Biological Conservation 225 (2018) 176–186

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

The threefold potential of environmental citizen science - Generating knowledge, creating learning opportunities and enabling civic participation

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ARTICLE INFO

Keywords:
Environmental citizen science
Public participation in scientific research
Environmental education
Learning
Civic participation
Citizen science funding

ABSTRACT

Citizen science offers significant innovation potential in science, society and policy. To foster environmental and conservation goals, citizen science can (i) generate new knowledge, (ii) enhance awareness raising and facilitate in-depth learning as well as (iii) enable civic participation. Here, we investigate how these aims are realised in citizen science projects and assess needs and challenges for advancing citizen science and stimulating future initiatives. To this end, we conducted a quantitative, web-based survey with 143 experts from the environmental and educational sector in Germany, Austria and Switzerland. Our findings show that citizen science project managers pursue goals related to all three areas of potential impact. Interestingly, enabling civic participation was considered slightly less important in relation to generating new knowledge and creating learning opportunities. Different areas of necessary action emerge from our analysis. To fully realize the potential of citizen science for generating knowledge, priority should be given to enhance capacities to more effectively share research results with the scientific community through publication, also in scientific journals. Systematic evaluation is needed to gain a better understanding of citizen science learning outcomes, for which criteria need to be developed. Fostering project formats that allow participants to get involved in the whole research process – from posing the study question to implementing results – could enhance the transformative aspect of citizen science at a societal level. Important structural aspects that need to be addressed include adjustments in funding schemes, facilitation of communication between citizens and academia-based scientists, and offers for training, guidance and networking.

1. Introduction

Citizen science bridges science and society by involving members of the public in scientific discovery across disciplines (Bonney et al., 2014; Kullenberg and Kasperowski, 2016; Theobald et al., 2015). Although it can be implemented in all areas of research, citizen science has gained relevance particularly as a tool to address environmental and conservation issues (Forrester et al., 2017; Newson et al., 2017; Pocock et al., 2017; Zapponi et al., 2017). By enabling people to engage with scientific inquiry, environmental citizen science can contribute to realizing goals in three important areas. First, it provides opportunities to generate knowledge and insights which are new for and relevant to science, society or administration and management, especially with respect to nature conservation (Chandler et al., 2016; Danielsen et al., 2014; Weise et al., 2017). Second, it can contribute to learning about science and the environment as individuals can acquire knowledge which is new to them and gain skills as well as scientific and environmental literacy through involvement in citizen science projects (Bela et al., 2016; Bonney et al., 2014, 2016; Forrester et al., 2017). Third, citizen science can allow for empowering citizens by providing scope for civic participation and involving people in policy-relevant debates and decision-making processes (Dillon et al., 2016; Jordan et al., 2012; Trimble and Berkes, 2013). By offering the potential to merge these three components, citizen science is embedded at the interface of science and knowledge generation, learning and civic participation (Fig. 1).

The emphasis on the generation of new knowledge and addressing authentic scientific objectives is necessarily key to citizen science as expressed in the 'ten principles of citizen science' (Robinson et al., 2018). This needs to be included in design and planning of citizen science projects (Bonney et al., 2014). With regards to knowledge generation, citizen science has been remarkably successful in producing

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https://doi.org/10.1016/j.biocon.2018.03.024
Received 10 December 2017; Received in revised form 14 March 2018; Accepted 20 March 2018
Available online 17 July 2018

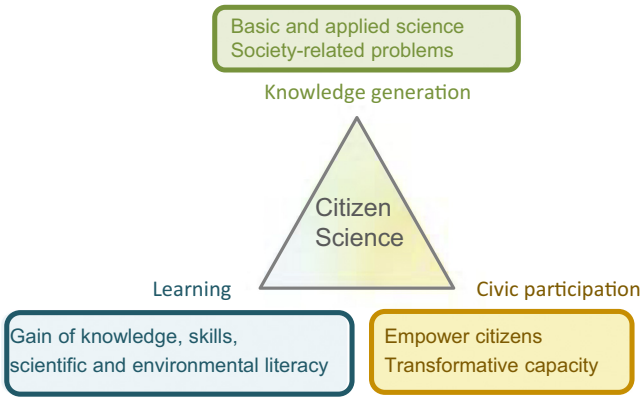

Fig. 1. The threefold potential of citizen science for generating new knowledge (green), creating learning opportunities (blue), and enabling civic participation (yellow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

large amounts of data, especially data spanning large spatial or temporal extents, which would otherwise be laborious and costly or even impossible to obtain (Dickinson et al., 2012; McKinley et al., 2017). These data can form the important basis for analyses of trends and drivers of environmental change (Chandler et al., 2016; Devictor et al., 2010) and support local and international environmental monitoring, nature conservation, land-use planning and administration (Theobald et al., 2015).

Next to generating new knowledge, citizen science is often promoted as a valuable means to create opportunities for in-depth learning. By engaging members of the public in research endeavours, citizen science holds the promise to enhance their learning experience and motivation to acquire new knowledge and skills needed to solve authentic problems, thereby fostering their understanding of both science and scientific processes (Wals et al., 2014). Furthermore, environmental citizen science endeavours often aim at encouraging participants to increase their awareness of environmental problems and gain ecological stewardship (Ballard et al., 2017; Bonney et al., 2014; Shirk et al., 2012). However, while citizen science is naturally regarded as a means to combine scientific and educational purposes, studies systematically evaluating learning outcomes of citizen science projects are still rare and finding evidence for specific learning outcomes of citizen science has been challenging (Ballard et al., 2017). In general, it has been easier to demonstrate that participants of citizen science projects have improved their knowledge or skills than showing that they have enhanced their scientific and environmental literacy or changed their attitudes and behaviours (Bonney et al., 2016; Brossard et al., 2005; Evans et al., 2005; Jordan et al., 2011; Merenlender et al., 2016). One possible reason is that the latter achievements are more complex constructs that are more difficult to measure. But it also likely plays a role that citizen science projects in the fields of environmental protection and nature conservation mainly attract individuals that already have a positive attitude towards these fields in the first place, so no further increase can be detected during the course of a citizen science project (Forrester et al., 2017).

The educational goals pursued within citizen science projects strongly overlap with those of traditional education programs both in formal and informal settings. For example, science education aims at teaching scientific knowledge and skills, while environmental education incorporates goals like raising the participant's awareness for environmental problems and fostering eco-friendly values and behaviours (Wals et al., 2014). The element that distinguishes citizen science from mere educational approaches is that it additionally adds the element of generating new scientific knowledge.

Third, in addition to the scientific knowledge generation and the possibilities it offers for individual learning, citizen science also holds significant potential for civic participation and thereby outcomes at a systemic level, i.e. at the level of institutions, organizations and the society. On the one hand, citizen science can democratize the processes of agenda setting and knowledge generation in research by including the perspectives of citizens, thereby making science more societally relevant (Bela et al., 2016). On the other hand, citizen science can empower members of the public to get involved in policy-relevant processes and to gain the knowledge that is needed to do so, thereby fostering deliberative decision-making in societally relevant processes (Ballard et al., 2017; Jordan et al., 2012).

As such, the potential of citizen science to empower citizens at a systemic level is highly linked to the opportunities it creates for individual learning, which fosters competent citizens who are able to make informed decisions (Bela et al., 2016). These goals are also embedded in the concept of education for sustainable development (ESD; de Haan, 2010). Building such problem-solving capacities within communities is especially important with respect to societal issues that are highly relevant, and at the same time markedly complex and ambiguous, concerning multiple stakeholders with potentially conflicting perspectives as it is often the case with environmental and conservation issues ('wicked problems'; Dillon et al., 2016). The timeliness of facilitating civic participation in research and policy is also highlighted by the fact that in recent years the objective to do so has entered political agendas (Federal Ministry of Science 2016; Owen et al., 2012; Rodríguez et al., 2013; Thorn, 2015). However, in contrast to project learning outcomes at the individual level, transformative effects at a systemic level of enabling civic participation (for example, a change in routines and norms of conducting research) is difficult to measure, and researchers have only recently begun to explore possible ways to do so for citizen science programmes (Bela et al., 2016; Jordan et al., 2012).

It is a unique feature of citizen science that it provides opportunities to align scientific inquiry with creating opportunities for learning about science and environmental issues and getting involved in societally relevant processes. While the goal to generate new knowledge is inherent to citizen science (as otherwise it would not qualify as science), educational goals and the goal to empower citizens are also key aims of many citizen science projects. The relative importance of these three goals within citizen science projects has, however, not yet been investigated systematically.

People that have a managing or coordinating function in citizen science projects play a key role in shaping this rapidly expanding field and realizing its potential for science, education and social transformation. Therefore, in this study we asked: (i) What relative importance do managers of citizen science projects attribute to the goal of creating new knowledge versus educational goals versus the goal to enable civic participation? (ii) How are these goals reflected within the structure of citizen science projects? Furthermore, we wanted to assess the potential of citizen science to become more broadly implemented. To this end, we investigated: (iii) What are the challenges and needs that arise during existing citizen science projects? (iv) What are barriers to and needs for the establishment of future projects and the involvement of institutions and organisations that are currently not engaged in citizen science?

To answer these questions, we conducted a quantitative web-based survey among 143 experts from environmental education, science, and nature conservation. Based on our analyses, we explored fields of activity to overcome the identified challenges to fully harness the potential of environmental citizen science for generating knowledge, creating learning opportunities and enabling civic participation in environmental protection and conservation.

2. Material and methods

To systematically investigate the realized and unrealized innovation potential of citizen science, we conducted a web-based survey across Germany, Austria and Switzerland. We invited experts focusing on