Expanding the Impact of Citizen Science

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The concept of citizen science, which engages the eyes and ears of volunteers to observe, record, and share information about the environment, is not new. Its origins go back centuries (Miller-Rushing et al. 2012). In the past few decades, however, the pace and volume of "amateur" environmental monitoring has exploded. The Internet and smartphones have fueled the upsurge with easily accessible tools for studying nature and sharing and accessing data. Consider the world's largest biodiversity-focused citizen science platform, eBird, which began in 2002. Since that year, 624,000 birders have submitted 51 million complete bird checklists, including 10,517 species.

Papers based on eBird data published in scientific journals now number in the hundreds, with 93 added in 2020 alone (see eBird.org for details). eBird status and trend maps are available for hundreds of species around the world, and applications of eBird data range from research and monitoring to conservation planning, including tangible actions such as site and habitat management, species management, habitat protection, and informing law and policy (Sullivan et al. 2017). Currently eBird is the largest contributor to the Global Biodiversity Information Facility (GBIF), and most eBird data can be downloaded from the website after a simple request for access.

Another major contributor to GBIF is iNaturalist (inaturalist.org), which allows its one million registered observers to enter data about multiple taxa. Still another is Nature's Notebook, a project of the National Phenology Network (usanpn.org), for which thousands of individuals track seasonal changes in plant and animal populations across the United States.

Lesser known but equally important to informed decision-making are the hundreds—perhaps thousands—of smaller community-based citizen science projects taking place around the world. Unlike large-scale projects, which typically are designed by scientists at museums or universities to collect data across large geographic regions over long spans of time, community-based projects focus on issues of regional concern and often are driven by the participants themselves (figure 1). Many such projects have launched as people have become frustrated about the inability or even disinterest of the scientific community in studying or engaging in environmental issues.

The potential for citizen science is far greater than its current reality, however. Consider a paper published in *Conservation Letters* in 2014 by Finn Danielsen, cofounder of the Nordic Foundation for Development and Ecology (nordeco.dk; Danielsen et al. 2014). This paper investigated the extent to which citizen science techniques could be used to monitor 186 indicators described in 12 international environmental agreements. The research showed that, although 37% of the indicators would require monitoring by professional scientists, 63% of them could be monitored by a range of citizen science activities, exposing a huge opportunity for further growth of the citizen science field.

Several issues hinder such growth, however. To consider some of them, we invited Danielsen and his colleagues to contribute a special section on community-based monitoring to this issue of *BioScience* (Danielsen et al. 2021, Eicken et al. 2021, Johnson et al. 2021, Tengö et al. 2021). Danielsen has been working in this field for more than 40 years, and Nordeco has spearheaded the development and institutionalization of bottom-up approaches to natural resource monitoring and management in many regions of the world.

An overriding issue for all forms of citizen science is, of course, data quality. Volunteers can definitely collect usable data; the trick is to design projects to gather data that are fit for purpose (Pocock et al. 2018), and many projects are succeeding. For illustration, search for the term *citizen science* on any biological database, and you'll find hundreds of papers published in journals of high scientific integrity. Clearly, reviewers are finding these papers to be based on data that are sufficiently reliable to draw conclusions about the issue being studied.

In fact, data collected by citizen science participants can be more accurate than data collected by professional scientists working on the same issue in the same location. This can happen when volunteers collect large amounts of information, when triangulation is used to optimize sampling accuracy, and when data are collected by volunteers who are very familiar with their local environment. These ideas are explored by Danielsen et al. (2021 [this issue]) in "The Concept, Practice, Application, and Results

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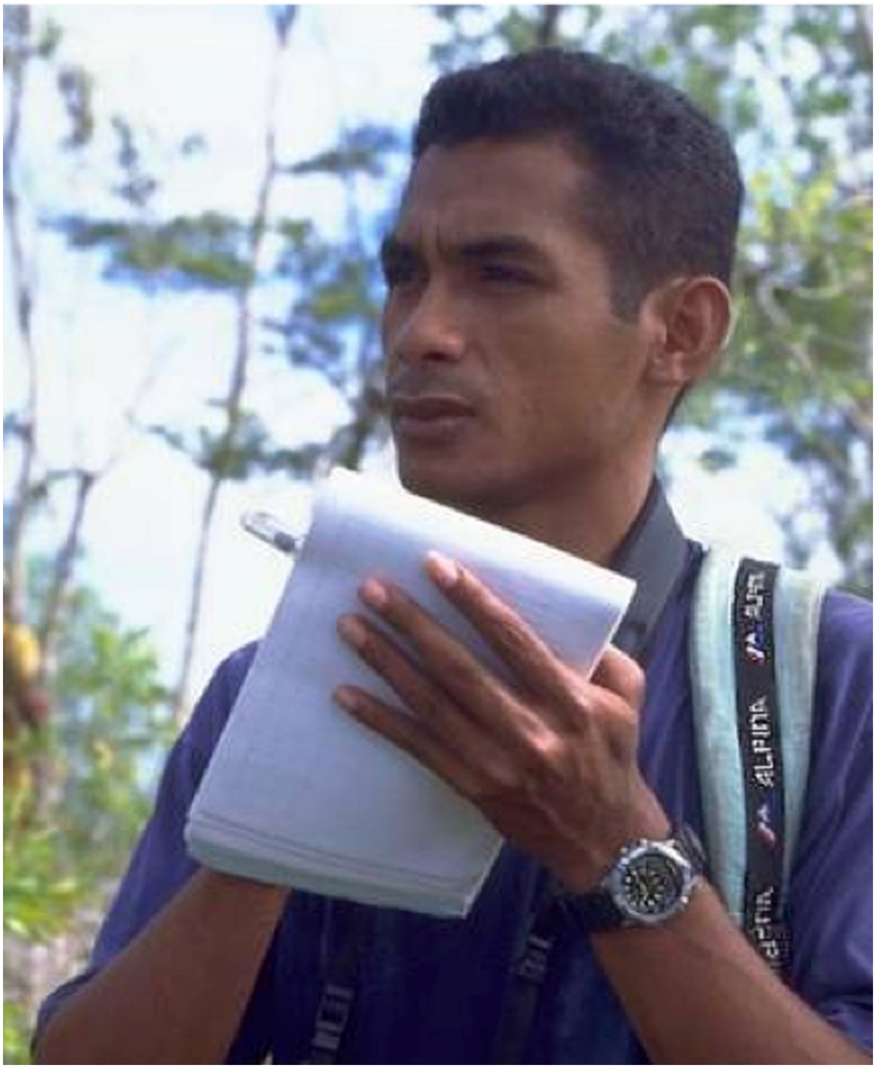

Figure 1. A community monitor in Indonesia. Community members are increasingly taking up environmental monitoring. Photograph: Michael K. Poulsen.

of Locally Based Monitoring of the Environment," which concludes that volunteer monitoring delivers credible data at local scale independent of external experts and can be used to inform local and national decision-making within a short time frame.

Another issue is the challenge of recruiting participants to gather data for projects focused on critical environmental variables that may be of limited interest to the public. For instance, many projects have tried to build eBird-like platforms focused on other taxa with limited success in finding audiences. This fact shouldn't be surprising: Everybody loves birds! In fact, one of the reasons that eBird was started was to create a database to which birders could contribute data they already were collecting—to get information out of notebooks and shoeboxes and into a database that could be curated, archived, and easily accessed. So, although hundreds of environmental indicators might be measurable by volunteers, potential volunteers might not be interested in tracking them.

Even eBird got off to a slow start when it was launched by the Cornell Lab of Ornithology in 2002, using the message long employed by the lab's citizen science staff: "Help scientists track the birds." A decade later, however, after eBird's messaging was changed to show birders how they could use eBird tools to track their own bird sightings, participation grew rapidly (Sullivan et al. 2014). How could this concept translate to other taxa? As one example, a project to monitor native bees across the United States is currently beginning to form (Woodard et al. 2020). Although many people certainly enjoy watching pollinators, the number specifically watching native bees is probably limited. However, if the project emphasized how collecting information on bees could help participants with their gardens, a substantial audience might be possible.

Still another issue is the considerable cost of developing platforms required to support individual monitoring projects. To help projects such as a national native bee-monitoring program get under way, major investments in extendable data-collection and management platforms would be highly valuable. Such platforms do exist; for example, projects can be started and managed on citsci.org, but this platform is underfunded and unable to meet the full needs of the growing monitoring community.

In the article "The Use of Digital Platforms for Community-Based Monitoring" (Johnson et al. 2021 [this issue]), Danielsen et al. describe several challenges that digital platforms must overcome in supporting bottom-up, environmental monitoring, including managing sensitive data, addressing inequities in digital access, and sustaining such platforms. Groups that are building new platforms intended for informing decision-making should pay careful attention to these concerns and identify solutions to ensure that platform use translates into tangible results.

Another important issue for the field of citizen science relates to the burgeoning awareness of the need for EDI—equity, diversity, and inclusion—in many parts of the world. Some citizen science projects have been criticized because their audiences are lacking in diversity. At one level, this criticism is not fair. A group that starts a citizen science project to collect a specific type of badly needed data—for instance, catch data from an ocean fishery—has a specific audience—in this case, commercial and recreational fishers—that they need to engage. Expecting such a project to engage a diverse audience of data collectors is simply not feasible. On the other hand, many projects do overlook key audiences that are appropriate for their projects. In the case of ocean fish, such audiences could include Native American tribes that subsist on fish.

Danielsen et al. discuss this concern in the article “Creating Synergies between Citizen Science and Indigenous and Local Knowledge” (Tengö et al. 2021 [this issue]). As the authors state, Indigenous and local peoples’ *in situ* knowledge practices have the potential to make significant contributions to meeting contemporary sustainability challenges both locally and around the globe. Examples of such projects include local monitoring projects in Greenland, Tanzania, and the Philippines, all of which have led to policy changes with potential long-term impacts on sustainable development. However, working with multiple knowledge systems requires flexible, diverse, reflexive, and sometimes divergent modes of making meaning from data, all of which need to be taken into account. Citizen science must address historic inequities that have limited whose knowledge is valued by and represented in both academic research and regulatory monitoring. Put another way, many stakeholders in environmental decisions have frequently been excluded from or don’t see themselves as represented in scientific endeavors.

Citizen science, including community-based monitoring, has opportunities to be on the front lines of addressing such inequalities by building projects that meet audience needs and aspirations and that respect community knowledge and understanding, and several programs around the world are guiding the development of such projects. These include the Thriving Earth Exchange, which helps scientists, community leaders, and sponsors develop participatory projects to solve local challenges related to natural resources, climate change, and natural hazards (thrivingearthexchange.org). Other examples are Public Lab (publiclab.org), which develops community-created and open-source tools and technology to support community science projects focused on environmental health, and Extreme Citizen Science (www.geog.ucl.ac.uk/research/research-centres/excites), which embraces local needs, practices, and culture to design and build new devices and knowledge creation processes at the community level.

Of course both top-down and bottom-up projects are important, and one way for the citizen science field to become more robust is to build programs that employ the best practices of each. Danielsen et al. discuss this idea in “Connecting Top-Down and Bottom-Up Approaches in Environmental Observing” (Eicken et al. 2021 [this issue]). They offer several recommendations for the field, all enhanced by focusing on pressing societal issues at a scale that brings together interests of local communities in a particular region and large-scale observing efforts.

Building on these ideas, the citizen science community could start developing centers of citizen science to employ multiple project-design models focused on specific issues and questions. This approach has not yet been tried at scale, but an example is the new citizen science program at the South Atlantic Fisheries Management Council. This program began with a specific resource need—data for use in fish stock assessments—and brought together fishers, scientists, and resource managers to design a program to collect needed data and to build trust among the various stakeholders. A fifth article in this issue, “Sea Change: Using Citizen Science to Inform Fisheries Management” (Bonney et al. 2021 [this issue]), describes this burgeoning program and demonstrates the huge interest among resource users in industrialized countries to self-monitor the environment to inform natural resources management decisions.

A final issue in expanding the field of citizen science is the name citizen science itself. This nomenclature has garnered controversy in recent years, primarily because it is perceived as being noninclusive. A bit of history is helpful here.

The term citizen science arose quite recently and independently in the United States and Europe. In the United States, it came into prominence in 1995, when it was adopted by the Cornell Lab of Ornithology as a new name for what had been the lab’s Cooperative Research Program (Bonney 1996). That program had been the home of several of the lab’s public data collection projects, including its first one, the Nest Record Card Program, and Project FeederWatch, which started in 1987.

In Europe, the term also came into use in 1995, after publication of the book Citizen Science by Alan Irwin (1995). Irwin’s fine book focused less on public data collection and more on what he called “scientific citizenship.”

Neither of these authors knew of the other’s work—this was pre-Internet—and they didn’t meet until more than 20 years later. Meanwhile, the term citizen science had grown and flourished, having somewhat different but complementary meanings in the different hemispheres. In most parts of the world today, citizen science refers primarily to projects involving public collection of data, although some researchers, particularly in the field of science and technology studies, have not picked up on this fact, which can be confusing and which sometimes leads to odd manuscript reviews.

That said, if the staff at the Cornell Lab of Ornithology in 1995 had any idea how the use of the term to refer to public data collection would grow—even making it into the Oxford English Dictionary in 2014—they would have thought harder about the use of the word *citizen*. Although they were considering the word in the context of *citizen of the world*, it is understandable how some people have found the term problematic or even demeaning in the context of twenty-first century politics. Notice that only one of the four Danielsen articles uses the word, instead relying on the term *locally or community-based monitoring*.

Some groups have started referring to citizen science with the term community science, which can feel more inclusive. The problem here is that community science is also a term with an important and historic meaning, and not all public data collection fits the definition, which requires meaningful public involvement in multiple aspects of a project (Pandya 2019). So, community science (https://thrivingearthexchange.org/what-is-community-science-a-blog-and-a-quiz/) for example, eBird itself is not community science. However, when the eBird platform is used to develop a project led by local birders or conservationists—for example, a project to study birds for a specific region in a specific area, such as the Sagebrush Songbird Survey in the state of Washington—then that project becomes community science. A caution here is that projects that adopt the term community science without also adopting truly inclusive approaches to project design could effectively be "woke-washing" their projects, giving a perception of being aware of injustices without actually confronting them.

However this debate turns out, the important thing is that public participation in scientific research—citizen science, community-based monitoring, community science—is growing, adapting, and evolving. And that's great, because even as remote sensing becomes more accurate, ground truthing and calibration—and engagement of local actors—always will be needed. What better way to accomplish these tasks than through well-designed projects engaging people who care deeply about their environment.

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