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Review Article

Jewels of Africa: Citizen Science on the African Continent

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Abstract

In their recent publication entitled Diamonds on the Soles of their Feet, Goldin, et al.,[1] present a project on groundwater monitoring in the Hout Catchment, Limpopo. The title of the article captures the idea of wealth (democratisation of knowledge, water literacy, social justice) attributed to citizen scientists with their feet on the ground, gathering valuable information-in the case of their study-on groundwater levels and rainfall. Jewels of Africa takes up the idea of democratisation of knowledge and what we see as 'science of the people' within the context of the African Continent. We first present some background ideas on CS before defining CS and then, whilst acknowledging the vagaries of coming up with a CS definition, and the huge efforts made by the CS community to define CS, we offer a new and more simple working definition for CS. We then consider CS applications in general before giving nine examples within the African context. We look briefly at the potential of CS in East Africa before we make our contribution to debates around CS and propose ten guidelines which, we believe, complement the ten principles for CS proposed in 2015 by the European Citizen Science Association (ECSA) but which are pertinent when considering CS projects in a developing country context.

Keywords: Citizen science, Africa, transformative, Emancipatory, Citizen science guidelines

Introduction[1]

[1]Our study offers a review of selected CS projects in Africa. It has been based on a meta-analysis of secondary data rather than any original primary data. There are undoubtedly many additional citizen science projects and this 'list' of nine Jewels of Africa is by no means comprehensive. It draws heavily on authors writing in some selected regions in Africa (e.g. Ethiopia, Kenya, Malawi, Rwanda, Tanzania, South Africa). Undoubtedly there will be more clarity in the near future on citizen science activities in Africa following on from the first inaugural Citizen Science Africa meeting that was held on the 5th November 202, defining the shape and character of the Citizen Science Umbrella body. This inaugural meeting was housed within the School of Graduate Studies, Research and Extension at the United States International University Africa

In their recent publication entitled Diamonds on the Soles of their Feet, Goldin, et al., [1] present a project on groundwater monitoring in the Hout Catchment, Limpopo. The title of the article captures the idea of wealth (democratisation of knowledge, water literacy, social justice) attributed to citizen scientists with their feet on the ground, gathering valuable information-in the case of their study-on groundwater levels and rainfall. Jewels of Africa takes up the idea of democratisation of knowledge and what we see as 'science of the people' within the context of the African Continent. We first present some background ideas on CS before defining CS and then, whilst acknowledging the vagaries of coming up with a CS definition, and the huge efforts made by the CS community to define CS, we offer a new and more simple working definition for CS. We then consider CS applications in general before giving nine examples within the African context[2]. We look briefly at the potential of CS in East Africa before we make our contribution to debates around CS and propose ten guidelines which, we believe, complement the ten principles for CS proposed in 2015 by the European Citizen Science Association (ECSA) but which are pertinent when considering CS projects in a developing country context.

Background to CS

Over the past decade, an exciting trend has been recorded worldwide, with thousands of lay people providing as Hulbert [2] puts it many 'scientific eyes' from, in, and across different countries, becoming engaged in CS projects, through various modes and channels of collecting, commenting, transcribing and analysing data Tauginienė, et al., [3]. Pocock, et al., [4] undertook a comprehensive search for CS projects in ecology and the environment (land, water and air) finding that the majority of projects were focused on biodiversity (77%) and for most (93%) volunteer involvement was limited to what the authors define as contributing data, rather than collaborative or co-created project development. Concerns have been raised by Chandler, et al., [5] that when scientists do assimilate local ecological knowledge it is often within Western worldviews where there is a risk that it may further marginalize indigenous and local people.

In line with the findings from Goldin, et al., [1], Pocock, et al., [4] propose that an outcome of good CS is not only scientifically robust data, useful for environmental monitoring but that CS activity itself can be valuable for individuals and society (and their interactions with the environment). Undertaking and participating in CS endeavours can broker trust, support responsiveness, democratise knowledge, promote research integrity, social justice, empowerment and general feelings of emotional well-being such as pride, hope, dignity and feelings of belonging Goldin, et al., [1]. In considering the distinction that Pocock, et al., [4] draw between contributory or collaborative CS projects we find it more helpful to view CS projects on a continuum-moving from citizen scientists simply being 'collectors' to 'co-active' citizen scientists. It is most unlikely that the broader intrinsic benefits of CS engagement would flourish in instances where citizen scientists are simply collecting data but are not involved meaningfully in project design and interpretation of data, not only losing an opportunity to foster scientific literacy in the process but also diminishing the transformative potential that CS hass.

The central role of CS in many disciplines of academic research has been acknowledged by the Citizen Science Alliance (CSA)[3] , Oxford, which has almost 2 million volunteers and by the work of the European Citizen Science Association (ECSA), Germany, and other CS bodies[4]. CS permits the validation and classification of huge datasets that would otherwise be unmanageable, tackling widespread issues of social and environmental justice as well as questions about effective conservation practices Bonney, et al., [6]. As Bonney, et al., [6] claim, CS thus holds the potential for developing new ways to collectively solve big problems and to fundamentally change the relationship between science and society. Similar to the findings of Pocock et al., stated above, a survey of CS projects in Europe showed that more than 80% of current CS practice is confined to life and natural sciences and only 11% to the social sciences and humanities Hecker, et al., [7]. The underrepresentation of SSH may be due to several reasons. One of them is the stable and long-lasting bonds between CS and the natural sciences, with pioneer lay scientists mainly directing their interest towards the study of physical and natural phenomena by making use of positivistic methods of data collection and analysis Tauginiene, et al., [3]. However, the skew has repercussions in that it implies a notable bias towards 'collector' rather than 'co-active' endeavours.

[2] Presented in alphabetical order of authors writing about the study. Acknowledging the contribution of student Aqeelah Carrim who was working under the Graduate Employment Programme funded by the Water Research Commission

[s] See also Shirk, et al. (2012) [8] on public participation in scientific research

[3] Almost two million volunteers www.zooniverse.org

[4] For example the Australia Citizen Science Association. See also footnote one for information on Citizen Science Africa Association (CitSci-Africa)

Defining CS

The National Geographic Encyclopaedia defines CS as the practice of public participation and collaboration in scientific research to increase scientific knowledge. The British sociologist Alan Irwin defined CS in the mid 1990's as both a science which assists the needs and concerns of citizens and as a form of science developed and enacted by the citizens themselves. Irwin's definition foregrounds the necessity of opening up science and science policy processes to the public. Irwin sought to reclaim two dimensions of the relationship between citizens and science

a) that science should be responsive to citizens' concerns and needs and

b) that citizens themselves could produce reliable scientific knowledge Cavalier and Zachary [9].

The field celebrated a milestone when "citizen science" appeared in the Oxford English Dictionary in 2014 with the following definition: "the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists" Bonney, et al., [6].

Wehn et al., [10] go more deeply into the capturing and communicating impact of CS for policy using a story telling approach (CSISTA). Eitzel, et al., [11] on citizen science terminology matters and Haklay, et al., [12] draw attention to the proliferation of definitions and typologies. Wehn and Almomani [13] refer to the new roles involving citizens as data collection as community based monitoring (CBM) and information systems, also seen as citizen observatories. Wehn et al., [10] also reflect on the many forms, definitions and meanings of citizen science reminding us that while some definitions focus more on citizen science as a tool for collection and analysis of data (e.g. Oxford English Dictionary 2014), "others define it as a multi-stakeholder process that aims at increasing democratization of science and policy, scientific citizenship, public engagement, transparency, equity, inclusiveness and justice" Wehn et al., [10].

There is a complexity involved in the collection and analysis of the data, the commitment of the public, ideas behind what collaboration entails and what and how one defines a professional scientist. Within our groundwater monitoring work in the Hout Catchment, Limpopo Province, South Africa[5] we consider CS to be an approach whereby non-scientists are actively involved, to differing degrees, in the generation of new scientific knowledge, from which they also actively stand to benefit either intrinsically (e.g. increased scientific literacy) or extrinsically (e.g. increased social capital and improved well-being). However, we propose a far simpler definition of CS that captures the spirit of the flurry of CS definitions that have been offered thus far: citizen science is taking science from the laboratory into life, opening up science and science policy to the public, simplified even further to citizen science is taking science from the laboratory into life. This definition has been criticised for being oversimplistic and for its bias towards science but we believe, nonetheless, that it does capture the essence of many CS projects and that the notion of science is for us in sync with Lisa Thompson's [14] work on environmental security and her idea of a science of (and for) the people.

[5] Acknowledgements to the Water Research Commission (WRC) Pretoria for funding two projects in the Hout Catchment. The first is entitled CISMOL: Citizen Science Monitoring Groundwater in the Limpopo (WRC 2020/2021 00085) and the second, building on CISMOL is entitled POPLUC: Polycentricity, pluralism and citizen science: a nexus approach to water resources management (WRC 2020/2023 000413). These projects build on a DANIDA funded project in 2019 entitled Enhanced Sustainable Use of Groundwater (ESGUSA)

Citizen Science application

Some of the longest-running CS records in the world are from Japan. For example, the timing of cherry blossoms has been recorded in Kyoto for 1200 years, so long that they have been used in climate reconstructions Aono & Kazui [15]. Centuries- long phenology data also exist for other plant and animal species across Japan Primack et al., [16]. The study of Ivan and Margary [17] is also pertinent as it reports how many centuries ago, in 1736, Robert Marsham started recording 27 phenological events, such as first flowering, leafing and the appearance of migratory birds, for more than 20 common plant and animal species in his family estates in Norfolk. An impactful example is the work of the Entomological Society Krefeld, where the work of citizen scientists over the course of nearly three decades allowed tracing a 75% decline in biomass Hallmann, et al., [18]. SciStarter monitors active and non-complete projects and according to this source, there are currently more than 1500 CS projects globally that are registered and are active[6]. From these 1500 projects about 200 are CS projects that are practiced in Africa[7].

a) CSIR - Council for Scientific and Industrial Research

b) SANSA - S.A National Space Agency

c) SANBI - S.A National Biodiversity Institute

d) CREW-Custodian

Citizen Science application in Africa

Taking the definition of CS to be (people's) science-from the laboratory into life - we are faced with the challenge of selecting CS projects in Africa. How to decide which project would qualify as a CS project, if, as is the case with the Diamonds on the Soles of their Feet (DSF) there is the idea of wealth, education, social justice and in the case of DSF, better water resources management being achieved by (extra)ordinary citizens with their feet on the ground. If we consider these ideals, there are a myriad of valuable community projects where science and science policy is being taken up by the public and where non-scientists and community members are gathering valuable data that fills a void where, otherwise, data would not be available. Haklay, et al., [12] in their important article on contours of citizen science: a novel vignette study to understand the views and perspectives on what the authors found constituted citizen science, are acknowledging the need to further address the plurality and diversity of interpretations in the field of citizen science and as an opportunity for growth in the domain of CS for science innovation. The results of the vignette survey provided the foundation for the compilation of the ECSA characteristics of citizen science[8]. In order to solve the conundrum-of what does or does not constitute a CS project, we have agreed to only include projects where the authors themselves apply the concept of CS to their project and self-identify their work as an example of CS practice[9].

[6] Also see the Zooniverse which gives people of all ages and backgrounds the chance to participate in research with over 50 active online CS projects such as Sounds of New York (SONYC) based at New York University, involving a smart citizen sensor network with machine listening capabilities to identify and mitigate the sources of noise pollution in New York City.

[7] We thus acknowledge the many dozens of projects - taking science from the laboratory into life and opening up science and science policy to the public-that are not included in the selection of projects below. In South Africa alone, for instance, there is no exact number of recorded CS projects but many projects are being implemented through of Rare and Endangered Wildflowers 5) iNaturalist 6) rePhotoSA 7) Cape Citizen Science. Also the important project by Van Koppen et al., (2021) Operationalising community-led water services for multiple uses in South Africa (WRC Report No TT 840/20 for projects K5/2607 and K5/2609). See also footnote nine.

[8] See Haklay et al. 2020 explanation notes on ECSA's characteristics of citizen science, Zenodo. (doi:10.5281/zenodo.3758555)

[9] Such projects include (and this list is by no means exhaustive) the identification of new mushroom species in Kenya, the rescue of marine turtles in Cameroon, the South African Bird Atlas Project or the identification of plant pathogens in fynbos in the Cape Floral Region, the eradication of invasive species in Nigeria and the monitoring of the habitat of the shoebill population in the Mabamba Wetlands, Uganda, Alexander Gwanvalla's Cocoa Farm Development project in Cameroon, PROCOL Kenya [19] Understanding the Future of Agriculture in Elgeyo-Marakwet. See also Chingombe, et al. (2015) [20]. on a participatory approach in GIS data collection for flood risk management in Zimbabwe, Musungu, et al., [23], using multi criteria evaluation and GIS for flood risk analysis in informal settlements of Cape Town, and the many projects in South Africa listed in footnote six

Malaria prevention in Rwanda

Asingizwe, et al., [21] report that Rwanda has seen an eleven-fold increase in reported malaria since 2011. As the authors note, malaria prevention and control displays features of a 'wicked' public health problem, meaning that it is difficult to define the problem, it involves multiple stakeholders, is also influenced by very complex political and social factors, and it is a problem that although it might be managed, it is hard to solve. According to the World Health Organization (WHO), malaria is one of the most important parasitic and infectious diseases worldwide. As Asingiswe, et al., [23] claim, several studies have indicated that engaging citizens in malaria prevention and control interventions can stimulate their consistent and effective application. Their paper explores potential determinants of two of the most important malaria preventive measures: the use of Long-Lasting Insecticide-treated Nets (LLINs) and acceptance of Indoor Residual Spraying (IRS). In particular, in line with the President's Malaria Initiative of 2017, the authors state that Rwanda plans to support social and behavioural change communication strategies through the use of interpersonal communication, community radio with a focus on community mobilization and engagement in the use of LLINS and early diagnosis and treatment. However, the authors claim that to date no studies have been published that evaluate how the involvement of citizens in the monitoring of mosquito dynamics and malaria episode can be set up in an efficient way in rural areas of a country such as Rwanda. Asingizwe, et al., [23] present the key features of a CS platform that would be implemented in Ruhuha, a malaria endemic area in Rwanda. At the community level, social support, social pressure and social norms can influence the consistent and effective use of LLINs by community members. In Africa, IRS is among the primary malaria vector control interventions. According to Rickard, et al., [22], malaria interventions that are embedded in the community and that involve citizens allow more discussion and in-depth analysis on the benefits of those interventions and this would mean that there is more acceptance and use.

Through the use of CS, there could be the prevention and control of malaria, as this would help citizens identify and prioritize their own health concerns, whilst encouraging interaction amongst and between communities, whereby individuals of these communities are invited and facilitated to share their views by providing feedback on malaria prevention. Rwanda aims-and has plans-to support social and behavioural change strategies by using personal communication, as well as using the community radio which can focus on community deployment. This makes Rwanda a great place to test the application of a CS approach. In a CS approach like this one, the citizens who are participating are actively involved in the collection, and in a small way also the interpretation and analysis of scientific data. The study draws on information which is about mosquito nuisance, mosquito habitats, and the history of specific malaria episodes. The authors remind us that most research projects and studies which are being conducted involve workers within the health sector and not the general public. In this instance, Rwanda has implemented a country wide RapidSMS initiative, which permits community health workers to be actively involved in monitoring malaria incidence in children under the age of five. By using a CS approach, the monitoring of ecological changes is likely to be more effective and to be a consistent way to prevent and to control malaria by providing timely information.

[10] Water Research Commission project WRC K5-2854 authored by Sisitka, H, Ward, M, Taylor, J, Vallabh, P, Madiba, M, Graham, M, Louw A and Brownell, F (2022) [25] entitled Research into Alignment, Scaling and Resourcing of Citizen Based Water Quality Monitoring (CBWQM) to realizing the DWS Integrated Water Quality Management Strategy

The model coming out of this study is meant to guide future research based on behavioural and contextual factors, and may contribute and give rise to more effective and consistent use of malaria preventive and control interventions elsewhere. The authors claim that it is a missed opportunity to not involve the general public and community members in these type of projects, as in the end the community members are the receivers within the public health programs.

MiniSASS, scaling CS based water quality monitoring[10]

Graham, et al., [24] present a unique method for measuring pollutants in rivers. Reliable indicators of water quality and river health are often difficult and expensive to derive. Taking water samples to a local testing laboratory for testing further, distances the user from the resource and from having a potential engagement with the water quality issues. The authors report on a process to develop a low technology, scientifically reliable and robust technique to monitor water quality and river health in rivers and streams. A more rigorous method of biomonitoring is the South African Scoring System (SASS) but while it is a relatively simple technique for a trained practitioner, for the layman it is generally beyond reach because of the need to be able to identify up to 90 different aquatic invertebrate families that form the backbone of the technique. For this reason a miniSASS method was developed by the authors. The sites selected represented a range of water quality conditions all in KwaZulu-Natal (KZN), and had a relatively broad geographical spread, represented both large and small rivers and streams, and covered near pristine water quality to highly polluted waters. The total number of SASS taxa identified is counted and presented as an Average Score Per Taxon (ASPT). The authors claim that the results were encouraging and showed small differences between ASPT scores achieved by miniSASS and a full SASS4 analysis. This suggested that miniSASS warranted further development.

There were three principal geographical sources of SASS4 data that miniSASS was tested against representing the largest coverage of data where historical biological monitoring using SASS4 had taken place. Sistika, et al., [25] claim that potentially, every school, environmental/community group or NGO in South Africa could become a monitoring cell, and with this geographical spread, miniSASS could become a powerful tool providing an important 'red flag' for the identification of aquatic pollution sources and events. The parallel and supporting initiative is to be able to enter this biomonitoring data onto an internet web based mapping programme (see www.riverhealth.co.za). Globally aquatic ecosystems are highly threatened and concerted efforts by government and civil society to turn the situation around are not working. The authors consider enabling responses such as CS and co-engaged action learning as better alternatives.

As such the Stream Assessment Scoring System (miniSASS) enables members of the public to engage with water monitoring at a local level. The technique costs very little to implement and can be applied by children and scientists alike. As a bio-monitoring approach it is based on families of macro-invertebrates that are present in most of the perennial rivers around the globe. miniSASS is thus a simple tool which can be used by anyone to monitor the health of a river. Members of the public collect a sample of macroinvertebrates (small organisms large enough to be seen with the naked eye) from a natural river or stream, and depending on which groups are present, scientists can calculate a River Health Index for the river. This score helps classify the health, or ecological condition of the river, ranging across five categories from natural (blue) to very poor (purple). In order to assess the ability of miniSASS to act as a proxy for formal water quality monitoring programmes, miniSASS data were compared against data collected by the River Ecostatus Monitoring Programme

(REMP). Healthy rivers generally mean healthy people and by linking research processes to indicator species such as through miniSASS, one has a useful, and accessible tool, for public participation. miniSASS has much merit in engaging citizens in active and meaningful research that is real and applied[11].

Sanitary inspections in Malawi

Herschan, et al.,(2020) [26] consider the potential of CS for improving the reach of sanitary inspections (SI) in Malawi. The background to this work is an interest in the Sustainable Development Goal (SDG) 6 which is universal and equitable access to safe and affordable drinking water quality and sanitation, coupled with SDG 10, to reduce inequality. The authors are concerned that the achievement of these goals is lagging and acknowledge many reasons for the disparity in progress including the remoteness of access to small drinking-water supplies and the lack of technical and financial capacity for monitoring supplies. The World Health Organization (WHO) promotes the use of SI as an on-site assessment of risk. Despite the potential to increase the body of knowledge and information on supplies in a region, there has been limited research into the role of CS and SIs. To meet SDG targets, there is a need to improve the reach of SIs. Data gaps on safely managed drinking-water services urgently need to be filled to direct efforts to improve drinking-water services, to target those furthest behind, and to track changes in services over time.

[11] Hulbert (2016) [2] presents three CS tools (Ispot, WhatSpecies, and Virtual Museum) to be used in ecological research which have the potential to promote inclusive and participatory practices. These tools are more likely to be used in 'co-active' rather than 'collector' endeavours.

This study uses a mixed methods approach of quantitative on-site SI data collection and remote SI data collection via photographic images, together with qualitative data collection, collected by non-expert students, who are citizens of Malawi-as well as a panel of experts in the field of SI. Though WHO recommends that SIs should be carried out by "qualified individuals," a recent qualitative study, by Pond, et al., [27], discussed a main benefit of SIs to be their ease-of-use for lay people. SIs by potentially less qualified or inexperienced individuals are more likely to be undertaken at small drinking-water supplies, typically owing to a lack of available professionals to undertake these activities.

Herschan, et al., [26] explain the way that data were collected, in three sequential study phases, using 24 undergraduate students from the University of Malawi. A quarter of the students were majoring in Water Engineering, therefore indicating an interest in the broader topic of drinking-water. However, the collective limited experience of working with SIs, the diversity in personal and educational backgrounds and the voluntary nature of their participation qualified the students to be classed as members of the general public, thus participating as citizen scientists in this study-and the students were thus described as 'citizens.' SIs are encouraged by the WHO to identify hazards and risks to small drinking-water supplies. The interpretation of risk is an important factor when completing SI forms and can lead to variation in results even between professionals. The perception of risk is an inherent part of decision-making processes. In Herschan, et al's., [26] study, the perception of the existence of risk aligned well between citizens recruited to complete the forms regardless of their technical background and which degree subject they were studying. There was also similarity in the risk level responses between citizens. These results are encouraging and confirm that although the initial SI forms published by WHO in 1997 were intended for use by qualified individuals, with appropriate support and verification steps in place, including validation from more qualified individuals, it is possible for citizens to contribute to producing useable data[13].

The authors found it very encouraging that when the citizens and the experts were asked to undertake the SI remotely using an image of the borehole water supplies, results correlated well with both on-site and remote results from citizens and the expert's remote results. Generally, both the citizens and experts were able to answer questions which related to the borehole headworks and structure of the supply. The method was developed to be low cost, requiring little equipment, and to be useable by persons of low technical knowledge. The use of CS can thus help to overcome the personnel and resourcing issues which are commonly noted for small drinking-water supplies, whilst also offering a number of benefits especially where a sample of the inspections are verified by experts remotely.

Cardio-vascular disease (CVD) prevention

Okop, et al.,[28] work in four countries, Rwanda, Malawi, Ethiopia and South Africa. The rationale for their work is that sub-Saharan Africa (SSA) experiences a disproportionately high CVD burden and population-based screening and prevention measures are hampered by low levels of knowledge about CVD and associated risk factors, and inaccurate perceptions of severity of risk. This protocol describes the planned processes for implementing community-driven participatory research, using a CS method to explore CVD risk perceptions and to develop community-specific advocacy and prevention strategies in rural and urban SSA settings. Multi-disciplinary research teams in these four selected African countries will engage with and train community members living in rural and urban communities as citizen scientists to facilitate conceptualization, co-designing of research, data gathering, and co-creation of knowledge that can lead to a shared agenda to support collaborative participation in community-engaged science. Previous research by Okop, et al.,[28] has demonstrated that community health workers (CHWs) in four low and middle income countries were able to accurately screen members of the community for CVD risk using a simple risk assessment tool, and do so more efficiently with the aid of a mobile phone app. The primary aim of the current study is to explore CVD risk perceptions and develop community-specific advocacy and prevention strategies in rural and urban SSA settings. The study reflects participatory action research (PAR) using CS processes.

At the time of writing Jewels of Africa, the project has only just begun and initial engagement with the project teams has been undertaken in three of the countries (Rwanda, Malawi, and Ethiopia) following the approval of the research by the respective country ethics committees. The recoded participant's data from the EpiCollect database in all project communities will be harmonised, and pooled for joint analysis, for the purpose of providing a comparison of findings by countries and locations. The participant's data in the database comprises demographic variables (viz. country, location, age, and gender), recoded variables (and pictures) on general health risk, perceived CVD risk, perceived threat, communication/presentation of CVD risk, and health seeking behaviour. This proposed study is part of a larger project that aims to contribute to the development of evidence-informed policies and practices on screening approaches for hypertension, diabetes, and CVD risk in SSA. It is envisaged that using PAR and engaging citizen scientists will more effectively elicit lay understanding and interpretation of the concept of health risk, contributing to the production of more socially robust scientific knowledge around this question. The study also refers to the work by Asingiswe, et al.,[21] above on malaria in Malawi.

South Africa roadkill study

Research by Periquet, et al.,[29] is on the value of CS for roadkill studies as a South African case study. Roads impact wildlife through a range of mechanisms from habitat loss and decreased landscape connectivity to direct mortality through wildlife-vehicle collisions (roadkill). These collisions have been rated amongst the highest modern risks to wildlife. With the development of CS projects, in which members of the public participate in data collection, the authors claim that it is now possible to monitor the impacts of roads over scales far beyond the limit of traditional studies. However, up till now, the reliability of data provided by citizen scientists for roadkill studies remained largely untested. This study is a first of its kind to test the accuracy of roadkill studies using a dataset of 2,666 roadkill reports between 2011 and 2014 on national and regional roads in South Africa (total length of 170,000km) over a three year period.

The study compared the data which was provided by two groups of citizen scientists across South Africa of which (1) those who work in the zoology/conservation sector (who were termed "regular observers" assumed to be more accurate due to their experience and knowledge within the field), and (2) others termed the "occasional observers" where reports then needed further verification by experts. Along the same section of the N3 highway (431km) the results suggest that data collected by ad-hoc CS (i.e., occasional reporters), can be as accurate as those obtained by trained or informed reporters in terms of broad spatial patterns and species identification. However, the one difference was that the occasional observers were more likely to recognise the more easily identifiable and charismatic species compared to the regular observers or the road patrols. The article concluded that CS can indeed provide reliable data based on roadkill studies associated with identifying general patterns and high-risk areas where usually it would be impractical and very costly when trying to collect data using the standard data collection methodologies. The analysis of these authors demonstrates that the assumption made by Batini and Scannapieca [30] that we target only "educated citizens" for the collection of roadkill data, appears to be unnecessary. The study demonstrates that ad-hoc CS has the potential to map roadkill occurrence and identify hotspots in a reliable and robust manner compared to that of trained road patrols and informed reporters.

Snapshot Serengeti

Swanson, et al.,[31] describe their project entitled 'Snapshot Serengeti' which involves high frequency camera trap images of 40 mammalian species. The camera traps were used to address large-scale questions in community ecology by providing systematic data to evaluate spatial and temporal inter-species dynamics. Over the last 20 years, camera traps-remote, automatic cameras-have revolutionized wildlife ecology and conservation and are now emerging as a key tool in the broader disciplines of behavioural, population and community ecology. Historically, cameras had been used to document the presence of rare species in understudied protected areas or to estimate densities of individually identifiable animals. The advances in digital technology that Rowcliffe, et al., [32] in Swanson, et al., [31] report have increased capacity while lowering prices, resulting in a dramatic increase in the number and diversity of camera trap studies. While traditional analytical approaches for camera trapping data require individually identifiable animals, recent developments have allowed the expansion of camera trap inference to multiple 'unmarked' species. Camera-trap surveys are increasing in popularity and scope, they can produce overwhelming large amounts of data, highlighting the need for efficient image processing techniques. Snapshot Serengeti implemented a camera survey to evaluate spatial and temporal dynamics of large predators and their prey in the Serengeti National Park (SNP) which is the core of a 25,000 km^2 savannah ecosystem that straddles the Kenya-Tanzania border in East Africa. The cameras operated continuously from 2010 and accumulated 99,241 camera-trap days, producing 1.2 million sets of pictures by 2013. Members of the general public classified the images via the CS website www.snapshotserengeti.org. Multiple users viewed each image and recorded the species, number of individuals, associated behaviours and presence of young. The Serengeti is dominated by the annual migration of the combined 1.6 million wildebeest and zebra that follow the seasonal rainfall onto the nutrient rich plains. Every image set was circulated to multiple users to improve data accuracy . There was a contribution from more than 28,000 registered users and 40,000 unregistered users who together contributed 10.8 million classifications for the 1.2 million image sets. Snapshot Serengeti partnered with the online CS platform Zooniverse (www.zooniverse.org) to develop the Snapshot Serengeti website (www.snapshotserengeti.org), an online interface where the general public helps process camera trap data .

On the Snapshot Serengeti interface, volunteers identify species in each image set, count the number of individuals, classify behaviour, and indicate the presence/absence of young. For image sets that contain more than one image, volunteers initially see the second image in the set and can toggle between images or use the 'play' feature to animate the images. A task flow feature was designed to help guide people with no background knowledge through the process of identifying the animal(s) in question from 48 possible species and species groups while still providing a rapid route to classification for more knowledgeable participants. Five researchers with extensive wildlife identification experience classified 4,149 randomly selected image sets containing animals using the Snapshot Serengeti interface: 263 image sets received two expert classifications and 8 image sets received three, for a total of 4,428 classifications. The experts noted whether any image sets were especially difficult or whether they thought the image was identifiable at all.

Baobab tree and flower visitors

Taylor, et al.,[35] used a CS framework to monitor baobab tree and flower visitors from dusk till midnight at 23 individual baobab trees over a period of 27 nights during the flowering seasons (November-December) of 2016 and 2017 in northern South Africa and southern Zimbabwe, reporting about 1 650 visitors. The African baobab, Adansonia digitata, is widespread on mainland Africa, occurring throughout most of west, east and southern Africa in a variety of habitats from deserts to subtropical forests and in diverse landscapes including rocky ridges, plains, river valleys, and human-modified landscapes such as fields and villages. As long-distance fliers capable of carrying large pollen loads, bats should be effective pollinators and central to reproductive success in many populations. The possible absence of an important pollinator raises concerns about the vulnerability of the baobab population in southern Africa and the impact this could have on people who rely on baobabs for their livelihoods. Baobabs provide an important source of food, fibre and medicine, and in recent years, the increase in global demand for the fruit powder and seed oil has allowed thousands of African people to earn an income from harvesting the fruit. In order to obtain quantitative observations about nocturnal baobab flower visitors in southern Africa, and specifically to try to answer the question whether fruit bats pollinate baobabs in southern Africa, citizen scientists were recruited (including researchers, students and the wider public) through a public project termed the "Baobab Blitz."

The data were obtained by guiding participants (usually two or more in a group) to use a standard datasheet and to spend at least one night (from 18:00 to midnight) at a flowering baobab tree. In total, over the 2016 and 2017 flowering periods, during 117 hours of observations, 575 baobab flower visitors and 1076 baobab tree visitors were recorded. In order to test for possible biases due to year (2016 or 2017), observer expertise (experts such as students and researchers versus non-academics) and weather (fine or "bad", with bad defined as strong winds and/or rain), the authors conducted generalized linear models to test these predictors against each response variable (moth visitors to trees and flowers, bat visitors to trees and other visitors to trees and flowers).

Taken together, the data starkly indicate an absence of fruit bat visits to baobab flowers in southern Africa, compared to frequent visits by moths. Another possible reason for low bat visits may be differences in baobab flower scent between different regions of Africa. Baobab flowers in West Africa have been described as having an unpleasant sulphurous smell which is typical of bat-pollinated flowers. Conservation efforts should focus on conserving the moths and ensuring that there are no negative impacts on the moths, such as the use of chemicals or protecting other species that the moths need in their life cycle. Thus, these results are of importance to policy makers and resource managers ensuring that management decisions take into account the importance of these pollinators.

Reconstituting flood events

Sy, et al., [36] present a case study which is located in Yeumbeul North (YN), Senegal, where flood impacts represent a growing concern for the local community. As the authors claim, there is no catalogue of past flood events available for the Dakar region, and they investigated the potential of citizen science in the retrieval of this information. In 2017 the authors developed a framework combining different participatory approaches together in the field of citizen science. In selecting the citizen scientists three criteria were applied, whether or not the person had witnessed three flood events in 2005, 2009 and 2012, whether or not they would have a good spatial knowledge of the floods and the study area and thirdly, that the person should have social standing. The objective of this work is twofold:

a) retrieve flood extents and water depths for different past events and

b) determine whether citizens can clarify the causal chain of flood events. The authors also assessed the reliability of these data by comparing them against independent methods, such as remote sensing.

Their study shows the potential of citizen science in retrieving quantitative and reliable information on past flood events, especially in areas where no or few records of past events are available. The integration of local knowledge together with remote sensing shows that this can improve data, when satellite images are covered by clouds and also yield new or more accurate information in terms of hazard intensity, exposure and location of key infrastructures.

Sy, et al., [36] have an investigation strategy that involves two different groups of citizens and increases the reliability of the obtained data. They used a two-stage approach to optimise the validity and reliability-and utility-of the data collected where they interviewed chiefs in 82 neighbourhoods using a qualitative face to face interview technique that draws on episodic memory. According to the authors, episodic memory is the process by which humans remember events in context (date, place and emotional state). This was to transform memories of past floods into temporal and spatial information. They also used participatory hands on mapping and where citizens were unfamiliar with mapping processes, they were trained how to read a map and locate themselves. The authors claim from their study that provided that the functioning of the society subject to floods is well understood, such an approach can be replicated in other parts of the world. Moreover, the citizens that have been involved in the various steps of this project have developed skills in flood data acquisition and an understanding of flood processes which means that they can thus better integrate into a decision-making process regarding flood risk.

Small mammal monitoring program (SEMICE)

Torre, et al., [37] analysed how volunteer experience influenced results of a small SEMICE based on a standardized trapping design. All volunteers, as well as scientific and technical coordinators, uploaded trapping information from February 2016 onwards, when the web of the project was made operational. At present, complete information is available from the four trapping campaigns performed between spring 2016 and fall 2017, involving 64 sampling stations (42 operated by volunteers and 22 by professionals). The authors considered extensive verification and provide a unique understanding of accuracy in reporting of volunteers- compared to professionals. Aptitudes of people involved in the SEMICE program were classified considering their experience according to the number of sampling sessions they have carried out from 2008 to 2017. Torre, et al., [37] considered non-experienced people those who carried out 1-3 sampling sessions, people with intermediate experience those who carried out 4-16 sampling sessions, and experienced people those who carried out more than 17 sampling sessions. Establishing sex and sexual conditions in shrews and rodents offers additional information to model and interpret their population dynamics and demography. The authors refer to the work of Newman, et al., [38] who recognise that accurate training and use of standardised methods are crucial to the success of volunteer surveys. However, data collected by volunteers still can be biased so that it is essential to assess the quality of the information collected and the influence of experience on this quality. The data collected by volunteers was of high quality at the quantitative level (i.e., providing unbiased and accurate information on species abundance), but low at the qualitative level (i.e. providing less information than professionals for some biological traits of individuals). Volunteers' work increased the number of monitoring sites. Hence, the SEMICE protocol and probably other similar protocols based on standardized trapping schemes, can be used as a monitoring program based on CS. This result encourages the launch of volunteer based monitoring projects for small mammals, and provides a standardized method for checking their accuracy.

Potential for CS in East Africa

Pocock, et al., [39] assess the global potential for environmental CS but focus their work on the relevance of CS in East Africa. A systematic assessment based on the potential for CS in East Africa was, according to the authors, the first such assessment outside of developed countries. The CS project started with a conference in Nairobi, Kenya in June 2016, entitled "Unlocking Africa's potential for citizen science" with 49 delegates from Kenya, Uganda and Tanzania. Following this, 22 people participated in a one day workshop. They mainly (but not exclusively) represented institutional users of environmental data and tended to consider large-scale (e.g."contributory")[14] CS activities, but some also had practical experience working with communities for environmental monitoring. The workshop participants identified 15 specific opportunities for CS in East Africa including subjects for which there were already successful CS projects in the region (e.g. distribution mapping of birds and mammals) and novel subjects (e.g. natural resource mapping). The participants concluded that the most fruitful opportunities for developing large-scale CS in East Africa over the next few years would be monitoring habitats, species and freshwater. The top-ranked benefits of CS in East Africa were a mix of social benefits, that is, increasing people's awareness and empowering young people and the provision of data, which can lead to better and more effective design and delivery of CS as collaborative rather than top down. The important benefits of CS were seen for people, as well as the environment. One of the key findings is that the barriers to and benefits of CS were mostly social and institutional. Pocock, et al., [39] earmarked policy implications which indicated that CS is able to provide data which can be used to support decision-making, as well as reporting against international targets. The authors conclude that participation can be used to provide societal benefits, by empowering and informing people. In the developing countries, there is a need for new innovation to help and develop culturally relevant CS which will benefit the participant, as well as the end users. The three recommendations put forward by the authors are

1) develop projects for the needs of multiple stakeholders
2) develop projects that are locally relevant and
3) establish networks to share, collaborate and act strategically[15].

[12] See also Willi, et al. (2018) [33, 34] who assess the accuracy of deep learning in classifying camera trap data, investigate how to process datasets with only a few classified images that are generally difficult to model and apply a trained model on a live online CS project. They confirm the finding of Swanson, et al. (2015) [31] that Snapshot Serengeti had an aggregated accuracy of 96.6.

[13] Projects worth noting as part of the Zooniverse CS efforts in Africa include

Chimp & See-https://www.zooniverse.org/projects/sassydumbledore/chimp-and-see

Power to the People-https://www.zooniverse.org/projects/alycialeonard/power-to-the-people

WildwatchKenya-https://www.zooniverse.org/projects/sandiegozooglobal/wildwatch-kenya

Elephant Expedition-https://www.zooniverse.org/projects/anabellecardoso/elephant-expedition

Parasite Safari-https://www.zooniverse.org/projects/gtitcomb/parasite-safari

Proposition for ten guidelines for CS in a developing country context

We argue that the full potential of CS in Africa lies in its ability to promote social justice, equity and to democratise knowledge with its transformative potential. Most citizen science participants today are involved in scientist-driven, contributory projects, as identified by Bonney et al., (2009) and Shirk, et al., [8], using citizens in the traditional form of data collection. The results could indicate that researchers see citizen science participants, for instance in South Africa, merely as unpaid 'hired hands' Weingart and Meyer [40]. Of the nine projects we have presented above, about half engage with citizen scientists as collectors only whilst in the case of the Other half, citizens are both collectors and co-active. In an endeavour to define a set of criteria that indicate citizen science and its emancipatory potential-achieving social justice, equity and democratisation of knowledge-we propose that these ten guidelines are helpful[16]. The ten guidelines apply to our own work (see Goldin, et al., [1] but we consider them to be critical ingredients for any meaningful 'co-active' CS undertaking. These are particularly pertinent for developing countries where disparities in terms of knowledge acquisition, socio-economic privilege and/or gender and racial bias are most prevalent (Figure 1).

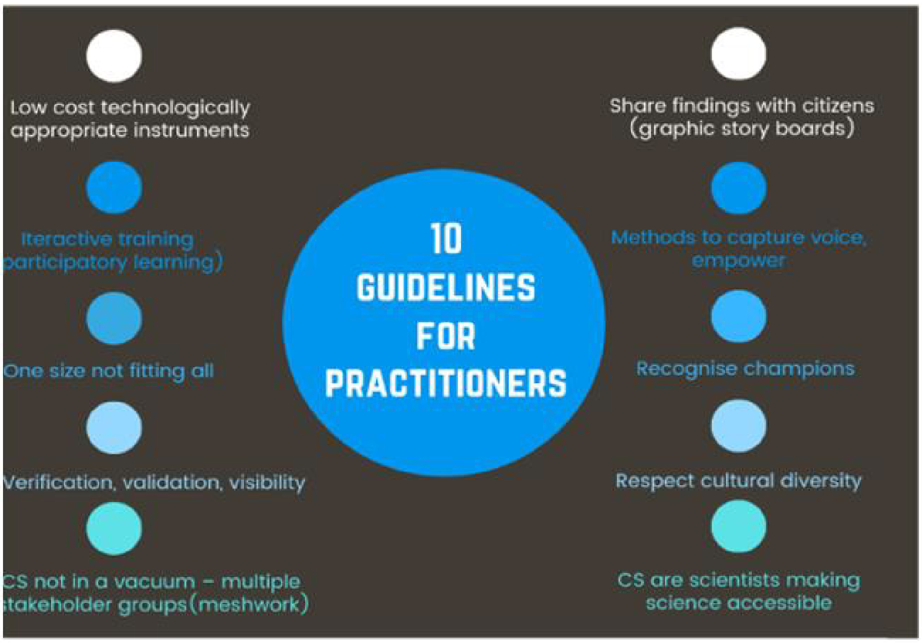

Figure 1:

The proposition for guidelines (see schema above) are

a) low cost, technologically appropriate instruments-this also matters for the sustainability of the project so that if an instrument were to break it could be replaced at low cost.

b) iterative training with an emphasis on ongoing training using participatory tools to engage meaningfully with citizen scientists-once off training might work for data collection but not for co-active citizen science.

c) one size does not fit all-attention to diversity and difference to address potential imbalances due to poverty, power or privilege.

d) verification, validation and visibility of data, with experts cross checking and preserving integrity of scientific findings-also ensuring visibility of findings, reading and interpreting graphs in collaboration with those who have gathered the data in the first place.

e) inclusivity of multiple stakeholder groups bearing in mind that citizen scientists do not operate in a vacuum -extending the idea of 'meshwork' and entanglements with multiple stakeholders where new knowledge is explored, shared, made accessible.

f) Sharing findings with citizens-one method we propose is the storyboard which fits well with the spirit of participatory processes, co-learning and research integrity-what we have elsewhere Goldin, et al., [1] referred to as the feminist ethics of care. Graphic facilitation with tools such as story boards is, we believe, a powerful art form to convey 'science' (where science and art 'collide') and to share key project findings and information from workshops.

g) methods are critical and to broker trust and in the spirit of democratising knowledge, we open up a toolkit that includes participatory methods (such as the knowledge café, river of life, stories of change, participatory monitoring and evaluation and participatory mapping)[17] which we see as part of 'authentic' learning and emphasise again the opportunity for science and art to meet.

h) champions are relevant, implying the recognition of the agency of volunteers and reminding us that citizen scientists are not a homogenous group allowing for some citizen scientists to become 'champs' taking on an important role in upscaling CS efforts and standing out as experts who can become trainers themselves.

i) attention to cultural diversity means not only recognising differences in gender, age, education (demographics) but the various subjectivities of interested or/and affected parties, again in line with feminist philosophers such as Nancy Fraser [42] Iris Young [43], Suransky and Alma [44] or/and Bozalek, et al., [45] and in the spirit of an ethics of care-respect and recognition of particular subjectivities, preferences, beliefs and values. And finally principle.

j) is to bolster the notion that citizen scientists are making science accessible and that CS projects find themselves on a continuum within some instances CS being purely 'collector' and at the other end of the spectrum being 'co-active' (what the same authors call collaborative projects). Guideline 10 emphasises the value of science beyond the laboratory where citizen scientists are enabling science and making it accessible to the public. For us this goes beyond simply data collection but on the continuum is much closer to contributory opportunities for citizen scientists.

Conclusion

As Pocock, et al., [39] remind us, there is relatively little visibility of CS activities in developing countries. Where they do occur they are more likely to be 'collector' rather than 'co-active' projects. We confirm that current CS practice is largely confined to life and natural sciences and not the social sciences and humanities. This is true for all nine projects that we have presented in our review. As the tendency in the life and natural sciences is to pursue knowledge from a positivist paradigm, it is not surprising that the impulse is to capture tangible goods (the data) rather than build on intangible or invisible assets (human well-being). However, despite this inclination, there is a potential to promote science awareness and capitalise on opportunities to democratise knowledge. In our review of the nine CS projects in Africa[18], we have four which are 'collector' Periquet, et al., [46], Swanson, et al., [31], Taylor, et al., and Torre, et al., [37] and five which could be classified as being 'co-active' Asingiwe, et al., [21], Graham, et al., [24], Herschan, et al., [26], Okop, et al., [28] and Sy, et al., [36] [47]). We propose, alongside Pocock, et al., [39], that there is not only space, but an urgent need, for future CS projects in Africa to become more co-active. We also note the significant attention paid to verification and validation of results with Periquet, et al., [29] reminding us that it is not only 'educated' citizen scientists who can give reliable data and verification by experts in the case of Swanson, et al., [31] in the Snapshot Serengeti project, confirming over 96% accuracy. Herschan, et al., [27] also contest the WHO's recommendation that only qualified individuals carry out data collection, in this case sanitation inspection. Extensive verification is provided by Torre, et al., [37] with a unique understanding of the accuracy in reporting by volunteers in the small mammal identification project, mimicked too in the study by Okop, et al., [28] on cardio-vascular disease and Sy, et al., [36] on their work on flood assessment, confirming that citizen scientists relay accurate data. Graham, et al., [24] also report very small differences between the miniSASS general public reporting and conventional SASS methods.

CS has a great potential for the democratisation of knowledge, achieving scientific literacy, empowering individuals and promoting social justice, integrity and an ethics of care. As the pendulum swings towards 'co-active' CS these attributes come to the fore. In the context of the African Continent, CS engagement offers an opportunity to renegotiate privilege, discrimination and inequality. We further contribute to current discourses on CS, proposing ten guidelines that resonate with our definition of CS which is from the laboratory to life, arguing that in the context of CS, 'life' is about emotional 'intangible' aspects of human well-being where science is the catalyst for change and for the application of an ethics of care. We argue more in- depth elsewhere that the participatory processes or aspects of transformation and social learning are not well embedded in theory and in so doing propose that ethics of care and feminist philosophy captures the idea of citizen science being transformative and addressing ideals of democracy and equity, particularly with an emphasis on the democratisation of knowledge and its emancipatory and transformative potential.

[14]What we prefer to see as co-active

[15]The Tropical Biology Association [41] has been training conservationists in Africa for over 25 years. TBA led a pioneering training programme called Citizen Science for Conservation in Africa (CISCA) in collaboration with British Trust for Ornithology, Museum of Zoology, University of Cambridge, National Museums of Kenya and the Kenya Bird Map Committee. The programme's two workshops trained 26 citizen science managers from 16 institutions in Benin, Botswana, Cameroon, Democratic Republic of Congo, Liberia, Nigeria, Tanzania and Uganda and Kenya

[16]These are by no means a substitute for the important work of ECSA in identifying 10 principles-see https://ecsa.citizen-science.net/documents/

[17]See Goldin, et al. (2021) [1]

[18]Other notable CS project in Africa not presented here include: using CS to improve agro-ecological and climatic accuracy of cacao planting material recommendations in Ghana and its regional-level access and delivery to farmers: CS contributions to environmental management and water security in Ethiopia: Coastsnap Mozambique which is a CS coastal monitoring initiative: conservationists from Fauna & Flora International (FFI) and Bucknell University biology researchers have teamed up with government and conservation authorities to capture more than 425,000 images through a camera wildlife survey in South Sudan.

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Disclosure of interest

The authors declare that there is no conflict of interest.

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