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Environmental citizen science practices in the ILTER community: Remarks from a case study at global scale

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In the last decades, citizen science (CS) has experienced an increasing interest as a practice in which scientists and citizens collaborate to produce new knowledge for science, society and policy. Environmental and ecological sciences are among the most active in proposing CS activities and new models for citizen participation in research. In addition to environmental dimensions, these fields necessarily include social and cultural dimensions to confront the complex local and global environmental challenges. This is particularly evident in the International Long-Term Ecological Research (ILTER) network, where the integration of social sciences has become a recognized priority. ILTER offers a valuable landscape to explore common CS features across a wide range of different cultural and socio-ecological contexts, as well as worldviews of science-society interactions. In 2020, we surveyed scientists working at ILTER sites across the globe to identify key features of CS initiatives in which they are/were involved and the levels of participation of the volunteers. We consider these features in the context of the internationally-developed "Ten Principles of Citizen Science" by examining scientific outcomes and societal/policy impact, type of volunteers' involvement, and sharing of data/findings and feedbacks and acknowledging volunteers. Our results indicate that the ILTER community demonstrated a good predisposition toward environmentally-focused CS initiatives with diverse scientific questions including biodiversity, water quality, ecosystem services and climate change. Most of the respondents reported that the volunteers were involved mainly in collecting samples or recording data; some other activities, such as dissemination of the project conclusions and discussion and translation of the results into action, were also mentioned. Volunteers were usually trained for these initiatives and acknowledged in peer-reviewed publication, however data from the initiatives were only partially shared openly. We conclude with remarks and suggestions for expanding design and implementation of CS in the ILTER community.

KEYWORDS
environmental citizen science, ILTER network, public engagement with science and technology (PEST), questionnaire, collaborative research, volunteers' involvement

1 Introduction

Citizen science (CS) refers to the active engagement of the general public in scientific research and is experiencing an increasing interest in the last decades as a practice in which scientists and citizens collaborate to produce new knowledge for science, society and policy (Silvertown, 2009; Theobald et al., 2015; Kullenberg and Kasperowski, 2016; Haklay et al., 2021). Data collection is the most popular form of citizens' engagement (Theobald et al., 2015; Kullenberg and Kasperowski, 2016; Turrini et al., 2018; Stylinski et al., 2020), although volunteers can contribute in other ways such as co-design and co-creation, through problem definition, data analysis, and interpretation and dissemination of results (Shirk et al., 2012; Haklay, 2013; Chapman and Hodges, 2017; Haklay, 2017).

Several authors have thoroughly discussed the many benefits of CS for scientific research, environmental monitoring, and the decision-making process; these include knowledge and skills gains for both volunteers and scientists as an avenue to promote two-way collaboration and engagement for both citizens and scientists (e.g., Lidskog, 2008; Hochachka et al., 2011; Aceves-Bueno et al., 2015; Branchini et al., 2015; Bonney et al., 2016; Ballard et al., 2017; Turbé et al., 2019). Moreover, CS is considered as an emerging example of a non-traditional data source that can contribute to the United Nations Sustainable Development Goals (SDGs; Fritz et al., 2019; Fraisl et al., 2020) and global biodiversity targets (Chandler et al., 2017). Many CS programs are well suit for this contribution because they cover a wide range of global biodiversity research (e.g., Greenwood, 2007; Theobald et al., 2015; Geijzendorffer et al., 2016; Chandler et al., 2017; Fraisl et al., 2022) and collect information on population dynamics, health and distribution of terrestrial and marine organisms (e.g., Miller-Rushing et al., 2012; Zapponi et al., 2017). CS may also provide valuable support to institutional long-term environmental monitoring programs by the Environmental Protection Agencies and Protected Areas in Europe and the United States (e.g., Owen and Parker, 2018; Rubio-Iglesias et al., 2020; Garcia-Soto et al., 2021; Halliwell et al., 2021; Vohland et al., 2021).

In the last decades, progress in CS has been also organizational, since several CS networks have been established and grown, such as the US Citizen Science Association (CSA), the Australian Citizen Science Association (ACSA) and the European Citizen Science Association (ECSA), providing forums for the exchange of knowledge and ideas, as well as identification of shared goals and best practices. In 2017, the Citizen Science Global Partnership (CSGP)[1] was launched as a network-of-networks seeking to promote and advance CS for a sustainable world and bringing together existing networks of CS researchers and practitioners with advisory boards representing policy, business, and community-based perspectives. Within this wide international community of CS practitioners and researchers, the "Ten Principles of Citizen Science" have been developed. They are a framework to assess new and existing CS initiatives with the aim of fostering excellence in all aspects and providing a common set of tenets for governments, decision-makers, researchers and project leaders, to consider when funding, developing or evaluating CS projects (ECSA, 2015; Eitzel et al., 2017; Robinson et al., 2018).

Environmental and ecological sciences are among the most active pursuing CS activities and new models for citizen participation in research (Vohland et al., 2021). In addition to environmental dimensions, these fields necessarily include social and cultural dimensions (Haberl et al., 2006; Groffman et al., 2010; EEA, 2021a; EEA, 2021b), in order to confront complex local and global environmental challenges. This is particularly evident in the International Long-Term Ecological Research (ILTER) network[2], where the integration of social sciences has become a recognized priority (Singh et al., 2013; Dick et al., 2018; Mirtl et al., 2018). ILTER comprises 44 active member-networks representing 700 LTER sites and 80 LTSER (Long-Term Socio-Ecological Research) platforms across all continents (Wohner et al., 2021). The overall purpose of ILTER is to provide a globally distributed network and infrastructure of long-term research sites for multiple uses in the fields of ecosystem, biodiversity, critical zone, and socio-ecological research (Mirtl et al., 2018). The high spatial and temporal resolution of ecosystem research and monitoring carried out by the LTER sites enables the detection of both slow and extreme changes in ecosystem functioning, responding to a number of drivers and pressures (Mirtl et al., 2018). ILTER is also an example of a multiple and inter-disciplinary community, engaging more than 200 institutions, several thousand scientists, and diverse disciplines. Socio-ecological research in LTER networks aims at addressing global and regional sustainability challenges involving a broad stakeholder community in the measurements and the co-design of investigation practices and in the definition of research priorities (Haberl et al., 2006; Mauz et al., 2012; Dick et al., 2018). This implies a strong commitment of scientists to work within an interdisciplinary context (involving natural, social and human scientists), and willing to engage with communities/stakeholders.

For all these reasons, ILTER offers a valuable opportunity to explore common CS characteristics across a wide range of different cultural and socio-ecological contexts, as well as worldviews of science-society interactions. With this purpose, in 2020 we surveyed scientists working at ILTER sites and LTSER platforms across the globe, to examine features of the ILTER CS initiatives, level of involvement of the volunteers, and the attitudes of ILTER scientists about CS. ILTER scientists' attitudes are reported in a companion paper (L'Astorina et al., 2023); here we focus on the features of ILTER CS initiatives: geographical and biogeographical distribution; spatial and temporal scale; research foci; type of volunteer involvement and of data collected, and data validation efforts. We consider these features in the context of the "Ten Principles of Citizen Science" by examining scientific outcomes and societal/policy impacts, type of volunteers' involvement, sharing of data/findings, the feedbacks and acknowledging volunteer involvement. We conclude with suggestions for expanding design and implementation of CS in the ILTER community.

2 Materials and methods

2.1 Questionnaire development

We collected information through an online questionnaire, available as Supplementary Material, aimed at the ILTER

1 http://www.globalcitizenscience.org.

2 https://www.ilter.network.

FIGURE 1
Phases and timing of the development of the questionnaire with the involved actors in each phase.

network. To draft and validate it, we held a workshop at the 2019 ILTER Open Science Meeting and asked the 14 attending science professionals to create a preliminary list of reasons why scientists would participate in CS, as well as a list of associated challenges. Building from this and related literature and inventories (e.g., Riesch et al., 2013; Golumbic et al., 2017; Tredick et al., 2017; Besley et al., 2018; Robertson Evia et al., 2018; Stylinski et al., 2018), the first version of the questions was developed and then pilot-tested by a group of 14 environmental scientists who were not involved within ILTER (10 were non-native English speakers). Based on the feedback from the pilot scientists, the questionnaire was revised and implemented on Qualtrics[3], an established online questionnaire tool. The different phases of the survey development are shown in Figure 1.

The final online questionnaire consisted of 35 single-answer/multiple-choice, multiple-answer/multiple-choice or open-ended questions, subdivided as follow.

1) Attitudes of scientists towards CS and other public engagement (4 questions on communication objectives, reasons, willingness and barriers)
2) Citizen scientists' involvement (1 question using a 5-point Likert scale)
3) Impact on scientists (1 question)
4) Inventory on a selected CS Initiative (22 questions)
5) Demographics (5 questions on role at the ILTER sites and platforms, career level, age, gender and scientific field of interest)
6) Geographic context (2 questions on country where they work and on the DEIMS. iD[4] of the ILTER site/platform they manage).

In this paper, we focus on the analysis of the inventory and demographic items and on the level of involvement of Citizen Scientists, while the others are described and analyzed in L'Astorina et al., 2023. To provide an in-depth viewpoint, the questionnaire respondents were asked to focus only on one specific CS initiative (current or past) in which they have been most active and to answer a number of questions to describe it. Questions addressed the following features.

i) Spatial and temporal scale of the CS initiatives
ii) Research focus and research question
iii) Type of volunteers and their level of involvement
iv) Training methodology
v) Data type and quality check
vi) Ways to share data and finding and to acknowledge the volunteers

The questionnaire was accompanied by an informative email specifying the purpose of the study and the use that was to be made with the data that the respondents provided. Respondents were free to choose whether or not to answer any questions. The average survey duration was approximately 20 min.

2.2 Questionnaire administration and response rate

A recruitment email with a link to the questionnaire was sent to all the ILTER site managers through the ILTER secretariat contact list, which encompasses 850 email recipients. The email stated the purpose of the study and asked recipients to complete the questionnaire and share the link with other scientists at their ILTER site/platform. The questionnaire remained open from the end of February to mid-September 2020, with two reminders sent within this period.

In total, we received 163 responses with completeness higher than or equal to the 75% (i.e., all of these respondents completed at least the 75% of the questionnaire). We assumed that site managers either filled out the questionnaire or passed it on to a scientist at their site. Thus, our pool of possible respondents was 850, and our response rate is 17%. This response rate appears consistent with those reported for other online questionnaires of expert communities (e.g., Scott et al., 2011; Dudo and Besley, 2016).

3 https://www.qualtrics.com.

4 DEIMS.iD is the identifier of ILTER sites/platforms on Dynamic Ecological Information Management System - Site and dataset registry (DEIMS-SDR), which is the ILTER information management system that allows to discover long-term ecosystem research sites around the globe. https://deims.org/docs/deimsid.html.

TABLE 1 Main features of the CS initiatives addressed in this study, clustered in three main issues and compared with the 10 ECSA principles (ECSA, 2015; Robinson et al., 2018).

Main features of CS projects	Main issues	Ten principles of citizen science
i. Spatial and temporal scale of the CS initiatives	Scientific outcomes and societal/policy impact	2. Citizen science projects have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions or environmental policy
ii. Research focus and research question		9. Citizen science programs are evaluated for their scientific output, data quality, participant experience and wider societal or policy impact
iii. Type of volunteers and their level of involvement	Type of volunteers' involvement	1. Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding. Citizens may act as contributors, collaborators or as project leaders and have a meaningful role in the project
iv. Training methodology		4. Citizen scientists may, if they wish, participate in multiple stages of the scientific process. This may include developing the research question, designing the method, gathering and analysing data, and communicating the results
		6. Citizen science is considered a research approach like any other, with limitations and biases that should be considered and controlled for. However unlike traditional research approaches, citizen science provides opportunity for greater public engagement and democratisation of science
v. Data type and quality check	Sharing of data and findings, feedbacks and acknowledgements	7. In Citizen science project data and metadata are made publicly available and where possible, results are published in an open-access format. Data sharing may occur during or after the project, unless there are security or privacy concerns that prevent this
vi. Ways to share data and finding and to acknowledge the volunteers		5. Citizen scientists receive feedback from the project. For example, how their data are being used and what the research, policy or societal outcomes are
		3. Both the professional scientists and the citizen scientists benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence, for example, to address local, national and international issues, and through that, the potential to influence policy
		8. Citizen scientists are acknowledged in project results and publications
		10. The leaders of citizen science projects take into consideration legal and ethical issues surrounding copyright, intellectual property, data-sharing agreements, confidentiality, attribution and the environmental impact of any activities

2.3 Data analysis

We used bar plots to visualize the percentage of responses for each feature of the selected CS initiatives and a matrix plot for the level of involvement of the citizens in the different activities. In the bar plots, each bar represents the percentages and the number of respondents that selected multiple choice option. We conducted mean comparisons (paired two-samples Wilcoxon test) to test for significant differences between the various demographic groups. Geographical distribution of CS activities was represented per bio-geographical region (see Olson et al., 2001 for the full list of regions). We also looked for common themes in the open-response questions. The statistical software R (version 4.1.2) was used for all the analyses (R Core Team, 2021). The performed analyses by using the R software are available as open code on GitHub (Oggioni and Bergami, 2022), while the questionnaire results are accessible on Zenodo (Bergami et al., 2022).

2.4 Features of the CS and relation with the ten principles of CS

We compared the six main features of the ILTER CS initiatives with the "Ten Principles of Citizen Science," which cover a broad range of characteristics of CS, from scientific outcomes and benefits for the citizens to data sharing and ethical issue. To simplify this comparison, we grouped the Ten Principles into three key issues, covering several principles and connected to the six features: i) Scientific outcomes and societal/policy impact, ii) Types of volunteers' involvement, iii) Sharing of data and findings, feedbacks and acknowledgements (Table 1; Figure 2).

3 Results

3.1 Respondents' demographics and geographical distribution of the ILTER initiatives

The most common demographic selections were male (61%), ILTER site managers (38%) and senior scientists (44%) and aged between 50 and 59 years (25%) (Table 2). Forty-seven percent of the respondents declared that they have been involved in at least one CS initiative during their scientific career. The total number of current and past CS initiatives carried out at the LTER site or LTSER platform by all the respondents was 392 with an average of

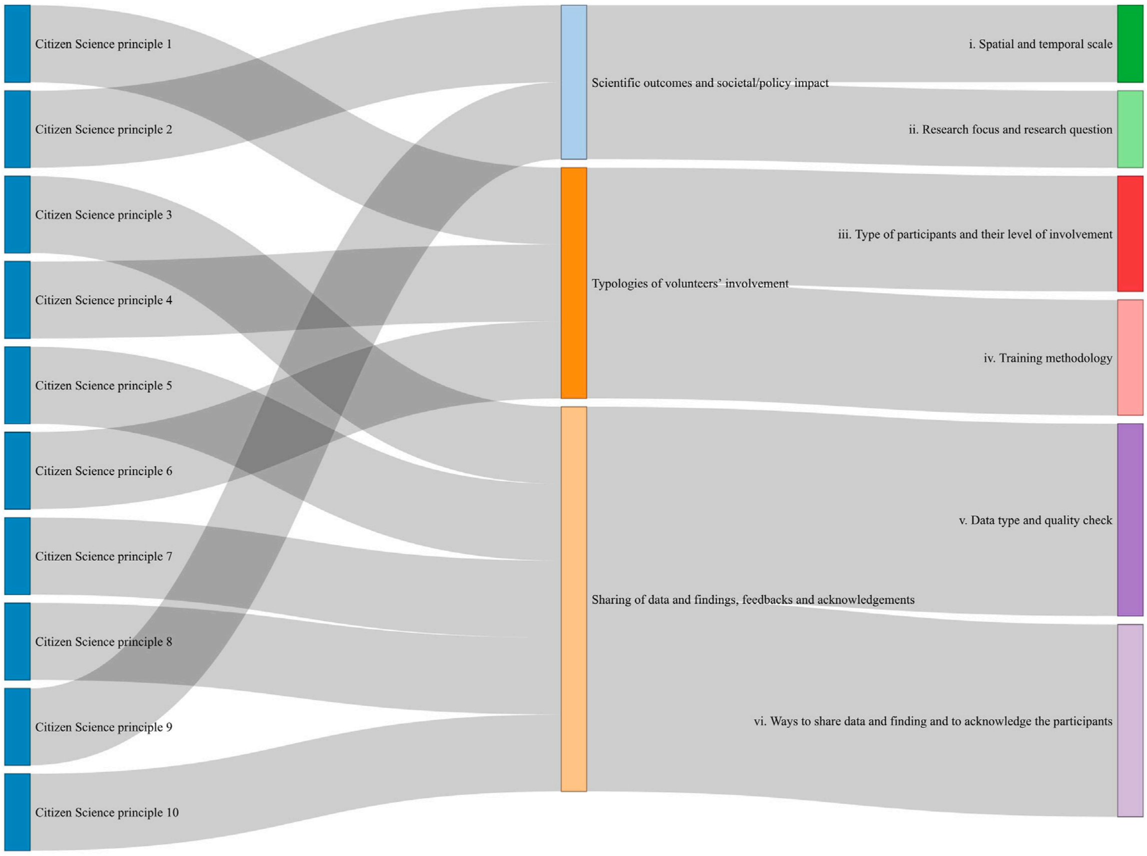

FIGURE 2
Sankey diagram representing the six main features of the selected CS initiatives, their clustering into three main issues and the connections with the Ten Citizen Science principles.

4.6 per respondent. Seventy-six were the selected CS initiatives of which the respondents described the main features.

Eighty-three percent of the respondents gave information about geographic context, which was useful for defining the provenance ILTER network. They primarily worked at LTER sites/platforms in Europe (58%) with additional respondents working in the US (10%), East-Asia-Pacific (7%), Central and South America (4%) and Africa (3%) (Figure 3). Most of the initiatives were distributed in Temperate and Mediterranean climate biogeographic regions (79%) with only 16 in other climate regions: two in Subtropical Arid climate, seven in Humid climate (at equatorial or tropical latitudes), four in Boreal climate and three in Warm Temperate climate (Figure 3).

No statistically significant relationships were detectable in the responses between the various demographic groups.

3.2 Features of the selected CS initiatives

3.2.1 Spatial and temporal scales and research questions

Seventy-one percent of the respondents carried on their CS initiatives at one ILTER site (local scale) or at several ILTER sites based in the same region (regional scale), while 17% worked at the whole country level and 12% involved other national LTER networks (Figure 4A). The average CS initiatives' duration was 4 years, and 69% were still active at the time of the questionnaire (Figure 4B). The principal research foci were environmental science (50%) and biology (26%), while the remaining 24% was shared among different disciplines, such as global change, hydrology, management, limnology and oceanography (Figure 5). The main research questions were water quality, biodiversity changes (in general or related to the distribution of species and specific groups of organisms), ecosystem services and management and climate/global changes.

3.2.2 Volunteers' involvement

The volunteers participating in the CS initiatives were mainly adults (43%) with 17% being involved through an organized group (e.g., birding clubs, groups of divers) (Figure 6A). Eighteen percent were children participating as part of school (12%) or out-of-school (6%) programs. The remaining 30% were undergraduate students (11%), seniors (11%) and families (8%). Fifty-three percent of the volunteers were part of underserved communities living in rural areas (21%) or with limited financial resources (21%) (Figure 6B).

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TABLE 2 Gender, role, career level and age of ILTER scientists in this study.

Demographic item	Percentage of ILTER scientist respondents (%)
Gender	
Female	39
Male	61
No answer	3
Role at ILTER site/platform	
Site manager	38
National Network Coordinator	7
Collaborator	13
Data manager	6
Other and No answer	38
Career level	
Senior	44
Mid-career	22
Junior	10
Other and No answer	24
Age	
20–39	5
40–59-45	38
over 60	19
No answer	38

Eighty-one percent of the volunteers had participated two or more times in the same initiative (Figure 6C). The most common type of volunteer involvement was to "help collect samples and record data" (75% of the respondents' rated this as "high" and "very high"). Some respondents also gave "high" and "very high" to the following types of involvement: "help disseminate conclusions" (44%), "help discuss results and ask new questions" (42%), "help gather information and resources for research" (34%), and "help translate the results into action" (33%). Least common were involving volunteers in "helping design data collection methodologies" (11%), "helping to develop hypotheses" (7%), and "helping to analyze data" (5%). Similar results were apparent in responses to the open-response question: "What do volunteers do in your selected citizen science initiative?"; that is, 60% of the listed activities were collection of samples and sightings, as well as mapping of animals and plants species distribution (Figure 6D). Ninety-seven percent of the volunteers were trained or supported in some way for participation in these initiatives (Figure 7), and this was primarily *via* mandatory or voluntary short face-to-face workshops (44%) or *via* written instructions (33%).

3.2.3 Citizen science data and findings

Respondents declared that, in their initiatives, volunteers collected numeric and Boolean data (37%), images (20%), geographic information (20%) and text (17%) (Figure 8A). Ninety-eight percent of the data from the initiatives were validated in some ways; this validation was by scientists (40%), other volunteers (10%) or by using other methods and term of comparison (48%) (Figure 8B). Some initiatives shared research data with volunteers through online repositories (61%) (Figure 8C), while many share research findings with the volunteers (95%) mainly during in-person meetings (50%), as well as through online direct communications, such as email (19%) and indirect communications (15%), such as newsletters and reports (Figure 9A). Ninety-seven percent of the initiatives acknowledged the volunteers in reports or journal articles *via* the acknowledgment section (50%) or by describing their contribution in the material and methods section (27%); occasionally they were listed as coauthors (13%) (Figure 9B).

4 Discussion

The main aim of this paper was to examine CS practices of scientists working at ILTER sites and platforms across the globe. ILTER sites and platforms offer the opportunity to explore various dimensions of CS across a wide range of different geographic, cultural and socio-ecological contexts and in the context of the interests to multiple stakeholders and at different scales. In this study, we examined the main features of CS initiatives in which ILTER scientists are/were involved (i.e., spatial and temporal scale, research foci, type of volunteers, type of data collected and quality check, training methodologies

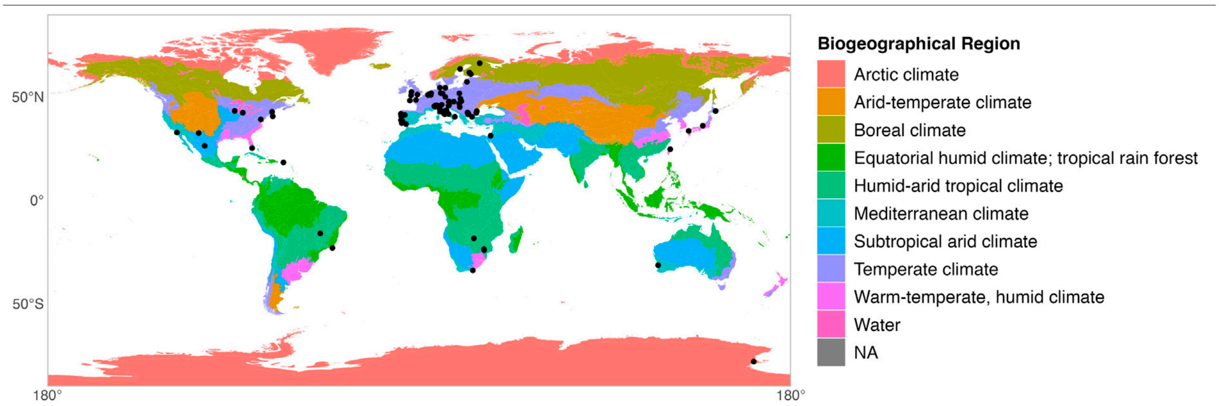

FIGURE 3
Map of the distribution of respondents by biogeographic regions.

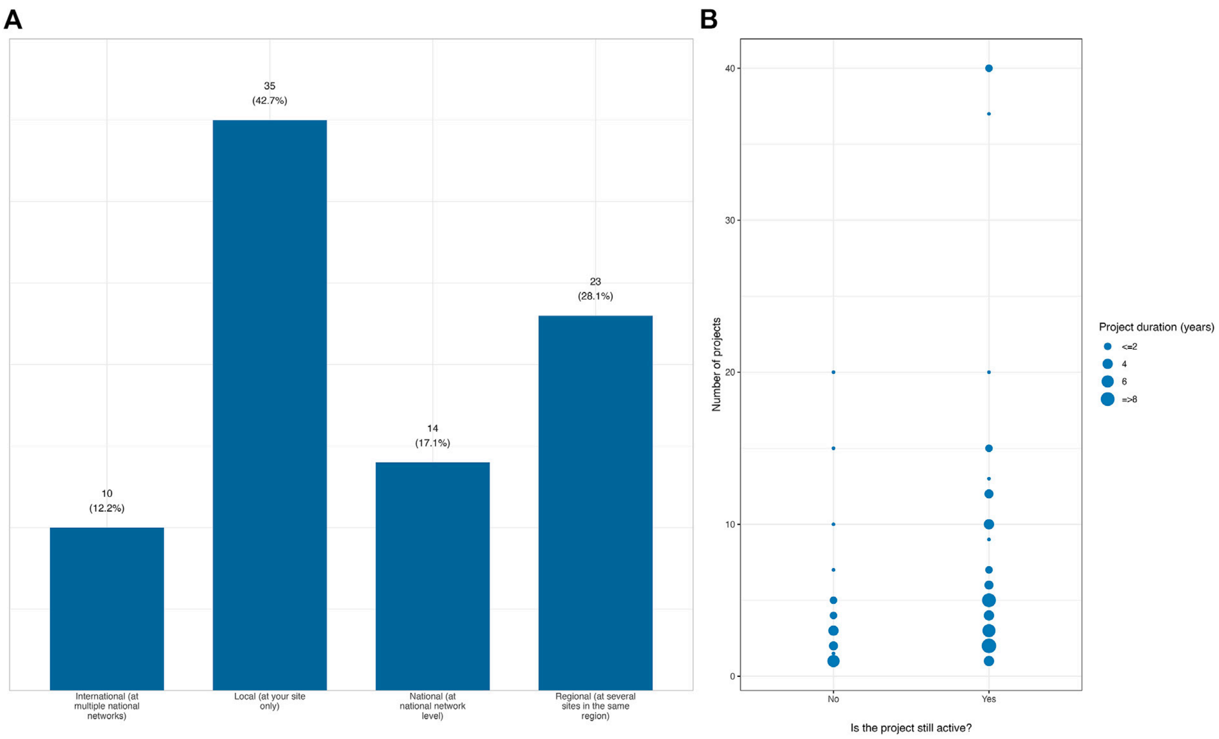

FIGURE 4
CS initiatives: percentage of responses for the different spatial scales **(A)** and information on duration and state of activity of the projects **(B)**.

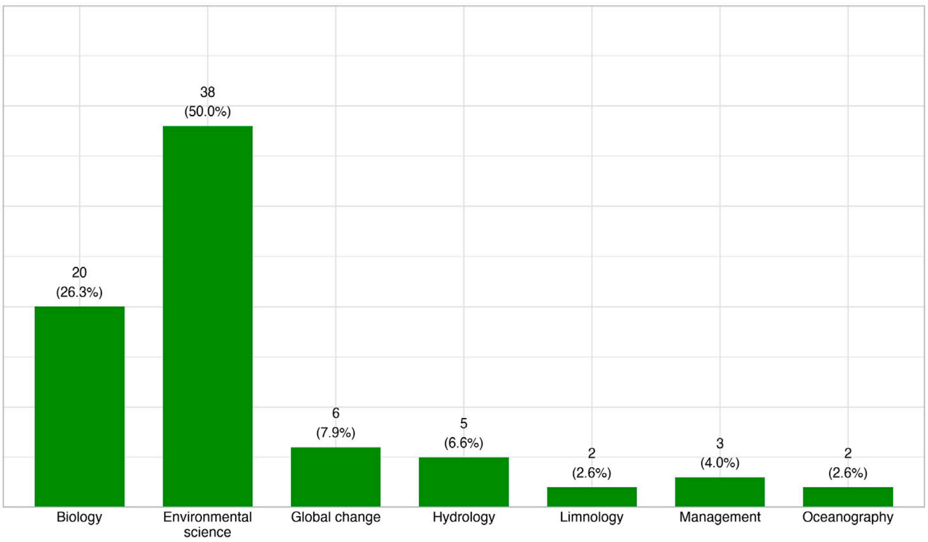

FIGURE 5
Percentage of responses for the main research areas of CS initiatives.

and ways to share data and findings) and the level of involvement of the volunteers in these initiatives.

In general, our findings show that the responding ILTER scientists were open to adopting and promoting CS; indeed, approximately half of respondents have participated in CS initiatives with many involved in more than one during their scientific career. The involvement in CS initiatives did not seem affected by the respondents' demographic and geographic provenance. This could be mainly due to the distribution of respondents to our questionnaire, which was biased to staff who are senior/mid-career and over 50 years and working in regions with higher economic density (Wohner et al., 2021).

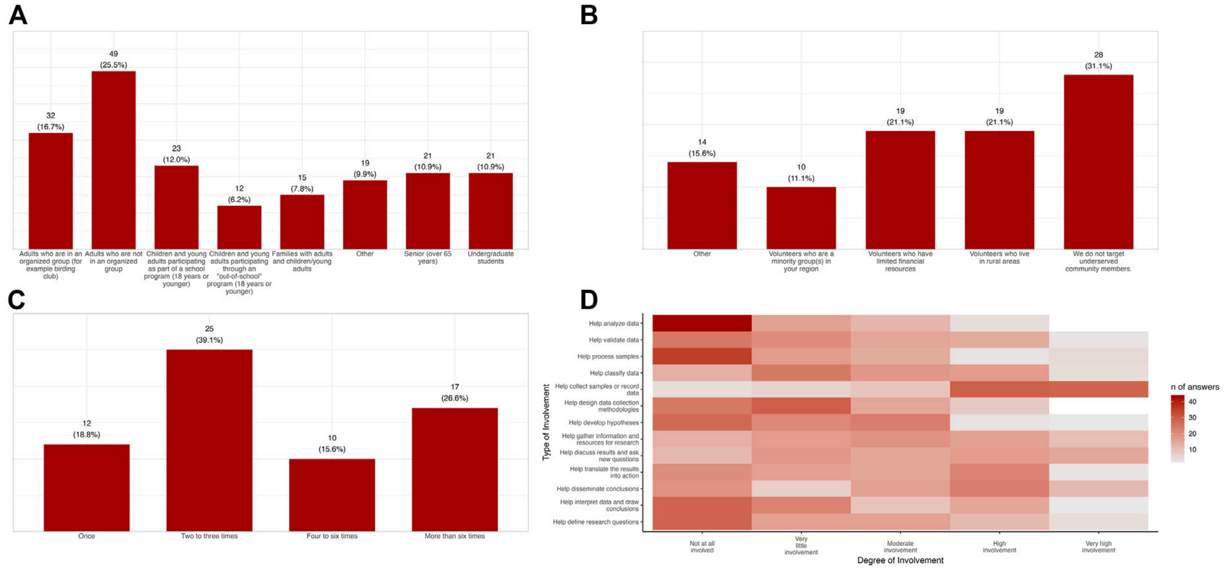

FIGURE 6
Percentage of responses for the different types of volunteers involved in the CS initiatives **(A)**, the engaged underserved communities **(B)**, the frequency of participation of volunteers **(C)**, and the degree of involvement of volunteers in the different activities **(D)**.

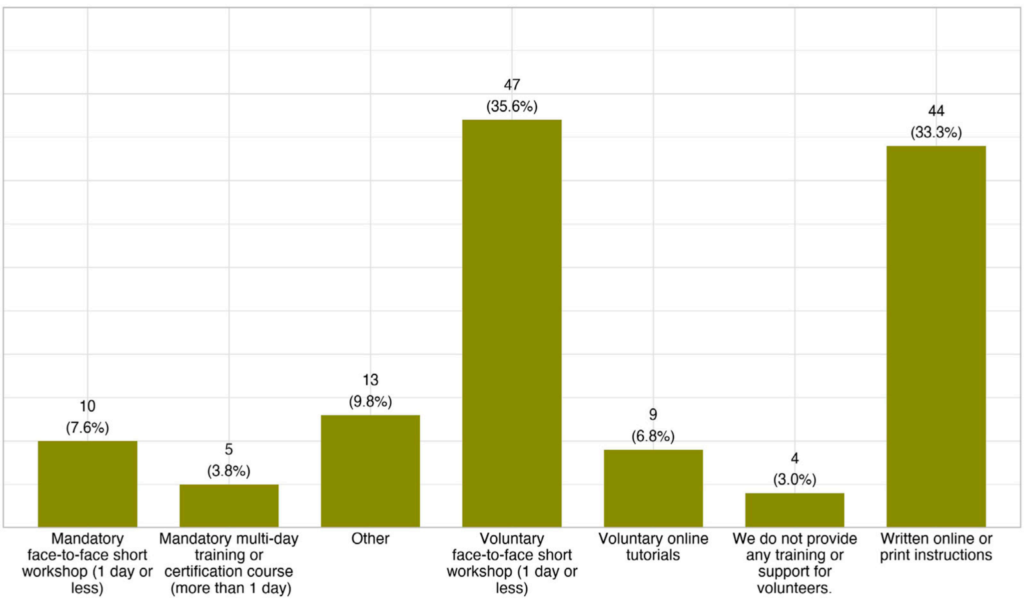

FIGURE 7
Percentage of responses for the different training methodologies of volunteers.

In the following sections, we will discuss the six main features of the ILTER CS initiatives described by the questionnaire respondents in the context of the international framework of the "Ten Principles of Citizen Science (ECSA, 2015; Eitzel et al., 2017; Robinson et al., 2018), which we organized into the three overarching categories: i) Scientific outcomes and societal/policy impact, ii) Type of volunteers involvement, iii) Sharing of data and findings, feedbacks and acknowledgements (see Table 1; Figure 2).

4.1 Scientific outcomes and societal/policy impact

CS initiatives have a genuine science outcome, and this distinguishes them from purely education and outreach programs (Bonney et al., 2009). At the same time, it is very relevant their—real or potential—societal and policy impacts, even though this is not always properly developed and

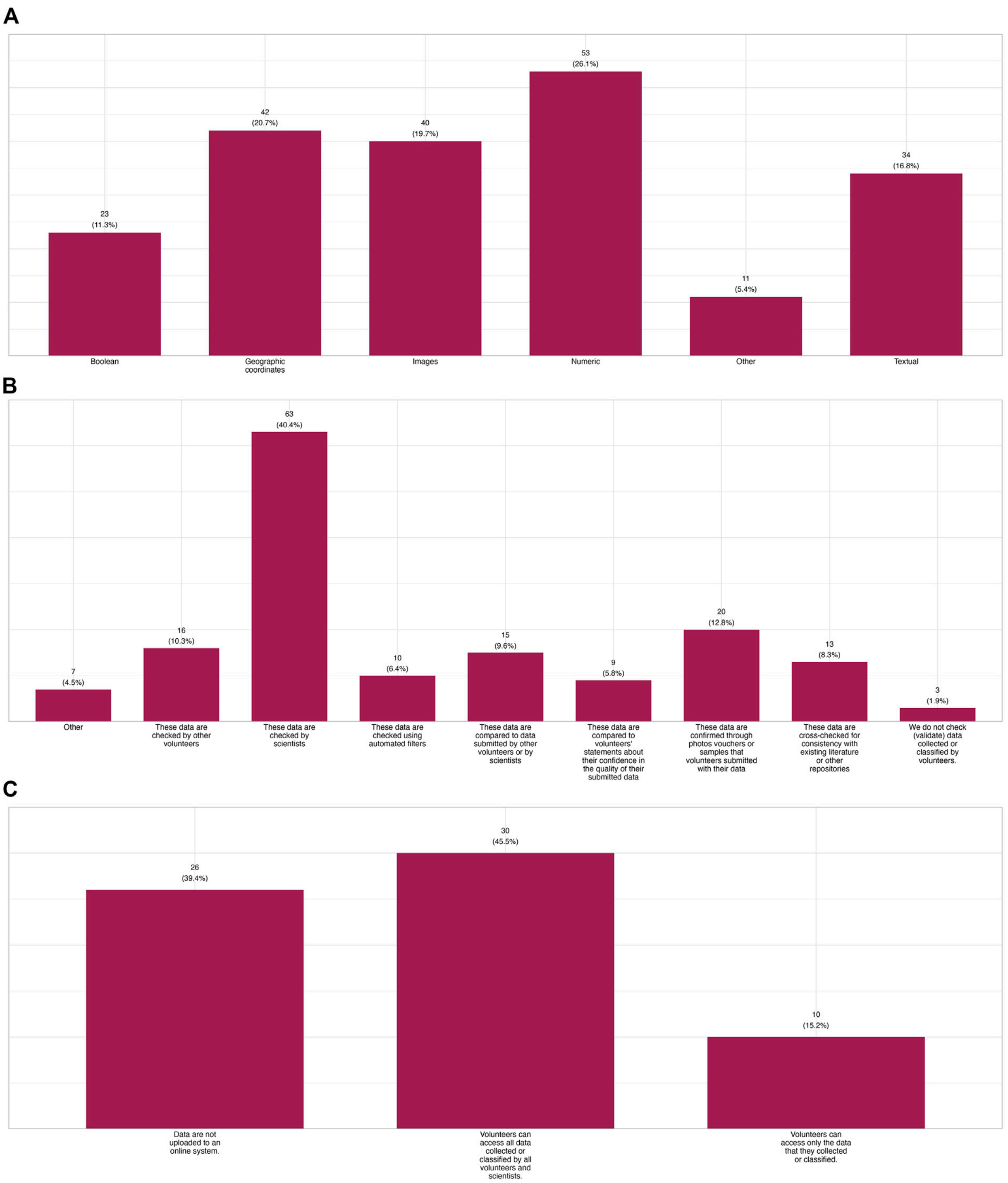

FIGURE 8
Percentage of responses for the different types of data collected from the initiatives **(A)**, the quality check procedures **(B)**, and the methods to share data **(C)**.

evaluated (Robinson et al., 2018; Turbè et al., 2019; Stylinski et al., 2020).

As expected from the conceptual background and overall motivations of the ILTER network (Mirtl et al., 2018), the main research foci of the ILTER CS initiatives were biology and environmental science. The scientific questions addressed biodiversity, mainly the distribution of specific groups of organisms, but also water quality, ecosystem services and climate change (e.g., effects, mitigation). The ILTER community seems therefore to diverge, at least partially, from what is reported by reviews of environmental CS projects in other context, where the monitoring of biodiversity dominates (Schade

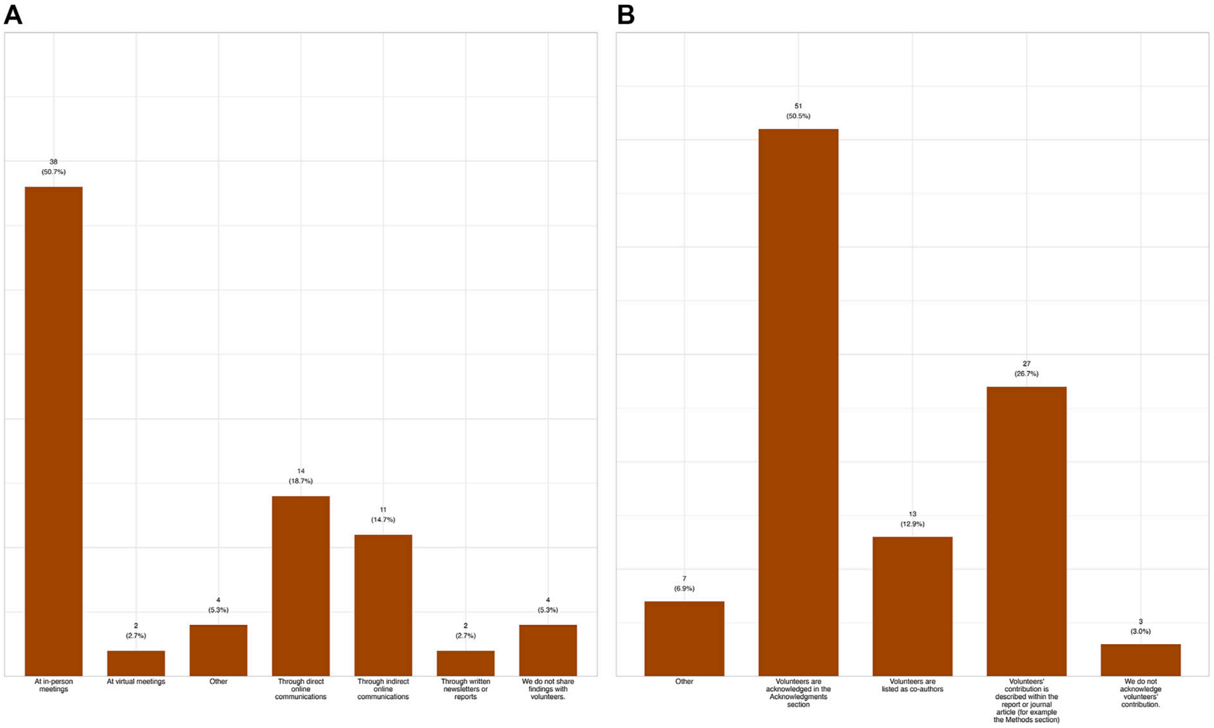

FIGURE 9
Percentage of responses for the different ways to share projects outcomes **(A)** and to acknowledge volunteers **(B)**.

and Tsinaraki, 2016; Pocock et al., 2017; Hecker et al., 2018; Turbè et al., 2019). Indeed, ILTER CS initiatives focusing on the ecological state and on the use of natural resources (air, water, land), and on ecosystem services and environmental management, conservation and protection are fairly well represented.

All the initiatives described in the questionnaire are potentially relevant for addressing a number of policy and conservation issues, such as biodiversity targets achievement and environmental Directives implementation. Furthermore, research conducted at the ILTER sites and platforms often addresses critical questions regarding natural resources management so that the data and knowledge produced are fundamental and irreplaceable for documenting long-term trends in environmental conditions and making for policy decisions at the local, regional and global levels (Hughes et al., 2017; Mirtl et al., 2018). In particular, ILTER may play a major role in global monitoring and evaluation frameworks, such as the Aichi targets, the UN SDGs, and the Sendai Framework. Given this, the involvement of citizen scientists into the scientific processes has the potential to increase policy impacts of ILTER studies. Overall, CS is emerging as a practice that effectively contributes to all the aspects of the policy process (Turbè et al., 2019); this includes carrying out research at scales that would not have been possible otherwise and early detection of a range of environmental issues, as well as highlighting new issues for decision makers and promoting policy implementation through CS monitoring programmes. However, it can be arduous to evaluate the uses of findings for policy and decision-making or to attribute this use to a specific policy area (e.g., Hyder et al., 2015; Turbè et al., 2019). ILTER could be in the position to reinforce the effectiveness of CS for policy, mostly by fostering CS projects that collect data over broad spatial and temporal scales, so that policymakers would have evidence-based knowledge that can be used to serve multiple objectives and meet current and future policy objectives. Most ILTER CS initiatives reported here do not contain these characteristics; that is, they are primarily implemented at the local scale (at one LTER site only) or, more rarely, at the regional scale (at several LTER sites in the same region) and are short-term with a mean duration of 4 years. Thus, a key value of ILTER (i.e., its broad-scale) does not emerge from our study. This is very likely the consequence of the lack of harmonized views, guidelines and dedicated funding for CS at ILTER. This leaves to each site or network own responsibility for running the project, bringing the constraints typical of short-term projects, failing the target to create and sustain a stable long-term citizen engagement.

At the same time, ILTER sites are in the position to powerfully address local scale, community-based initiatives to support not only science, but also policy and community actions, through co-designed or bottom-up projects. However, as described in the next paragraph, less than 10% of volunteers are engaged in the stage of CS project design, definition of hypothesis and data analysis: there is still much to be done to include citizen participation in all steps of the scientific process and to realize the full social potential of CS in terms of citizen empowerment and transformative capacity.

4.2 Types of volunteers' involvement

The patterns of volunteer participating in CS activities may give important clues about the level of representativeness of the wider society in science and about possible bias concerning age, gender, education, socio-economic status and other factors in CS overall (National Academies of Sciences, 2018; Pateman et al., 2021). CS initiatives often engage volunteers who are prevalently men, people identifying as from white ethnic groups, have high socio-economic status, and are in education at school, college, or university (Pateman et al., 2021). Surprisingly, participating ILTER scientists report that more than 50% of their volunteers are members of underserved communities, in particular those living in rural areas and having limited financial resources. A likely explanation is that most LTER sites are located in natural/rural areas (Wohner et al., 2021), where the local communities may fall mainly into the "underserved" category. The involvement of this kind of volunteer suggests that ILTER CS studies are potentially able to incorporate place-based knowledge provided by volunteers into the scientific process.

Almost two-thirds of the respondents stated that the volunteers are involved mainly in "helping collect samples or record data." Less than 10% of volunteers are engaged in the project design phase, definition of hypothesis and data analysis. This matches other studies (e.g., Phillips et al., 2018; Turrini et al., 2018; Stylinski et al., 2020); it limits opportunities for a meaningful dialogue between science and society, which could foster a greater sense of ownership among volunteers and benefit the research by incorporating local knowledge and expertise (Corburn, 2007). There are likely a number of reasons for this result. For example, scientists may maintain more traditional views of public engagement outcomes (e.g., focused on knowledge gains rather than mutual exchanges), or they may perceive data collection support aligns best with the research needs and ways in which volunteers can realistically contribute (Gray et al., 2017). That said, a large percentage of the ILTER scientists (30%–40%) listed several other types of involvement of volunteers, including dissemination of the project conclusions, discussion and translation of the results into action and applying them to new questions. This indicates that some ILTER scientists have a broader view of the volunteers' contribution and greater commitment to more collaborative aspects of CS; this was also apparent in findings reported in L'Astorina et al., 2023.

Almost the totality of the volunteers in ILTER initiatives were trained using a variety of methods, such as face-to-face workshops, written instructions, and online tutorials. This is noteworthy since an appropriate degree of structured training is considered one of the essential characteristics of CS (Haklay et al., 2021) and one of the ways to ensure high data quality (Kosmala et al., 2016), while also meeting education goals of CS efforts. Training of citizens should lay the essential foundations for the good quality of the data gathered, even though the leaders of the CS initiatives will always have the responsibility to control, measure and report data quality and quality assurance procedures to demonstrate the validity and reliability of the data (Williams et al., 2018). This will also help to overcome one of the barriers that hampers the integration of CS into policy, that is the concern about data quality, interoperability, and access, and mistrust of non-traditional data sources (Kosmala et al., 2016; Balázs et al., 2021).

4.3 Sharing of data and findings, feedbacks and acknowledgements

Data reliability and data quality in CS projects has been and continues to be discussed within the scientific community (e.g., Galloway et al., 2006; Silvertown, 2009; Hunter et al., 2013; Kosmala et al., 2016; Balázs et al., 2021) and is considered to be the main barrier to engaging scientists in CS projects (e.g., Riesch et al., 2013; Burgess et al., 2017; Golumbic et al., 2017).

For the ILTER CS initiatives, there is room for improvement in terms of the data accessibility, as less than half of the CS initiatives make the data produced fully accessible through online repositories after being validated by experts. Considering the growing tendency of the ILTER community to embrace an open science approach, following the expectations of a global research infrastructure (Mirtl et al., 2018), further steps are required to increase the dissemination of best practices for the promotion of open access and the set-up of adequate data infrastructure. ILTER could foster centralized access to the CS resources, creating a data and knowledge platform, which could also allow sharing tools and best practices all over the network with harmonized and interoperable metadata and data standards.

Questionnaire respondents most often reported sharing research findings with CS volunteers and other stakeholders *via* in-person meeting or informal online media only (e.g., reports, newsletters, email), which is congruent with outcomes from other studies (Theobald et al., 2015; Kullenberg and Kasperowski, 2016; Burgess et al., 2017; Turrini et al., 2018). Results published through these channels are relevant, since they may reach important local stakeholders; however, the rarer use of scientific publication, could preclude CS from really fulfilling the goal of advancing science as well as gaining grounds in more traditionally oriented research organizations.

When publishing peer-reviewed publications from their CS projects, almost all of the ILTER scientists cited their volunteers directly in the acknowledgments or by describing their contribution in the material and methods; a few even listed them as coauthors. Overall, this is an encouraging result, since it is proved that giving good feedbacks may provide many benefits (Robinson et al., 2018 and reference therein); in particular, it is a way to show volunteers that their contribution is meaningful, providing motivations for participation in other projects and reinforcing connection and trust between citizen scientists and professional scientists. It would be particularly useful to help improve the practice of CS scientists to describe how they recruited, trained, supported and provided benefits to volunteers in the methods section of their scientific papers (Davis et al., 2022).

5 Final remarks

The ILTER community demonstrated a good predisposition toward environmentally-focused CS initiatives. Hereafter, we try to summarize the outcomes emerged from our work into a set of key final remarks and suggestions.

- Efforts should be made to develop initiatives that involve volunteers in ways that extend beyond data collection. Environmental CS has multiple applications and a vast range of experiences and best practices has been so far accumulated, which make it possible to go beyond the simple collection of observations. As reported in the study by L'Astorina et al., 2023, the ILTER community has broad views on how CS volunteers can contribute to science research and is open to a wide array of possible outcomes including learning from local community members. There is still much to be done to include citizen participation in all steps of the scientific process and to realize the full social potential of CS in terms of citizen empowerment and transformative capacity.

- Careful consideration should be given to the scientific, educational and societal/policy outcomes of a CS initiative to properly undertake specific steps to broaden the diversity of volunteers, setting up appropriate recruitment methods, which should start since the early stages of the project planning, in a truly and effective co-designed process.
- The connections between CS and policies in ILTER should be improved, considering the huge potential of CS for policy. Useful recommendations were proposed by Turbè et al. (2019), and they could represent key inputs for the integration of CS in the environmental policy cycle. In particular, scientists at ILTER sites and platforms are in the position to lead local scale, community-based initiatives to support policy and community actions, through co-designed or bottom-up projects. Moreover, being ILTER a network of sites, the value of CS initiatives at "local" level has an intrinsic importance, since it allows incorporating local, place-based knowledge into the scientific process. Indeed, leveraging the "power of place" (as defined and analyzed by Newman et al., 2017) could generate substantial impacts on decision making (e.g., with regards to conservation and management of the land, and fostering participation and negotiation).
- Taking advantage of its worldwide distribution, the ILTER community should also work to implement CS initiatives with a larger spatial scale, fostering research between different national networks and on a global scale. Surprisingly, the broad-scale and long-term features of ILTER sites and platforms did not emerge from our study. The lack of harmonized views and guidelines for CS means each LTER site and platform is responsible for running their projects, hampering the creation of a stable long-term citizen engagement.
- As with all research, data management plans should be prepared, considering the peculiarity of CS and the different steps of the data cycle from collection to preservation, in order to ensure data reproducibility and reuse (Fraisl et al., 2022). Any data management system would be enriched with data on volunteers (e.g., demographic data, numbers of times they have contributed data, training approaches, evaluation efforts) that is coupled with submission by volunteers (Peterman et al., 2022). ILTER could create a data and knowledge platform dedicated to the access to CS resources, for sharing tools and best practices all over the network, with harmonized and interoperable methods and standards.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://doi.org/10.5281/zenodo.7148596 https://doi.org/10.5281/zenodo.7472885.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

All the Authors contributed to the design of the research and were organizers of the preparatory workshop during the ILTER 2nd Open Science Meeting (Leipzig, Germany; 3rd of September 2019); CD, CB, AL'A, and AC drafted the questionnaire, which was discussed with and approved by all the authors; AO and CB elaborated the questionnaire results. CB, AP, AC, and AO drafted the manuscript. All the Authors contributed to the discussion of the results and to the critical revisions of the text.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2023.1130020/full#supplementary-material

SUPPLEMENTARY MATERIAL

Survey provided to the ILTER community on scientists' perspectives and activities associated with citizen science and other forms of public engagement.

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