D., Briggs, R. D., Chapin, S. F., … Soukup, M. A. (2017). Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, *208*, 15–28. https://doi.org/10.1016/j.biocon.2016.05.015

Millennium Ecosystem Assessment (MEA) (Ed.). (2005). *Ecosystems and human well-being: synthesis*. Island Press.

Missemer, A. (2018). Natural Capital as an Economic Concept, History and Contemporary Issues. *Ecological Economics*, *143*, 90–96. https://doi.org/10.1016/j.ecolecon.2017.07.011

Naderifar, M., Goli, H., & Ghaljaie, F. (2017). Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. *Strides in Development of Medical Education*, *14*(3). https://doi.org/10.5812/sdme.67670

Njue, N., Stenfert Kroese, J., Gräf, J., Jacobs, S. R., Weeser, B., Breuer, L., & Rufino, M. C. (2019). Citizen science in hydrological monitoring and ecosystem services management: State of the art and future prospects. *Science of The Total Environment*, *693*, 133531. https://doi.org/10.1016/j.scitotenv.2019.07.337

Norris, M., & Oppenheim, C. (2007). Comparing alternatives to the Web of Science for coverage of the social sciences' literature. *Journal of Informetrics*, *1*(2), 161–169. https://doi.org/10.1016/j.joi.2006.12.001

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 160940691773384. https://doi.org/10.1177/1609406917733847

Okada, T., Mito, Y., Tokunaga, K., Sugino, H., Kubo, T., Akiyama, Y. B., Endo, T., Otani, S., Yamochi, S., Kozuki, Y., Kusakabe, T., Otsuka, K., Yamanaka, R., Shigematsu, T., & Kuwae, T. (2021). A comparative method for evaluating ecosystem services from the viewpoint of public works. *Ocean & Coastal Management*, *212*, 105848. https://doi.org/10.1016/j.ocecoaman.2021.105848

Formatted: Centered

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2020). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, n71. https://doi.org/10.1136/bmj.n71

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R. T., Başak Dessane, E., Islar, M., Kelemen, E., Maris, V., Quaas, M., Subramanian, S. M., Wittmer, H., Adlan, A., Ahn, S., Al-Hafedh, Y. S., Amankwah, E., Asah, S. T., … Yagi, N. (2017). Valuing nature's contributions to people: the IPBES approach. *Current Opinion in Environmental Sustainability*, *26–27*, 7–16. https://doi.org/10.1016/j.cosust.2016.12.006

Pateman, R., Dyke, A., & West, S. (2021). The Diversity of Participants in Environmental Citizen Science. *Citizen Science: Theory and Practice*, *6*(1), 9. https://doi.org/10.5334/cstp.369

Pearse, H. (2020). Deliberation, Citizen Science and Covid-19. *The Political Quarterly*, *91*(3), 571–577. https://doi.org/10.1111/1467-923X.12869

Petit-Boix, A., & Apul, D. (2018). From Cascade to Bottom-Up Ecosystem Services Model: How Does Social Cohesion Emerge from Urban Agriculture? *Sustainability*, *10*(4), 998. https://doi.org/10.3390/su10040998

Pocock, M. J. O., Hamlin, I., Christelow, J., Passmore, H., & Richardson, M. (2023). The benefits of citizen science and nature-noticing activities for well-being, nature connectedness and pro-nature conservation behaviours. *People and Nature*, *5*(2), 591–606. https://doi.org/10.1002/pan3.10432

Pocock, M. J. O., Tweddle, J. C., Savage, J., Robinson, L. D., & Roy, H. E. (2017). The diversity and evolution of ecological and environmental citizen science. *PLOS ONE*, *12*(4), e0172579. https://doi.org/10.1371/journal.pone.0172579

Primmer, E., Saarikoski, H., & Vatn, A. (2018). An Empirical Analysis of Institutional Demand for Valuation Knowledge. *Ecological Economics*, *152*, 152–160. https://doi.org/10.1016/j.ecolecon.2018.05.017

Quijas, S., Boit, A., Thonicke, K., Murray-Tortarolo, G., Mwampamba, T., Skutsch, M., Simoes, M., Ascarrunz, N., Peña-Claros, M., Jones, L., Arets, E., Jaramillo, V. J., Lazos, E., Toledo, M., Martorano, L. G., Ferraz, R., & Balvanera, P. (2019). Modelling carbon stock and carbon sequestration ecosystem

Formatted: Centered

services for policy design: a comprehensive approach using a dynamic vegetation model. *Ecosystems and People*, *15*(1), 42–60. https://doi.org/10.1080/26395908.2018.1542413

Resnik, D. B., Elliott, K. C., & Miller, A. K. (2015). A framework for addressing ethical issues in citizen science. *Environmental Science & Policy*, *54*, 475–481. https://doi.org/10.1016/j.envsci.2015.05.008

Roche, J., Bell, L., Galvão, C., Golumbic, Y. N., Kloetzer, L., Knoben, N., Laakso, M., Lorke, J., Mannion, G., Massetti, L., Mauchline, A., Pata, K., Ruck, A., Taraba, P., & Winter, S. (2020). Citizen Science, Education, and Learning: Challenges and Opportunities. *Frontiers in Sociology*, *5*, 613814. https://doi.org/10.3389/fsoc.2020.613814

Salido, L., Purse, B. V., Marrs, R., Chamberlain, D. E., & Shultz, S. (2012). Flexibility in phenology and habitat use act as buffers to long-term population declines in UK passerines. *Ecography*, *35*(7), 604–613. https://doi.org/10.1111/j.1600-0587.2011.06797.x

Sandahl, A., & Tøttrup, A. P. (2020). Marine Citizen Science: Recent Developments and Future Recommendations. *Citizen Science: Theory and Practice*, *5*(1), 24. https://doi.org/10.5334/cstp.270

Schröter, M., Kraemer, R., Mantel, M., Kabisch, N., Hecker, S., Richter, A., Neumeier, V., & Bonn, A. (2017). Citizen science for assessing ecosystem services: Status, challenges and opportunities. *Ecosystem Services*, *28*, 80–94. https://doi.org/10.1016/j.ecoser.2017.09.017

See, L., Comber, A., Salk, C., Fritz, S., Van Der Velde, M., Perger, C., Schill, C., McCallum, I., Kraxner, F., & Obersteiner, M. (2013). Comparing the Quality of Crowdsourced Data Contributed by Expert and Non-Experts. *PLoS ONE*, *8*(7), e69958. https://doi.org/10.1371/journal.pone.0069958

Seymour, V., Willls, B., Wilkin, P., Burt, P., Ikin, E., & Stevenson, P. C. (2022). Incorporating citizen science to advance the Natural Capital approach. *Ecosystem Services*, *54*, 101419. https://doi.org/10.1016/j.ecoser.2022.101419

Smith, H. E., Cooper, C. B., Busch, K. C., Harper, S., Muslim, A., McKenna, K., & Cavalier, D. (2023). Facilitator organizations enhance learning and action through citizen science: a case study of Girl Scouts' Think Like a Citizen Scientist journey on SciStarter. *Environmental Education Research*, *30*(2), 190–213. https://doi.org/10.1080/13504622.2023.2237705

Formatted: Centered

Storksdieck, M., Shirk, J. L., Cappadonna, J. L., Domroese, M., Göbel, C., Haklay, M., Miller-Rushing, A. J., Roetman, P., Sbrocchi, C., & Vohland, K. (2016). Associations for Citizen Science: Regional Knowledge, Global Collaboration. *Citizen Science: Theory and Practice*, *1*(2), 10. https://doi.org/10.5334/cstp.55

Strasser, B. J., Baudry, J., Mahr, D., Sanchez, G., & Tancoigne, E. (2018). "Citizen Science"? Rethinking Science and Public Participation. *Science & Technology Studies*, 52–76. https://doi.org/10.23987/sts.60425

Stuber, E. F., Robinson, O. J., Bjerre, E. R., Otto, M. C., Millsap, B. A., Zimmerman, G. S., Brasher, M. G., Ringelman, K. M., Fournier, A. M. V., Yetter, A., Isola, J. E., & Ruiz-Gutierrez, V. (2022). The potential of semi-structured citizen science data as a supplement for conservation decision-making: Validating the performance of eBird against targeted avian monitoring efforts. *Biological Conservation*, *270*, 109556. https://doi.org/10.1016/j.biocon.2022.109556

Stylinski, C. D., Peterman, K., Phillips, T., Linhart, J., & Becker-Klein, R. (2020). Assessing science inquiry skills of citizen science volunteers: a snapshot of the field. *International Journal of Science Education, Part B*, *10*(1), 77–92. https://doi.org/10.1080/21548455.2020.1719288

Theobald, E. J., Ettinger, A. K., Burgess, H. K., DeBey, L. B., Schmidt, N. R., Froehlich, H. E., Wagner, C., HilleRisLambers, J., Tewksbury, J., Harsch, M. A., & Parrish, J. K. (2015). Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biological Conservation*, *181*, 236–244. https://doi.org/10.1016/j.biocon.2014.10.021

Tweddle, J. C., Robinson, L. D., Pocock, M. J. O., & Roy, H. E. (2012). *Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. NERC/Centre for Ecology & Hydrology. http://www.ukeof.org.uk/documents/guide-to-citizen-science.pdf

UK Defra. (2020, January 22). *Enabling a natural capital approach guidance*. GOV.UK. https://www.gov.uk/government/publications/enabling-a-natural-capital-approach-enca-guidance/enabling-a-natural-capital-approach-guidance

UK National Ecosystem Assessment (2011) The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

UK NCC. (2020). *Natural Capital Committee's end of term report*. UK Defra. Retrieved 2024, from https://www.gov.uk/government/publications/natural-capital-committees-end-of-term-report.

Formatted: Centered

Wamsler, C., Niven, L., Beery, T., Bramryd, T., Ekelund, N., Jönsson, K. I., Osmani, A., Palo, T., & Stålhammar, S. (2016). Operationalizing ecosystem-based adaptation: harnessing ecosystem services to buffer communities against climate change. *Ecology and Society*, *21*(1). https://doi.org/10.5751/ES-08266-210131

Wardropper, C. B., Dayer, A. A., Goebel, M. S., & Martin, V. Y. (2021). Conducting conservation social science surveys online. *Conservation Biology*, *35*(5), 1650–1658. https://doi.org/10.1111/cobi.13747

Wilkinson, M. D., Dumontier, M., Aalbersberg, Ij. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J.-W., Da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., … Mons, B. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data*, *3*(1), 160018. https://doi.org/10.1038/sdata.2016.18

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6 Author Contributions

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

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8 Conflict of Interest Statement

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

9 Data availability statement

The data supporting this research will be available through the Oxford University Research Archive. DOI to be supplied soon.

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