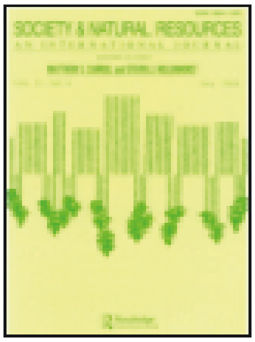

Routledge
Taylor & Francis Group

Society & Natural Resources
An International Journal

ISSN: 0894-1920 (Print) 1521-0723 (Online) Journal homepage: https://www.tandfonline.com/loi/usnr20

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To cite this article: Cynthia A. Grace-McCaskey, Briana Iatarola, Alex K. Manda & J. Randall Etheridge (2019): Eco-Ethnography and Citizen Science: Lessons from Within, Society & Natural Resources, DOI: 10.1080/08941920.2019.1584343

To link to this article: https://doi.org/10.1080/08941920.2019.1584343

Published online: 01 Apr 2019.

SOCIETY & NATURAL RESOURCES
https://doi.org/10.1080/08941920.2019.1584343

Eco-Ethnography and Citizen Science: Lessons from Within

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ABSTRACT

Citizen science is the participation of non-scientists in the collection of scientific data and other aspects of the scientific process. In this manuscript, we explore what it means to participate in citizen science from two perspectives—that of a researcher designing and facilitating a citizen science project, and that of a citizen scientist volunteering the time and energy required for participation. We examine the methods and goals of the projects, describing the challenges faced by researchers and science volunteers alike as they participate in research processes aimed to increase community involvement in science and, by extension, environmental management issues. We describe how the constraints of citizen science models and methods underscore the importance of incorporating alternative anthropological and ethnographic approaches in coastal research, and offer eco-ethnography as a way for scientists to extend their citizen science projects to better reflect the needs and concerns of local communities impacted by climate change and sea-level rise.

ARTICLE HISTORY
Received 19 March 2018
Accepted 24 January 2019

KEYWORDS
Coastal management; citizen science; eco-ethnography; increasing diversity in science; public engagement

Introduction

The term "citizen science" continues to evolve, as does the broad range of practices that fall under it. Viewed as both a scientific and methodological approach, citizen science is the practice of engaging the public in a scientific project (Dickinson and Bonney 2012). The extent of public engagement in citizen science projects varies greatly, and despite an ever-increasing number of scientists and organizations employing a citizen science approach, numerous questions persist regarding what the goals of such projects can and should be, as well as how those goals can most effectively be achieved.

There are three main types of citizen science projects: contributory projects, collaborative projects, and co-created projects (Bonney et al. 2009). Contributory projects are the most common, and primarily employ citizen scientists to collect data. Over the past twenty years these types of projects have grown in popularity as public spending on the environmental sciences has decreased. Their primary goals are often simply to enlist

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and train volunteers to collect large amounts of data. Examples of contributory projects can be found in the fields of biology, ecology, and astronomy (e.g. Brossard, Lewenstein, and Bonney 2005; Paul et al. 2014). Collaborative projects involve volunteers in data collection but may also enlist citizen scientists to participate in other aspects of the scientific process, including developing project goals or research questions, analyzing data, or producing project reports and summaries (Bonney et al. 2009). These types of projects often aim to achieve goals beyond the collection of large amounts of data, such as increasing participants' understanding of the scientific process or increasing knowledge of a particular scientific topic. One of the most well-known collaborative projects, the Galaxy Zoo project, led to the discovery of new galaxy types (Cardamone et al. 2009). Co-created projects are the least common (Price and Lee 2013). In these kinds of projects, scientists and volunteers co-design all aspects of the scientific process, ranging from research design to the dissemination of results. Often, co-created projects are driven and organized to a large degree by non-scientists with the goal of leveraging both scientific expertise and community engagement to address locally relevant environmental policy issues (Shirk et al. 2012).

Proponents of citizen science highlight how the approach enables the collection of large data sets, including data gathered from locations that are inaccessible to the scientists themselves due to geographical and/or funding limitations (Brudney 1999; Cooper et al. 2007; Danielsen et al. 2014; Johnson et al. 2014). This may be particularly useful for the establishment of ecological or environmental baselines, for the long-term monitoring of environmental conditions and populations of organisms, and for documenting shifts associated with global phenomena such as climate change (Dickinson et al. 2012; Fuccillo et al. 2015; McCormick 2012; Sullivan et al. 2009; Thomas et al. 2016). Although critics of citizen science projects question the accuracy and validity of data collected by volunteers, several studies have shown that with proper training, these data can be reliable and useful (e.g. Little, Hayashi, and Liang 2016; Lowry and Fienen 2013; Herman-Mercer et al. 2018). Further, in recent years, an increasing number of scientists and policy-makers alike have seen the citizen science approach as a cost-effective method for data collection and monitoring, particularly in light of shrinking research budgets and resources for academic and government institutions (Pocock et al. 2017).

Citizen science theorists and practitioners also emphasize that the approach has benefits beyond the production of large data sets, including increases in scientific knowledge and literacy, increased understanding of the scientific process, and increased engagement in conservation and management, all of which contribute to the democratization of science (McKinley et al. 2017; Newman et al. 2017; Kinchy 2017; Hecker et al. 2018). While many citizen science studies, particularly those that are collaborative or co-created projects (as described above), explicitly include goals and objectives related to increases in knowledge and engagement, only a small number have produced measurable outcomes (Brossard, Lewenstein, & Bonney 2005; Crall et al. 2013; Jordan et al. 2011). Phillips et al. (2018) describe several factors that contribute to this, including a lack of consensus among citizen science practitioners regarding how knowledge and engagement outcomes should be defined and measured, as well as a lack of dedicated resources and social science expertise needed to meaningfully evaluate these outcomes.

Participant retention is another challenge that researchers conducting citizen science projects experience. Many projects require long-term, continued engagement from volunteers, but participant recruitment and retention can create barriers to measuring learning and behavioral outcomes for participants, even leading to the abandonment of citizen science efforts (Morais, Raddick, & dos Santos 2013; West and Pateman 2016). Related to the challenge of participant retention is a lack of diversity of citizen science volunteers in terms of ethnicity, age, employment status, and socioeconomic status (Pandya 2012; Soleri et al. 2016). While several early environmental justice cases involving minority and low-income neighborhood residents collecting data from their own neighborhoods are often deemed citizen science (Dhillon 2017), the majority of citizen scientists in the United States are those with the time and resources to participate—white, older, retired, affluent, and well-educated (Pandya 2012; Chase and Levine 2018). Individuals from groups that have been historically underrepresented in science (e.g. African Americans, Latinos, American Indians) participate less than majority groups, and affluent participants outnumber less-affluent participants (Trumbull et al. 2000; Evans et al. 2005).

Several scholars have begun to interrogate the related issues of participant recruitment and retention, and lack of participant diversity in citizen science projects. West and Pateman (2016), synthesizing key theories from the volunteering literature with examples from environmental volunteering and citizen science academic and gray literatures, stress the importance of understanding participants' motivations for initial and sustained participation in citizen science opportunities. If those motivations can be fulfilled initially as well as consistently throughout the life of the volunteering time period, participants are more likely to continue volunteering (West and Pateman 2016; Peachey et al. 2014).

Understanding motivations for initial and continued participation in citizen science projects may be particularly critical for issues related to climate change impacts in coastal communities. While we see that private and government funding and interest is often focused on updating coastal infrastructure and reducing vulnerabilities to sea-level rise and coastal flooding in more affluent areas in the US and those areas of higher economic importance, many of the coastal areas are occupied by lower income and marginalized populations (Hardy, Milligan, and Heynen 2017; Bhattachan et al. 2018). If citizen science is to be used to reduce vulnerabilities to climate change related impacts, then it is critically important to engage individuals from these populations as well. We offer eco-ethnography as an evolving method to help do so.

Citizen Science, Coastal Research, and Eco-ethnography

Citizen science appeals to many scientists because of its pedagogical and educational purposes. Scientists use citizen science not only to involve the public in the scientific process, but also to educate community members about the impact of socio-environmental issues on their economic and cultural livelihoods. It has become a way for scientists, researchers, institutions, educators, and activists to engage with communities that must adapt to the effects of climate change and sea-level rise (SLR).

The role of citizen science in coastal research has transformed rapidly since the late 1990s. In climate change and SLR studies specifically, citizen science projects involve expansive spatial and temporal datasets for researchers studying ecological processes and environmental phenomena that affect the oceans and coasts. The spectrum for types of data that citizen scientists collect is broad, ranging from species surveys and wildlife observations to intertidal monitoring and recorded activity in marine protected areas (Goffredo et al. 2010; Cox et al. 2012; Dickinson and Bonney 2012). In some citizen science projects, scientists utilize volunteers' data to model projections of future beach erosion, stormwater flooding, and biodiversity collapse.

As previously mentioned, scientists may ask the public for help with their coastal research projects because of budget constraints, difficulty reaching desirable research sites, and limited resources (Goffredo et al. 2010; Little, Hayashi, and Liang 2016; Lowry and Fienen 2013; Herman-Mercer et al. 2018). As citizen science becomes increasingly accepted as a reliable and acceptable avenue for data collection, it may substitute as a feasible alternative for expensive, expert-driven data collection because it provides the "people-power needed for scientists to gather baseline ecological information" (Cox et al. 2012, 1201; Silvertown 2009). However, while citizen science broadens our scale of analysis in certain respects, it also limits our observations. In the cases described here, we found ourselves drawing on other knowledges to provide scientific, socio-cultural, and ecological context for our projects and findings.

What is Eco-ethnography?

Eco-ethnography builds on the understanding that citizen science is not just an approach to data collection. It is also a collaborative and educational means of involving the public in the production of knowledge about the environment (Iatarola 2018). Much like community-based participatory research, citizen science is "one more tool, and a potentially effective one, for communities to employ the fight for the health and well-being of their neighborhoods" (Tucker and Taylor 2004, 29). This analysis explores how scientists can extend their citizen science projects to better reflect the needs and concerns of local communities impacted by climate change and SLR. In the two case studies, the constraints of the citizen science models and methods underscore the importance of incorporating alternative anthropological and ethnographic approaches in coastal research. We make a case for the eco-ethnography approach, which responds to Bonney and Dickinson's (2012, 26) call for "new language to talk across the disciplines, new models for understanding project design and project results, and new tools to bring people, nature, and computers together in meaningful ways". This approach allows for an in-depth understanding of the socio-environmental context in which the citizen scientists are operating, something that is necessary but often overlooked when planning and facilitating collaborative citizen science projects aiming to engage participants beyond data collection.

An eco-ethnographic approach to citizen science encourages the co-production of knowledge between the citizen scientist and scientist, and accounts for and values qualitative data. This methodology also calls for scientists and citizen scientists to widen their understanding of the cultural landscape in which they are volunteering, and to be culturally cognizant of the ecological politics that are at play (or operate) in the landscapes where they are collecting data. Some questions emerge: Does the citizen scientist have a clear understanding of what "ways of knowing" are? Can the citizen scientist draw on other ways of knowing to provide cultural and ecological context for scientists' models and project designs, which are often unidimensional in scope? Equally important, do scientists' project designs account for and value other ways of knowing? Both groups can determine what other ways of knowing may help enhance or improve a project design.

Doing ethnographic citizen science requires the citizen scientist to recognize the social actors who utilize the spaces where they are collecting data (this being the scientists' study site). In which ways do these social actors relate to the landscape where scientists are conducting their research? Is the citizen scientist aware of racial and/or political dynamics at play? Do they have time to become acquainted with the cultural politics of the ecological space in which they are volunteering to spend time? Do they understand their efforts to participate in citizen science projects leaves its own set of ecological and cultural footprints? What type of relationship do locals have with the land that scientists are studying? Citizen scientists have an opportunity to actively cross-fertilize citizen science with their own local knowledge. They can consider volunteer efforts as interventions that will enable scholars and scientists to widen the scale of analysis. Citizen scientists' on-the-ground observations account for important cultural data that scientific instruments, quantitative surveys and geospatial representations cannot capture otherwise.

In the next section, we analyze two collaborative citizen science projects from two different lenses: that of researchers (authors Grace-McCaskey, Manda, and Etheridge) designing and facilitating a groundwater citizen science project, and that of an academic citizen scientist (co-author Iatarola) documenting tidal lines. After briefly describing the projects in terms of the methods employed to achieve project goals aimed to actively engage volunteer citizen scientists, we describe challenges experienced by project manager and citizen scientist alike, and discuss how an eco-ethnographic approach could be employed to help curtail some of the issues. We conclude with a discussion of how researchers designing, implementing, and facilitating citizen science projects can enhance the ability of their projects to meaningfully and continually engage participants by paying attention to the social, cultural, political, and ecological context within which the project is operating.

Case Study Descriptions

Bogue Banks, North Carolina

The Bogue Banks Coastal Groundwater and Stormwater Watch citizen science project was developed by an interdisciplinary group of researchers at East Carolina University (ECU), and involved citizen scientists in the characterization of the water table on Bogue Banks, North Carolina (NC). Bogue Banks is a barrier island off the NC coast, with about 7,500 residents (U.S. Census Bureau 2017) living in a small number of communities, including Emerald Isle, Pine Knoll Shores, and Atlantic Beach. As with numerous coastal communities worldwide, Bogue Banks is at risk from climate change and SLR (Kopp et al. 2015), and town managers are interested in implementing engineering solutions to address stormwater flooding events. However, the implementation of effective solutions is dependent on an understanding of the drivers of flooding on the island. Citizen scientists were recruited to assist researchers in characterizing the island's water table and assessing the proportion of land on Bogue Banks impacted by groundwater inundation (i.e., when the water table rises above the land surface) by regularly taking water-level measurements from groundwater wells over a three-month period in 2017.

The overall goals of the Bogue Banks project were: (1) to recruit, train, educate, and engage citizen scientists to measure and record hydrologic data; (2) to determine the validity and reliability of hydrologic data collected by citizen scientists; and (3) to assess the effects of participation in a groundwater monitoring project on participants' knowledge of hydrologic concepts; perceptions of flooding, SLR, and climate change; and attitudes towards science and the environment (via pretest-posttest design). The project was designed to be collaborative, and the authors hoped to engage citizen scientists not only in data collection, but also in other phases of the scientific process, including hypothesis testing, data analysis, and interpretation of results relative to the local environment.

Recruitment of citizen scientists for the Bogue Banks project occurred by posting fliers in popular locations on Bogue Banks and advertising the project through local organizations and newsletters. In February 2017, 31 participants attended information sessions designed to provide them with an overview of the project and their responsibilities as citizen scientists, which included: participating in a workshop and training session to learn about groundwater systems and how to properly take water-level measurements in shallow groundwater monitoring wells; measuring and recording groundwater levels at assigned wells over a three-month period; submitting those data to researchers via a dedicated website; completing pretest and posttest surveys; and participating in occasional meetings or email discussions with researchers and other citizen scientists during the research period. All attendees agreed to participate, and the workshop and training session was held immediately after. Participants first completed a pretest survey, designed by ECU researchers to test knowledge of hydrologic concepts, perceptions of flooding, SLR, and climate change, as well as attitudes towards science and the environment. The purpose of the workshop was to give participants an experiential learning opportunity, and they worked in small groups to manipulate physical groundwater models. A lead researcher led them through a series of hands-on activities in which they tested hypotheses about groundwater flow directions and water-level variations in monitoring wells. The authors hoped the experiential and hypothesis-based learning would not only educate participants about how the data they collected would be used by scientists to characterize the water table on Bogue Banks, but also provide them with a deeper understanding of and appreciation for the scientific process. During the second part of the workshop, citizen scientists received one-on-one training from ECU researchers at a groundwater well to ensure that they would take proper water-level measurements.

Throughout the three-month monitoring period, ECU researchers communicated with citizen scientists on a weekly basis via email or phone to confirm that they were not experiencing problems when taking measurements or submitting data via the web portal. The researchers also occasionally sent information and questions related to the project to the citizen scientists to encourage their continued interest and engagement in the project. Half-way through the data collection period (March 2017), a meeting was held, and the researchers presented the data collected up until that point and facilitated a discussion with the participants ($n = 9$) who attended. At the end of the three-month data collection period, final meetings were held on two different occasions (in May 2017) to debrief the participants. The citizen scientists were encouraged to attend the event to return their equipment, complete the posttest survey, participate in discussions regarding how the data will be analyzed and results disseminated, and provide feedback to the researchers regarding their experiences with the project. A total of 12 citizen scientists participated in the final meetings. The discussions at these meetings included examining time-series graphs of data collected by the citizen scientists, comparing groundwater levels to rainfall data, and evaluating groundwater contour maps developed from the citizen scientists' data. In addition, the group discussed potential solutions to the flooding issues, and ways the citizen scientists could help develop solutions. These discussions also provided useful information regarding motivations for participating, perceptions of citizen science, and the scientific process more generally.

Results of the study suggest that participation in the Bogue Banks Coastal Groundwater and Stormwater Watch citizen science project significantly increased knowledge of hydrological concepts (Grace-McCaskey et al. forthcoming). While previous citizen science studies have found increases in participants' knowledge of the biology, behavior, and identification of specific species (e.g. Brossard, Lewenstein, and Bonney 2005; Jordan et al. 2011), the Bogue Banks study is one of the first to show that participation in citizen science can also increase knowledge of physical processes such as concepts associated with hydrology. On the other hand, study results indicate that participation in the project did not significantly impact participants' attitudes toward science, attitudes toward the environment, perceptions of threats of and impacts from flooding on Bogue Banks, or perceptions of climate change (Grace-McCaskey et al. forthcoming). Rather, they support previous findings that individuals who volunteer for science-related activities tend to be those who already hold pro-science and pro-environment beliefs (Price and Lee 2013).

San Onofre State Beach, California

In Southern California, more than 65,000 residents (U.S. Census Bureau 2017) live near San Onofre State Beach, which comprises 20 acres of beach and 174 acres of park space between Los Angeles and San Diego. SLR is a principle threat to this site's ecosystem functionality. The University of Southern California Sea Grant (USCSG) Program has regionalized and localized efforts to conserve, preserve, and protect coastal communities, with the intention of actualizing "strategies that will help the region adapt to the future impacts of SLR" and cyclical events such as El Niño (USCSG 2016). The Urban Tides community science initiative emerged from the National Sea Grant College Program, a university-federal government partnership with the National Oceanic and Atmospheric Administration.

In 2016, the objectives of Urban Tides were: (1) to build a repository of public photos for scientists "to visualize current flooding risks at coastal locations in Southern California"; (2) "to ground truth and calibrate scientific models that project flooding and erosion due to future sea-level rise"; and (3) to strengthen or build existing and new connections with all stakeholders. Organizers turned to social media, newsletters, newspapers, television stations, radio programs, universities, and the Scripps Institution of Oceanography (SIO) to recruit citizen scientists for Urban Tides. Scientists also issued a call for volunteers in their research blogs.

In January 2016, USCSG held a half-day training session at SIO for prospective citizen scientists. Doctoral student (and co-author) Iatarola, who was studying the ecological politics of a controversial toll road project in San Onofre State Beach, responded to the call. Training included a walk at 7:45 a.m. from the La Jolla Shores parking lot northward along the beach to the SIO Pier during a king tide (i.e., extreme high tide). Organizers also conducted a tutorial on how to photograph tidal lines using the Liquid mobile app. Two presentations about the scientific fundamentals and ecological impacts of El Niño occurred after the walk. SIO researchers also solicited feedback from potential Urban Tides citizen scientists by doing a pre-participation survey to better understand their motives for engaging in the initiative. With this training, Iatarola hoped her photos of tidal lines at San Onofre State Beach would help scientists model SLR projections by 2050 for the nearby City of San Clemente.

To map citizen scientists' photos, United States Geological Survey (USGS) oceanographers and meteorologists used the Coastal Storm Modeling System for Southern California (CoSMoS). CoSMoS enables researchers to predict and prepare for environmental disasters (specifically coastal erosion and flooding) related to climate change. Photos from Urban Tides' citizen scientists were also used to show how and where the coastline is changing in low-lying coastal communities such as Del Mar and Imperial Beach. Throughout 2016, USCSG collaborated with USGS, as well as other local and state entities concerned about SLR and climate change impacts, by holding workshops, stakeholder meetings, and several webinar series (i.e. dornsife.usc.edu/uscseagrant/adaptla-webinars/).

The main role of Urban Tides citizen scientists was to use their phones (or cameras) to take photos of tidal lines, coastal flooding, or erosion events at any beach, preferably during king and high tides, and submit them through the Liquid mobile or desktop app. Synced photos were stored in publicly accessible datasets in a cloud-based storage system. Urban Tides was designed to work against a "more technocratic form of decision making" by involving citizen scientists in discussions about data results that inform resilience strategies (Frickel 2011, 24). Several goals were outlined for citizen scientists, which included: (1) boosting ocean-literacy levels; (2) engaging in "meaningful science" that affects adaptation strategies; and (3) contributing to "collective dialogue" about community resilience in age of SLR (USCSG 2016).

Iatarola officially began taking photos of tidal lines as a citizen scientist for Urban Tides at San Onofre State Beach on January 10, 2016, amassing a total of 121 records by January 16, 2017. Each month she set aside at least four hours to volunteer for the initiative. To become an Urban Tides contributor, she established a username and password, then downloaded the Liquid mobile app on her iPhone 6 s. With this feature, the

Urban Tides data set automatically loaded once this information was generated, the app opened, and login was complete. She created a new digital record for each photo session and included required information: location (auto-populated latitude and longitude with the tap of a small arrow), location description, and compass orientation. The fields for date and time were auto-populated. Each photo included space to note "something cool" about the site and other observations that may be useful.

Iatarola quickly realized that cross-fertilizing citizen science with the observations and knowledge she derived as an ethnographer and surfer could widen the scale of analysis for her own doctoral research. As a result, she began conducting an ethnography of citizen science within the context of Urban Tides as a case study. The eco-ethnography approach enabled her to better understand the ground-level politics of SLR at a collection of famous surf breaks known as Trestles in San Onofre State Beach (Iatarola 2018). As an academic researcher and surfer, she was gathering several types of data that appealed to very different audiences and wanted to become critically involved with their subsequent analyses.

Challenges Associated with a Citizen Science Approach

While the co-authors' roles in the case studies are different (i.e. Grace-McCaskey, Manda, and Etheridge as project co-managers, Iatarola as a citizen scientist), they experienced similar challenges related to the citizen science methodologies employed in the projects. If both projects are considered *collaborative* in that they aim to involve citizen scientists in the scientific process beyond data collection (see the aforementioned goals of each project), then we must examine whether and how those goals were achieved. In the Bogue Banks project, the pretest-posttest survey design allowed the researchers to determine that participation in the project resulted in increased knowledge of hydrologic concepts, but did not lead to changes in perceptions of risks associated with coastal flooding, SLR, and climate change, and/or changes in perceptions toward science and the environment. However, this assessment was dependent upon, and limited by, the continued engagement of the citizen scientists. Although a total of 31 citizen scientists agreed to participate in the study, and all 31 completed the pretest and submitted at least one water level measurement, engagement in the project steadily dropped over the three-month period. Participants rarely responded to emails and phone calls from Grace-McCaskey and colleagues aimed at checking in to make sure data collection procedures were going smoothly. Additionally, only 9 participants attended a meeting held half-way through the project, and only 12 attended the final meetings (two meeting times were offered), though 20 completed the posttest. Since one of the primary goals of these meetings with citizen scientists was to engage them in the aspects of the scientific process beyond simple data collection (thereby making the project collaborative in nature), the lack of participation calls into question the ability of the project to reach those goals, and emphasizes the fact that for collaborative projects to succeed, participants must be willing and able to participate in all aspects of the project.

Attrition is often an issue cited by citizen science project managers (Druschke and Seltzer 2012; Johnson et al. 2014), and most recommendations for addressing this challenge involve suggestions for keeping citizen scientists engaged via frequent communication, providing feedback to citizen scientists on submitted data, and encouraging continued participation. However, the Bogue Banks case illustrates that the successful implementation of these recommendations is context-specific. For example, individual participants have different preferences in terms of how frequently they want to be contacted by or receive information from project managers. Further, while researchers can do their best to clearly outline the responsibilities of citizen scientists at the start of a project, there is, of course, no way to guarantee that those expectations are perceived the same by all participants, or that circumstances won't arise during the course of the project that alter the extent to which participants can remain engaged. In Iatarola's case, for example, she experienced data-collecting fatigue as an Urban Tides citizen scientist stemming from encounters with dead wildlife during El Niño, including a dead gray whale (*Eschrichtius robustus*) in April 2016, a die-off of pelagic red crabs in May 2016, and a die-off of black sea hares (*aplysia californica*) in June 2016. Although Iatarola continued participating in Urban Tides, these ecologically disturbing events affected her desire to continue doing so.

The Urban Tides project can also be examined as a *collaborative* citizen science project in terms of Iatarola's experiences regarding the project's ability to achieve its goals of (1) boosting ocean-literacy levels; (2) engaging in "meaningful science" that affects adaptation strategies; and (3) contributing to "collective dialogue" about community resilience in the age of SLR (Urban Tides). Despite the initial training session, within a month Iatarola learned there were issues with her photos of tidal lines. She received a comment from a USGS project leader via the database-management platform's "discussion" tool, requesting she move closer to the shore so that geographers had a better perspective of the tidal lines at San Onofre State Beach. Iatarola re-calibrated the following weeks, but because she was still unsure whether her subsequent photos were useable for mapping SLR, she followed up with the USCSG coordinators, who confirmed they were. She had little to no interaction with USGS project leaders, however, until May 2016, when she expressed to USCSG coordinators her interest in discussing the CoSMoS technology and usability of her photos. They facilitated the exchange with USGS through email.

In June 2016, Iatarola experienced data-syncing issues with Liquid's mobile app. During her discussion with a USGS project scientist, she learned the locations for the bulk of her photos did not match the tidal positioning, a problem solved only by human intervention and labor. This made her feel inadequate as a citizen scientist. The situation also exposed a wide-spread and major weakness in the database-management technology's syncing capabilities. This meant that many Urban Tides citizen scientists were likely taking and submitting photos that the project's scientists could not use. Moreover, the only way Iatarola became aware of this problem was because she assumed an individual responsibility for seeking in-depth feedback on her photo submissions.

In this case, therefore, engagement in meaningful science depended on the citizen scientist's willingness to inquire about her data (i.e. photos). Surely not every citizen scientist was a doctoral student analyzing a case study of citizen science, however. This calls into question whether collective dialog was possible in this case. Who and what constituted the "collective," a concept that shaped Urban Tides' citizen science model for participation? What type of coastal politics were at play that potentially affected participation and community involvement? Further, who was not participating, and for whom were the adaptation strategies designed? Inland residents, for instance, faced barriers to participation, including lack of (public) transportation to the beaches and high parking costs. Seemingly, generating collective dialog about SLR for Urban Tides rested on ideal, overly engaged citizen scientists who had the time, energy, reliable transportation and easy beach access to participate. Although Iatarola's personal experience volunteering for Urban Tides was different than she was expecting, she believed an eco-ethnographic approach to data collection and analysis would yield socio-ecological insights to help the initiative's scientists, leaders and coordinators meet the goals the project initially set out to achieve.

The aforementioned issues regarding barriers to participation in citizen science and questions surrounding who and what contributed to Urban Tides' collective reflect another challenge frequently cited by those conducting citizen science-based projects—a lack of social and ethnic diversity in citizen science volunteers (Pandya 2012; Bonney et al. 2016). Socioeconomic barriers and lack of access to transportation affect the diversity of participants, an issue evidenced by low participation rates from racial groups historically underrepresented in the sciences (Pandya 2012, 314). The Bogue Banks citizen scientists were overwhelmingly white (95% white, 5% black), well-educated (75% received bachelor's degrees), and nearly half were retirees. As is often the case with projects requiring volunteers, it is those individuals with the economic means (e.g., personal transportation) and time (e.g., retirees) who are willing and able to participate. As a citizen scientist, Iatarola recognized her relatively flexible schedule and access to a vehicle enabled her to participate in Urban Tides. Each trip by car to San Onofre State Beach took between 35 to 55 minutes each way. Iatarola's flexible timeframe made the commute generally fast and uninterrupted, provided she avoided rush hour and holiday traffic. The drawback was that her timeframe for collecting data always fell within traditional business hours. Additionally, given the scope of political issues affecting San Onofre State Beach's ecological future, Iatarola felt constrained by citizen science as the primary mode of collecting data to project the impacts of SLR on nearby coastal communities including San Clemente. She needed to draw on other ways of knowing as an academic researcher and surfer to explain the eco-social dynamics of San Onofre State Beach. An eco-ethnographic approach respected the "non-scientific" voices that Iatarola believed should be involved in designs for citizen science projects, as well as discussions regarding resilience strategies for SLR and climate change.

If we view these challenges through an eco-ethnographic lens, we can highlight the importance of the mutual exchange of information and knowledge among researchers and citizen scientists, and that participation in citizen science can be seen as a means for community and individual empowerment. For instance, during a group discussion with a small number of participants at one of the final meetings for the Bogue Banks project, they emphasized that they were motivated to join the project and to continually participate, often above and beyond what was expected of them (e.g. taking more water-level measurements than asked) because they wanted to feel like they were making a difference locally and globally in terms of issues related to SLR and climate change. They were, essentially, hoping to find a way to become empowered to work together with researchers, contributing data that will help inform local coastal management policies. An eco-ethnographic approach examines who informs those policies, how they are enacted, and what type of impacts they have on the communities whose voices lack representation in citizen science projects regarding the coasts (Iatarola 2018). It is not an alternative to doing citizen science. Rather, it is a methodological tool that researchers can use in their citizen science projects to improve the quality of their social, cultural, and political data. As such, it provides deeper context for the less visible impacts of SLR and climate change, especially on vulnerable communities where participation in citizen science projects is low or nonexistent. It allows for an in-depth understanding of the socio-environmental context in which the citizen scientists are operating, something that is necessary but often overlooked when planning and facilitating collaborative citizen science projects looking to engage participants beyond data collection.

Conclusions

We have described two collaborative citizen science projects from two different lenses: that of project managers (authors Grace-McCaskey, Manda, and Etheridge) designing and facilitating a groundwater citizen science project on Bogue Banks, NC, and that of an academic citizen scientist (author Iatarola) documenting tidal lines at San Onofre State Beach, CA. Collaborative citizen science projects often face similar challenges in terms of keeping volunteers engaged, ensuring data being collected is accurate and useful, and securing and retaining involvement from all socioeconomic groups of the local community (not only those with the time and economic means to participate).

To address these challenges, we emphasize the need to pay closer attention to the larger social, political, and ecological context in which citizen science projects—and the citizen scientists themselves—are entangled. We have proposed eco-ethnography as an evolving ethnographic and anthropological approach that can improve researchers' understanding of the enviro-social and ecological relationships surrounding them. This approach enables researchers to see politics and processes at the ground-level that they may not have otherwise, or that are typically invisible in quantitative analyses or technological representations of citizen science data. This method strengthens the diversity of knowledges that conventional citizen science models addressing coastal management issues may overlook or neglect. The eco-ethnographic approach considers ecology a political subject activated by environmental advocacy, (citizen) science and transdisciplinary ways of doing research. It draws from conventional and new means of collecting, interpreting, and analyzing data, and citizen science is seen as a tool of community empowerment.

An eco-ethnographic approach encourages multiple levels of methodological engagement, as well as a hybridity of knowledge or convergence of nomenclature that matters beyond citizen science (Iatarola 2018). An openness to different, creative ways of collecting data and "doing" ethnography may unmask the underlying social disparities that affect communities and their participation in environmental citizen science projects. An eco-ethnographic analysis critically explores who drives the production of knowledge about our coasts, and what power individuals and communities have in helping their communities adapt to the short- and long-term impacts of SLR and climate change.

One way for citizen scientists to accumulate knowledge would involve the use of teaching materials that draw explicit connections between culture, ecology and environmental politics. Such materials could include journal or news articles, environmental reports, videos, oral histories, interviews, music, poetry, photographs and similar cultural artifacts. Scientists should incorporate into citizen scientists' training a cultural debriefing of land politics as well as historical information about indigenous or other groups that inhabit or once resided in the geographic landscapes being studied. This action recognizes the connection of indigenous and/or otherwise marginalized populations that is often nonexistent in scientific understandings and conceptualizations of ecological spaces. Awareness of these histories provides important historical and cultural context for understanding and discussing the ecological effects of modernity and environmental phenomena including SLR.

When designing citizen science projects using an eco-ethnographic approach, scientists and citizen scientists should work together to establish a theoretical framework, preferably one that considers both the production of space and co-production of knowledge, to analyze the scientific narratives that emerge from scientists' representations of collected data. They can interrogate their engagement with and notion of citizen science as a way of democratizing science within the context of a specific initiative or project. Such a design should encourage volunteers to contribute and record on-the-ground observations that may provide cultural context and insight for scientific representations of space.

Natural resource social scientists can improve the citizen science methodology to garner more meaningful involvement by designing initiatives that are adroit in their efforts to include the voices of underrepresented communities whose ecological health is equally at risk due to SLR and climate change. This calls for collaboration, which is not a transparent term and needs to be dealt with more critically by closely interrogating the roles and relations of collaborators (Ross et al. 2010). In closing, as researchers and scientists continue using citizen science "to push the frontiers of understanding with regard to how people learn and how they begin to think scientifically across geographic regions and cultures," they must be open to different methodological approaches that challenge their projects and research results (Bonney and Dickinson 2012, 26). An eco-ethnographic approach may aid these objectives.

Acknowledgements

The authors would like to thank all those who participated in both projects, without whom this research would not have been possible. Special thanks to: the Bogue Banks Coastal Groundwater and Stormwater Watch citizen scientists, North Carolina Aquarium at Pine Knoll Shores, the town managers of Pine Knoll Shores and Emerald Isle, the mayor of Atlantic Beach, and the North Carolina Coastal Federation. We also wish to thank Dr. Elana Zilberg, Dr. Richard Carson, Dr. Brian Goldfarb, Cary D. Lowe, Dr. Keith Pezzoli, Dr. Fernando Dominguez-Rubio, and the reviewers and editors for providing invaluable feedback during the conceptualization and drafting stages.

Funding

Funding for the Bogue Banks project was provided by The National Science Foundation [grant #1756914] and North Carolina Sea Grant [grant # 2014-NCSG-02].

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