Received: 25 January 2018 | Accepted: 13 August 2018

DOI: 10.1111/1365-2664.13279

POLICY DIRECTION

Journal of Applied Ecology | BRITISH ECOLOGICAL SOCIETY

Developing the global potential of citizen science: Assessing opportunities that benefit people, society and the environment in East Africa

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Funding information
British Ecological Society; Tropical Biology Association; Natural Environment Research Council

Handling Editor: Ailsa McKenzie

Abstract

1. Citizen science is gaining increasing prominence as a tool for science and engagement. However, despite being a potentially valuable tool for sustainable development, citizen science has little visibility in many developing countries.
2. We undertook a collaborative prioritisation process with experts in conservation and the environment to assess the potential of environmental citizen science in East Africa, including its opportunities, benefits and barriers. This provided principles that are applicable across developing countries, particularly for large-scale citizen science.
3. We found that there was great potential for citizen science to add to our scientific knowledge of natural resources and biodiversity trends. Many of the important benefits of citizen science were for people, as well as the environment directly. Major barriers to citizen science were mostly social and institutional, although projects should also consider access to suitable technology and language barriers.
4. *Policy implications.* Citizen science can provide data to support decision-making and reporting against international targets. Participation can also provide societal benefits, informing and empowering people, thus supporting the United Nations'

Sustainable Development Goals. In developing countries, innovation is needed to further develop culturally relevant citizen science that benefits participants and end users. This should be supported through regional networks of stakeholders for sharing best practice.

KEYWORDS
conservation: citizen science, Eastern Africa, monitoring, public engagement, science-policy, social capital, sustainable development

1 | INTRODUCTION

The world is increasingly facing rapid and dramatic change with the loss of habitats and species, and alteration of ecosystems, with detrimental impacts on people. Concern about this is highlighted through international treaties. For example, the United Nations Sustainable Development Goals (UN SDGs) seek to increase human wellbeing while ensuring environmental sustainability (UNGA, 2015). The Convention on biological diversity's Aichi biodiversity targets sought to reduce biodiversity loss with benefits for people (SCBD, 2010). It is vital to make progress towards these goals, and to assess progress.

Citizen science is the involvement of people in the scientific process, including participating in environmental recording and monitoring. It has a twofold role to play in supporting international agreements. First, an outcome of good citizen science is scientifically robust data, useful for environmental monitoring and assessing progress towards environment targets (Chandler et al., 2017; Danielsen et al., 2014). Second, the citizen science activity itself can be valuable for individuals and society (and their interactions with the environment) because undertaking, and participating in citizen science can increase social capital, support awareness raising, empower individuals and communities and inspire action (McKinley et al., 2015; Pretty & Smith, 2004; West & Pateman, 2017).

1.1 | Citizen science beyond the "western world"

Citizen science includes a diversity of approaches, but it is useful to distinguish between contributory approaches, in which people engage with activities designed by professionals, and collaborative approaches (also called participatory or community-based monitoring), in which potential participants are involved in defining the scope, purpose and methodology (Bonney, Ballard, et al., 2009; Danielsen, Burgess, & Balmford, 2005). Recent surveys have reported that the majority of environmental citizen science is "contributory" and most prevalent in North America, Europe and Australia (Bonney et al., 2014; Chandler et al., 2017; Pocock, Tweddle, Savage, Robinson, & Roy, 2017; Theobald et al., 2015). Currently, there is relatively little visibility of activities in developing countries, but they do occur: there are both contributory projects (e.g. recording plants in southern Africa;

TABLE 1 Summary of the questions asked to create and rank lists of the opportunities for, benefits of and barriers for citizen science in East Africa

Topic	Open question for gathering and refining the set of answers	Question for ranking within the set of answers	Linked to policy context (frameworks and targets)	Comments
Opportunities	What topics are suitable and important for citizen science activities in East Africa in the next 5 years?	Which topics would be most fruitful[a] for citizen science in East Africa in the next 5 years?	Aichi biodiversity targets; DPSIR framework	Participants considered measurable attributes of biodiversity and the environment
Benefits	What are benefits of citizen science in East Africa?	What are the most important benefits of citizen science in East Africa?	Aichi biodiversity targets; DPSIR framework	Including benefits for science (applied science and "blue skies" research), participants (direct and indirect benefits to individuals and communities) and society (including decision makers)
Barriers	What are barriers that limit the use of citizen science in East Africa?	Overcoming which barriers would have most impact on citizen science in East Africa?	Social capital	We considered where support would be beneficial, for example, resources (for personnel or infrastructure), strategic support or increased understanding (of issues or benefits)

[a]We defined "fruitful" as "achievable, useful and likely to be successful, considering current and new activities".

TABLE 2 Opportunities for citizen science in ecology and the environment in East Africa as ranked at a collaborative prioritisation workshop, and the targets they support

Rank	Opportunity[a]	Score from collaborative prioritisation[b]	Data can support[c]	
			Aichi biodiversity target	DPSIR causal framework[c]
1	Monitoring habitats and their change	25	5, 7, 12	SI
2	Monitoring species (including counting and census)	18	7, 12	SI
3	Fresh water quality and quantity	14	8, 14	PSI
4	Impact of development on wildlife and natural resources	12	5, 7	I
5	Distribution mapping of species	12	7	SI
6	Assessing habitat quality	11	5, 7, 8	SI
7	Natural resource mapping	10	5	PS
8	Natural resource utilisation (legal and incidental)	8	1, 3, 6, 14	P
9	Pollution	6	8	P
10	Productivity of food (includes pollination)	5	7, 14	I
11	Detecting invasive species	4	9	P
12	Illegal resource use	2	6	P
13	Human-wildlife conflict	2	3	PI
14	Understanding potential for citizen science	2	1, 19	—
15	Documenting indigenous local knowledge	1	18	—

[a]Full wording, as agreed by workshop participants, listed in Appendix S3. [b]Sum of the ranks from individuals, where their top priority was scored three, second scored two and third scored one. The area of the circle is proportional to the score. [c]Classification made after the workshop. Aichi biodiversity targets are listed in Appendix S4. DPSIR categories (European Environment Agency, 2010): D: Driver; P: Pressure; S: State; I: Impact; R: Response.

Hulbert, 2016), and participatory monitoring projects (such as reviewed by Danielsen et al., 2005; Chandler et al., 2017). There are also activities with international reach that are: field-based, for example, iNaturalist (https://www.inaturalist.org/), eBird (https://www.ebird.org), iSpot (https://www.ispotnature.org/) and the EarthEcho Water Challenge (http://www.monitorwater.org/); and online, for example, identification of mammal species from camera traps (Swanson et al., 2015).

1.2 | Collaborative prioritisation of the potential of citizen science in East Africa

Here, we undertook a systematic assessment of the potential for citizen science in East Africa; the first such assessment outside of developed countries. In June 2016, we held a conference in Nairobi, Kenya, entitled "Unlocking Africa's potential for citizen science" for 49 delegates from Kenya, Uganda and Tanzania (Appendix S1). Following this, 22 people (Appendix S2) participated in a 1-day workshop. The workshop participants (authors of this paper) are experts in conservation and natural resource management and were drawn from government, non-governmental organisations and research organisations/academia in Kenya, Uganda and Tanzania (henceforth termed "East Africa"). Therefore, they mainly (but not exclusively) represented institutional users of environmental data and tended to consider large-scale (e.g. "contributory") citizen science activities, but some also had practical experience working with communities for environmental monitoring. Our objectives were to identify and prioritise the (a) opportunities for, (b) benefits of and (c) barriers to citizen science and to show how these are related to policies for sustainable development (Table 1). The remit of this assessment was all East Africa, the whole environment (air, land and water, as well as biodiversity), and with emphasis on outcomes within 5 years. We used a collaborative prioritisation approach, which is useful for collating expert opinions (Sutherland, Fleishman, Mascia, Pretty, & Rudd, 2011) and ranking issues (Pocock et al., 2015).

Our workshop had two parts. First, we identified the key opportunities, benefits and barriers for citizen science in East Africa. We undertook initial consultation with conference attendees, and then refined the lists and their wording through discussion at the workshop

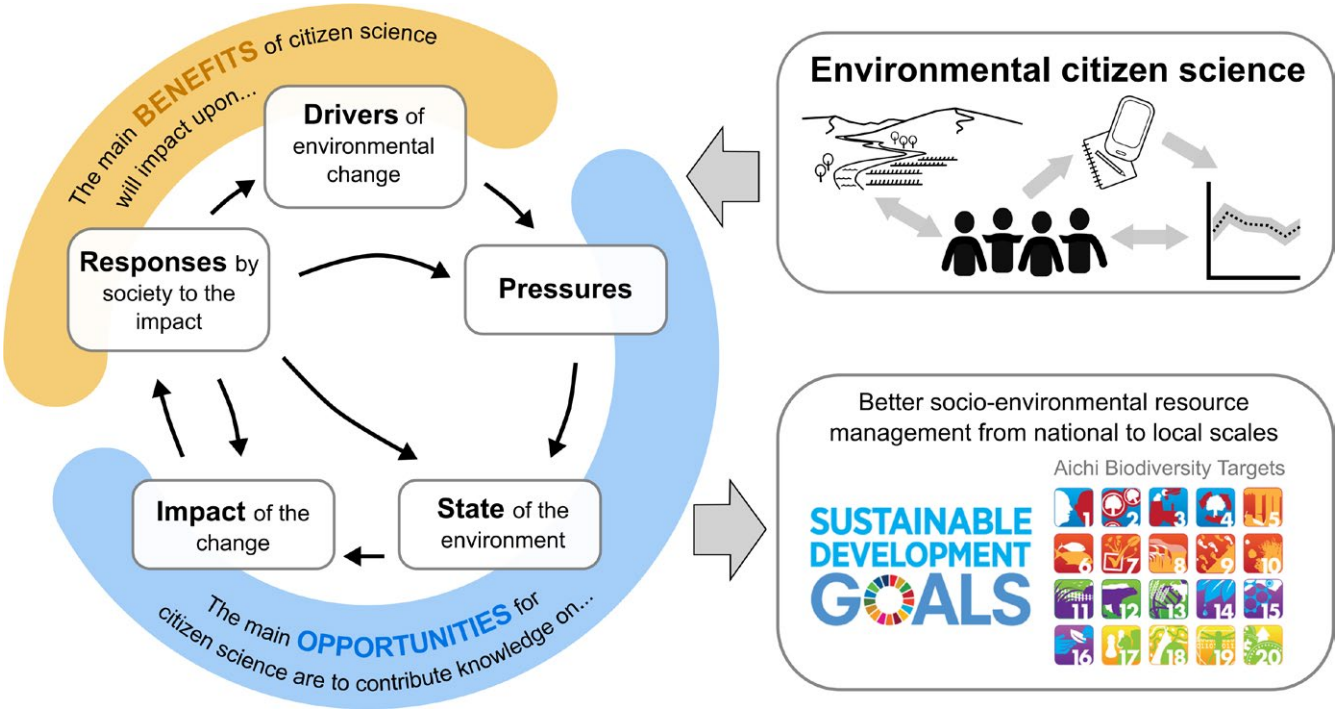

FIGURE 1 The opportunities and benefits of environmental citizen science could support knowledge and action across the DPSIR causal framework of interactions between people and the environment, in line with international goals, as established through our workshop on citizen science in East Africa. Icons: United Nations Sustainable Development Goals: copyright UNIC; Aichi biodiversity target icons: used with permission, copyright BIP/SCBD

(Table 1). Second, we used anonymous voting to rank these opportunities, benefits and barriers to support future decision-making about citizen science. The overall ranks were unanimously accepted at the workshop. After the workshop, we classified items on each list according to their policy context (Table 1) considering Aichi biodiversity targets (SCBD, 2010) and the DPSIR (Drivers, Pressures, States, Impacts and Responses) framework (Smeets & Weterings, 1999).

1.3 | The opportunities for citizen science

We identified 15 specific opportunities for citizen science in East Africa (Table 2) including subjects for which there were already successful citizen science projects in the region (e.g. distribution mapping of birds and mammals) and novel subjects (e.g. natural resource mapping). These would help assess progress towards 11 of 20 of the Aichi biodiversity targets (Appendix S3). We concluded that the most fruitful opportunities for developing large-scale citizen science in East Africa over the next few years would be monitoring habitats, species and freshwater. This would provide valuable information on environmental States (including natural capital assessment, mapping of natural resources and species), thus supporting conservation assessments. By collecting data across time or space, citizen science could also provide information on Impacts, that is, measures of change due to pressures (Table 2; Figure 1; Danielsen et al., 2014). Specific activities could also assess Pressures (e.g. utilisation of natural resources or pollution). Other relevant opportunities for citizen science, that is, human health and disaster relief, were outside of our remit.

1.4 | The benefits from citizen science

Our top-ranked benefits of citizen science in East Africa were a mix of social benefits, that is, increasing people's awareness and empowering young people (see also Conrad & Hilchey, 2011) and the provision of data, which can lead to better and more effective action (Table 3). This means that citizen science could have most influence on the societal responses to, and the drivers of, environmental change (Figure 1; Table 3), thus supporting the UN SDGs and Aichi biodiversity targets to "mainstream biodiversity". We identified many different beneficiaries of citizen science: including participants in citizen science, communities, decision makers and data users. We concluded that these beneficiaries were inter-dependent, and should all be included in the design and delivery of citizen science, rather than being involved independently. This would ensure the design and delivery of citizen science is collaborative rather than "top down".

1.5 | The barriers to the increased use of citizen science

The current barriers to citizen science that we ranked highly were mostly about people and institutions, so requiring social solutions, rather than concerns of data quality or coverage (Table 4). Institutional-level barriers (e.g. organisational capacity, perceived value of data and staff member's awareness of opportunities for citizen science) were regarded as especially fruitful to resolve, although this could have been influenced by institutional backgrounds of the workshop participants. Some additional barriers ("structural": access

TABLE 3 Benefits of citizen science in ecology and the environment in East Africa as ranked at a collaborative prioritisation workshop, and the targets that they support

Rank	Benefit[a]	Score from collaborative prioritisation[b]	Benefits	Data can support[c]	
				Aichi biodiversity targets	DPSIR causal framework
1	Increased awareness of conservation and the environment by individuals, communities, media, NGOs and governments	44	Social	1, 4	R
2	Enhanced data collection, including coverage, resolution (spatial, temporal and taxonomic), accuracy and inter-disciplinarity	22	Data	1	PSI
3	Creating next-generation conservation leaders and champions	15	Social	1	R
4	Improved conservation action leading to better environment including ecosystem function, ecosystem services and resilience	13	Data	1, 2, 4	D
5	Improved wellbeing and livelihoods through connection to (and consequent ownership of) nature and sense of belonging	7	Social	1	R
6	Increased ability to leverage funds and enhance sustainability through cost-effectiveness	6	Data	4	DR
7	Enhanced capacity and empowerment of all stakeholders in conservation, leading to action	6	Social	1, 2, 4	DR
8	Greater ownership through involvement at every stage, including motivations for monitoring and action, increased trust, tolerance and attitudes to nature	5	Social	1, 2, 4	DR
9	Wider user of data, including appropriate dissemination which improves accessibility of data and understanding	4	Data	2	SI
10	Widening perspectives through better integration of indigenous knowledge and reflections from participants	4	Social	1	R
11	Widens participation to all stakeholders (not just elites)	3	Social	1, 2	DR
12	Developing and enhancing skills sets, including organisation and science	3	Social	1, 4	R

[a]Full wording, as agreed by workshop participants, listed in Appendix S3. [b]Score as defined in Table 2. [c]Classification made after the workshop. Description of categories as in Table 2.

to technology, uneven spatial distribution of participants, literacy of participants and language barriers) could be tackled with appropriate project design.

2 | RECOMMENDATIONS FOR REALISING THE POTENTIAL OF CITIZEN SCIENCE IN DEVELOPING COUNTRIES

Our findings were directly applicable to East Africa, but have relevance elsewhere. We make three recommendations for citizen science in developing countries, in addition to existing principles for best practice in citizen science (e.g. Bonney, Ballard, et al., 2009; Bonney, Cooper, et al., 2009; Tweddle, Robinson, Pocock, & Roy, 2012; ECSA, 2015).

2.1 | Develop projects for the needs of multiple stakeholders

We concluded that citizen science has many different beneficiaries (Table 3), and so recommend that funders, data users, policymakers, communities and participants should all be involved in the development of projects. This will ensure that the data are useable (scientifically rigorous) and useful. But for activities to be successful and sustained, local participants need to be involved from inception to implementation of each project, so that it meets their needs and motivations (Participatory Monitoring and Management Partnership [PMMP], 2015). The involvement of all beneficiaries is necessary to address the drivers of and societal responses to environmental change (Figure 1; Danielsen, Burgess, Jensen, & Pirhofer-Walzl, 2010).

2.2 | Develop projects that are locally relevant

One of our key findings was that the barriers to and benefits of citizen science were predominantly social. This emphasises that each citizen science activity takes place within a specific social context (e.g. cultural and technological), which must be considered for activities to be successful (Conrad & Hilchey, 2011; Loos et al., 2015). Context will vary across the world: there is a culture of contributory citizen science in western countries as "serious leisure" volunteering for personal enjoyment and to "help nature" (Haklay, 2013; reviews in Geoghegan, Dyke, Pateman, West, & Everett, 2016), but attitudes towards "volunteering"

TABLE 4 Barriers to citizen science in ecology and the environment in East Africa as ranked at a collaborative prioritisation workshop, and the type and target of solutions for these barriers

Rank	Barrier	Score from collaborative prioritisation[a]		Type of solution[b]
1	Limited awareness of opportunities	23	●	Social: institutions + participants
2	Limited organisational capacity, including planning, leadership and coordination	19	●	Social: institutions
3	Lack of interest	13	●	Social: participants
4	Lack of appreciation of the value of citizen science from decision makers	13	●	Social: institutions
5	Limited access to the right technology, including access to the Internet and mobile coverage	13	●	Structural
6	Lack of skilled participants	11	●	Social: participants
7	Limited networking and collaboration	11	●	Social: institutions
8	Inadequate funding	7	●	Social: institutions
9	Uneven distribution of citizen scientists	6	●	Structural
10	Limited incentives (financial or other)	6	●	Social: participants
11	Cultural barriers to participation	3	●	Social: participants
12	Limited confidence and trust among participants	2	●	Social: participants
13	Data/information not fit for purpose	2	●	Social: institutions
14	Site accessibility	2	●	Structural
15	Corruption and democracy in government and local communities	1	●	Social: institutions
16	Language barrier	0		Structural
17	Threat of adverse outcomes, including legal action	0		Social: institutions
18	Lack of understanding between sectors and stakeholders (and conflict of interest, including institutional competition)	0		Social: institutions
19	Limited access to reference sources, for example, field guides	0		Structural

[a]Score as defined in Table 2. [b]Classification made after the workshop.

vary culturally (Hacker, Picken, & Lewis, 2017). We (and others, including Danielsen et al., 2005) concluded that focusing on action towards solutions to environmental and societal problems could be especially important in developing countries. Access to technology, especially smartphones, facilitates participation in citizen science (Newman et al., 2012; Pocock et al., 2017) so the interconnected growth in Internet use and smartphone ownership in developing nations is noteworthy (Pew Research Center, 2016), but access varies across East African countries (e.g. smartphone ownership varies from 4% to 26%). This could constrain the use of existing technological solutions for citizen science (e.g. online databases, mobile applications and data visualisation tools) that have developed elsewhere. Cultural context and technological accessibility also varies between demographics: urban/rural, across incomes and between languages. It would be good to test whether large-scale contributory activities can be developed in East Africa that successfully motivate diverse audiences, or whether activities need to be targeted for (and designed collaboratively with) each demographic.

2.3 | Establish networks to share, collaborate and act strategically

Evaluation of our citizen science conference in East Africa (TBA, 2016) showed the benefits of this opportunity to interact with other practitioners. We recommend governments and NGOs fund regional networks of citizen science stakeholders (see Vogel, Bowser, & Brocklehurst, 2017; http://citizenscience.asia/). These should not only include funders and data users for greatest strategic impact, but also ensure that participants' values and motivations are represented. Such networks should link with each other internationally for two-way learning in innovation and evaluation.

3 | CONCLUSIONS

Our study shows that citizen science has great potential in East Africa, which is indicative of the global potential for citizen

science (Pocock, Chandler, et al., 2018). Sustained investment and commitment should be made available to overcome important social barriers (especially for institutions), to develop locally relevant approaches (including participatory approaches based around the needs of participants, not just institutions) and to support networks of practitioners. This will help the opportunities we identified to provide great benefits to nature, people and society.

ACKNOWLEDGEMENTS

The conference and workshop was financially supported by the British Ecological Society, with additional support from the Tropical Biology Association (TBA) and the Natural Environment Research Council via national capability funding to the Centre for Ecology & Hydrology. TBA staff gave organisational support. Authors have no conflicts of interest to declare.

AUTHORS' CONTRIBUTIONS

M.J.O.P., H.E.R., T.A. and R.T. designed and chaired the workshop; all other authors contributed to the workshop. M.J.O.P. led the writing of the manuscript. All other authors contributed to the drafts and gave final approval for publication.

DATA ACCESSIBILITY

Participant's scores are available via the Dryad Digital Repository https://doi.org/10.5061/dryad.v6028g3 (Pocock, Roy, et al., 2018).

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SUPPORTING INFORMATION

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

How to cite this article: Pocock MJO, Roy HE, August T, et al. Developing the global potential of citizen science: Assessing opportunities that benefit people, society and the environment in East Africa. *J Appl Ecol*. 2018;00:1–8. https://doi.org/10.1111/1365-2664.13279