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Citizen science can improve conservation science, natural resource management, and environmental protection

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ABSTRACT

Citizen science has advanced science for hundreds of years, contributed to many peer-reviewed articles, and informed land management decisions and policies across the United States. Over the last 10 years, citizen science has grown immensely in the United States and many other countries. Here, we show how citizen science is a powerful tool for tackling many of the challenges faced in the field of conservation biology. We describe the two interwoven paths by which citizen science can improve conservation efforts, natural resource management, and environmental protection. The first path includes building scientific knowledge, while the other path involves informing policy and encouraging public action. We explore how citizen science is currently used and describe the investments needed to create a citizen science program. We find that:

1. Citizen science already contributes substantially to many domains of science, including conservation, natural resource, and environmental science. Citizen science informs natural resource management, environmental protection, and policymaking and fosters public input and engagement.
2. Many types of projects can benefit from citizen science, but one must be careful to match the needs for science and public involvement with the right type of citizen science project and the right method of public participation.
3. Citizen science is a rigorous process of scientific discovery, indistinguishable from conventional science apart from the participation of volunteers. When properly designed, carried out, and evaluated, citizen science can provide sound science, efficiently generate high-quality data, and help solve problems.

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1. Introduction

The enormous scale and complexity of current environmental problems pose serious challenges for the fields of conservation biology, natural resource management, and environmental protection. Citizen science offers a powerful tool for tackling these challenges.

The challenges are immense. The biological and physical systems of our planet are undergoing rapid rates of change as the impact of human activities becomes nearly ubiquitous (Pimm and Raven, 2000; Steffen et al., 2011). Stressors like urbanization, deforestation, land conversion to agriculture, and climate change strain the capacity of natural systems to sustain life and threaten the persistence of many species (Dirzo et al., 2014; McCauley et al., 2015; Pimm and Raven, 2000; Steffen et al., 2011). Extinction rates might be as high as 100 to 1000 times greater than pre-human levels (Pimm et al., 1995), and these bleak estimates may be too low if unidentified species disappear before they are discovered (Scheffers et al., 2012).

Yet cataloguing even a fraction of the unknown diversity is ambitious (Carbayo and Marques, 2011). Conservation strategies require knowledge of species distributions, but even well-known species can have poorly resolved geographic ranges (Jetz et al., 2012) that can shift in response to climate change (Chen et al., 2011). Moreover, successful conservation efforts must focus on more than ecological dynamics and address the social, cultural, and political factors that affect natural ecosystems (e.g., Balmford and Cowling, 2006; Mascia et al., 2003). To be effective, conservation efforts must also incorporate public input and engagement in crafting solutions (Eden, 1996; Germain et al., 2001; Steelman, 2001).

We describe here how citizen science can improve conservation outcomes by building scientific knowledge, informing policy formulation, and inspiring public action. We focus on the United States, but many of our findings are relevant to other countries with similar systems of governance. We start by describing citizen science and discussing how it can help to address major conservation challenges. We then describe the value and limitations of citizen science for meeting core scientific needs, as well as the value and limitations of citizens for promoting public input and engagement in conservation. We end by discussing the investments that citizen science requires.

Our goal is to help people involved in conservation science and decisionmaking, natural resource management, and environmental protection (1) decide whether citizen science will help them meet their science and/or public input and engagement needs, and (2) make informed decisions about investing in citizen science. We aim to provide a balanced assessment of whether, when, and how to employ citizen science to help meet information and public engagement needs.

2. Methods

We assembled a team of citizen science experts and practitioners from multiple federal and state agencies, universities, and non-governmental organizations. Individuals on the team have many years of experience designing, managing, and evaluating citizen science projects from across the United States. We also represent many different perspectives and take different approaches to studying and using citizen science in research, education, and management applications.

Our team of coauthors was challenged to answer the question, can citizen science improve conservation science, natural resource management, and environmental protection? We gathered at two intensive workshops in June and September 2013 where we mapped out the conceptual framework for answering the question and identified the most essential papers to reference. We also worked extensively outside of the workshops to review the literature and consult with other experts and practitioners. We used Web of Science to identify additional references to better substantiate some of the points raised at the workshop and to frame the paper in a broader context. Given the multi-disciplinary nature of the subject matter in a variety of contexts, requiring many search terms, we can cite only the most pertinent references and examples. This review represents the authors' consensus view of the state of the field that emerged from those workshops.

3. Results and discussion

3.1. What is citizen science?

Citizen science means different things to different people, causing confusion about its nature and utility. We define the term as the practice of engaging the public in a scientific project—a project that produces reliable data and information usable by scientists, decisionmakers, or the public and that is open to the same system of peer review that applies to conventional science. The public can also contribute to science through crowdsourcing, a practice that typically involves large numbers of people processing and analyzing data, but in this paper we focus on public involvement in data collection. Apart from the participation of volunteers, citizen science, as we define it, is indistinguishable from conventional science led by paid scientists at academic, government, non-profit, or commercial organizations and carried out by a mix of professional scientists and paid technicians or students. Both citizen science and conventional science use a variety of methods to achieve a variety of goals, including basic research, management, and education. Citizen science is science (with the addition of volunteers) and should be treated as such in its design, implementation, and evaluation.

Citizen science is not new. Before science first emerged as a profession, keen amateurs and volunteers conducted scientific research and made key contributions to the understanding of climate, evolution, geology, electricity, astronomy, and other phenomena (Miller-Rushing et al., 2012; Silvertown, 2009). Their work continues to provide valuable information. Henry David Thoreau's painstaking records from the 1850s of the first flowers, leaves, and bird arrivals each spring are now used by scientists to identify the impacts of climate change (Ellwood et al., 2010; Polgar et al., 2014; Primack and Miller-Rushing, 2012). In the 1930s and 1940s, Aldo Leopold noted a range of discoveries made by contemporary citizen science volunteers and concluded that “the sport-value of amateur research is just beginning to be realized.” In fact, citizen science volunteers continue many of Leopold's research projects today (Ellwood et al., 2013).

Citizen science projects can pursue basic or applied science. They can monitor ecological or environmental baselines, respond to crises, and inform management actions (Hemmi and Graham, 2014; McCormick, 2012; Nichols and Williams, 2006; Sullivan et al., 2009). Citizen science can tackle issues at local scales, such as identifying the source of pollution in a single stream (Danielsen et al., 2010; Middleton, 2001); it can also address issues at regional or global scales, such as climate change or the world's great animal migrations (Fuccillo et al., 2015; Sullivan et al., 2009).

Volunteers can participate in a little or a lot of the scientific process. For instance, they might formulate a scientific question and then contract with professional scientists to conduct the research; or they might collaborate closely with professional scientists to jointly develop a project, collect and analyze data, and report the results (Shirk et al., 2012). Members of the public, alone or in groups, may even pursue scientific research wholly on their own and fill needs unmet by professionals (Shirk et al., 2012 (collegial model); Middleton, 2001). However, volunteers usually contribute by collecting data in projects designed by professional scientists.

The information technology revolution and the advent of the Internet and location-aware mobile technologies equipped with cameras and other sensors (Hart and Martinez, 2006; Zerger et al., 2010) have greatly increased the capacity of what citizen scientists can do, leading to the rising use of citizen science data in peer-reviewed publications (Ries and Oberhauser, 2015). People can now access, store, manage, analyze, and share vast amounts of data and communicate information

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