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Contributions to conservation outcomes by natural history museum-led citizen science: Examining evidence and next steps

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ABSTRACT

Through their unique combination of specimen collections, scientific and public education expertise, and wide audience reach and trust, natural history museums (NHMs) are obvious settings for bridging conservation science and education through citizen science. Building on over 100 years of amateur naturalist contributions to biodiversity science, a wide range of NHM-based citizen science programs have emerged recently. Yet no comparative studies of the conservation outcomes of this work exist. Here we ask, what is the evidence that NHM citizen science contributes to conservation, what kinds of programs and strategies do so, and how could this approach be better realized for conservation goals? We analyzed 44 citizen science programs across three museums (one U.K., two U.S.) to assess whether and how they contribute to conservation-relevant outcomes. We found evidence that they support conservation both directly, through site and species management, and indirectly through research, education and policy impacts. This study has implications for understanding the role NHMs can play in maximizing the socio-ecological impacts of citizen science, including bringing citizen science to new audiences, mobilizing volunteers to collect and analyze data to study species invasions and impacts of global changes, and conducting locally-relevant research in urban systems. NHM citizen science can provide multiple entry-points and levels of engagement for participants in science and access to new means of studying biodiversity, both in the field and virtually. From our findings we recommend collaboration among the research and education staff within NHMs and other similar conservation organizations, as well as partnerships with external organizations to successfully contribute to conservation outcomes.

1. Introduction

Natural history museums (NHMs) and the field of citizen science share the dual goals of education and generating new scientific knowledge. Through their unique combination of specimen collections, scientific and public education expertise, and wide audience reach and trust, NHMs are obvious settings for bridging conservation science and education through citizen science. Building on over 100 years of amateur naturalist contributions to biodiversity science, a wide range of NHM-based citizen science projects have recently emerged. Yet, no comparative studies of the outcomes of this work exist, particularly with respect to conservation outcomes. Analyzing past and current citizen science programs at three high-profile natural history museums in the U.S. and U.K., we examined the evidence of whether and how NHM-led citizen science contributes to conservation, and how this approach could further advance conservation goals. The implications of these findings apply not just to NHMs, but also provide a lens through which a broader range of conservation organizations can examine how citizen science may or may not contribute to conservation outcomes such as education, research, and species and land management.

Citizen science has been defined in recent years, with slight variation, as members of the public collaborating with professional scientists to collect, transcribe, categorize, and/or analyze data that contributes to our understanding or management of the natural world (Bonney et al., 2009, 2014; Gura, 2013). We see citizen science as an inherently interdisciplinary field encompassing the range of natural and social sciences, including education, psychology, and sociology among others. While Sullivan et al. (2014) have recently noted the effectiveness of interdisciplinary approaches to citizen science across disciplines like biology and informatics, this merely scratches the surface of the collaborations potentially involved in effective programs. A variety of typologies for sorting and categorizing different citizen science programs exist in the recent literature that help illuminate differences in level of community

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or public involvement and program structure (Haklay, 2013; Shirk et al., 2012), impacts on public understanding of science (Bonney et al., 2015), or primary organizational goals (Wiggins and Crowston, 2011). For our purposes of exploring, characterizing, and analyzing citizen science that particularly involves NHMs, we define NHM-led citizen science as citizen science programs that are initiated or coordinated by NHM staff and/or involve the specimen collections and curatorial research of an NHM. We are interested in what is unique about NHM-led citizen science for conservation, as opposed to what NHMs or citizen science programs might do separately, and also the generalizable lessons that can be applied to conservation practice more broadly.

Conservation organizations and museums alike often struggle to evaluate the conservation impacts of their work (Miller et al., 2004; Spooner et al., 2015). To address this need, the Cambridge Conservation Forum (CCF) developed a conceptual framework to evaluate conservation activities and to help organizations clarify their objectives, based on a review of current conservation research and the input of 36 conservation organizations. They delineated seven categories that directly or indirectly lead to targeted improvements in the status of species, ecosystems or landscapes: Species Management and Site Management (Direct), and Research, Education, Policy, Livelihood, and Capacity-Building activities (Indirect) (Kapos et al., 2008). Rather than limit to only direct conservation activities, the CCF framework included the myriad activities that contribute to conservation indirectly, such as public education programs that influence individual conservation behaviors.

Evidence that citizen science contributes to these conservation activities has only recently begun to be examined (Conrad and Hilchey, 2011), despite the recent surge in citizen science projects globally (Bonney et al., 2014). We adapted the CCF framework for evaluating conservation effectiveness to align with the NHM and citizen science fields (Table 1), and then asked whether NHM-led citizen science efforts contribute to conservation outcomes. Importantly, NHMs and citizen science programs each have a variety of goals in addition to conservation; conversely, not all conservation activities can or should be expected of them. For the purposes of our analysis, we adapted the CCF framework by combining species management and site management into a single category. Further, the CCF category "capacity-building", which Kapos et al. (2008) defined as "actions to enhance specific skills among those directly involved in conservation" was not a goal for any of the projects considered in this analysis, nor is it a common goal of NHM or citizen science efforts individually; thus, we excluded this category. For the remaining five categories, in this article we review the existing empirical or theoretical research on how citizen science and NHMs independently have or might contribute to these conservation outcomes. We then analyzed citizen science projects at three NHMs to determine to what extent, and under what circumstances, NHM-led citizen science projects contribute to these outcomes.

Table 1
Definitions of conservation activities (adapted from Kapos et al., 2008).

Conservation Activity Type	Definition and examples
Species and Site Management	Managing species and populations, (e.g., captive breeding), and managing sites, habitats, landscapes and ecosystems.
Research	Research aimed at improving the information base on which conservation decisions are made (e.g., surveys, inventories, monitoring, and mapping).
Education	Education and awareness-raising to improve understanding and influence behavior among people (e.g., campaigns, lobbying, and educational programs).
Policy	Developing, adopting or implementing policy or legislation (e.g., management plans, trade regulations, and actions that make conservation goals official).
Livelihoods	Enhancing and/or providing alternative livelihoods to improve the well-being of people that are impacting the species/habitats of conservation interest, such as through sustainable resource management, income-generating activities, and others.

1.1. Species and Site Management

NHMs contribute to conservation through species and site management primarily through their collections, which can both inform conservation assessments and practical management. As more museums digitize their collections, land managers can increasingly access high-quality, voucher-referenced information crucial for species conservation (Drew, 2011). Furthermore, specimen and observational data combined with environmental data lead to applied biodiversity informatics such as species distribution modeling that can inform management and conservation (Anderson, 2012; Gaubert et al., 2006). Similarly, for citizen science, McKinley et al. (2017) found evidence that citizen science has contributed to natural resource management and policy by providing high quality information and through public engagement. Further, collaborative monitoring can help land managers work with local communities to monitor the effects of resource management practices (Fernandez-Gimenez et al., 2008). Sullivan et al. (2017) also note the value of timely spatial and temporal data generated through the citizen science program eBird for informing species management.

1.2. Research

NHMs have a long history in both the U.S. and the U.K. for contributing to biodiversity research and conservation education. NHMs are particularly well-positioned to answer some of the grand research challenges in biodiversity conservation in the 21st Century: species' response to habitat loss and fragmentation, biological invasions, and the effects of climate change (Drew, 2011; Krishtalka and Humphrey, 2000; Suarez and Tsutsui, 2004; Winker, 2004). Specifically, because of the historical record provided by specimens, museums can study the effects of environmental and human-related change on the distribution and abundance of species, phenology, and pollination rates, over long time periods (Hoeksema et al., 2011; Johnson et al., 2011; Robbirt et al., 2010; Shaffer et al., 1998). This vast stored potential, however, presents two challenges: the need to digitize historical and current biodiversity data, and to acquire modern records for comparison. Citizen science can provide a means to address both challenges. Notes from Nature and other crowdsourcing initiatives are liberating vast quantities of historical data from museum specimens and catalogs (Hill et al., 2012), and citizen scientists are also gathering vast datasets of contemporary biodiversity and environmental records, contributing extensively to biodiversity research as evidenced by hundreds of peer-review journal articles (Sullivan et al., 2017; Theobald et al., 2015).

1.3. Conservation Education

In a time where biodiversity is highly threatened, the most pressing issues require scientific literacy and conservation action (Hacker and Harris, 1992); yet society as a whole has become more and more disconnected from the natural world (McKee, 2005). NHMs are located primarily in urban settings and have an opportunity to link urban populations to their own biodiversity, to help people understand it, feel a connection to their place, and a desire to conserve it. As informal science education institutions, NHMs have the goal of increasing public understanding of science as well as appreciation for the natural world (Miller et al., 2004). Research reviews in environmental and museum education confirm that NHMs reach a wide range of public audiences with free-choice learning opportunities (Dillon, 2003; Falk, 2005), and also reach schools and youth through intensive schools programming. Citizen science programs also have evidence of conservation education outcomes, such as increasing participants' knowledge of target taxa and their understanding of the scientific process (Bonney et al., 2015; Brossard et al., 2009, Crall et al., 2013). Furthermore, evidence has