DISSERTATION

THE NEED FOR INTENTIONAL COMMUNICATION AND DESIGN IN ENVIRONMENTAL CITIZEN SCIENCE

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Danielle Elizabeth Yut Yun Lin Hunter

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Doctoral Committee:

Advisor: Meena M. Balgopal

Gregory J. Newman
Joseph G. Champ
Joe C. von Fischer

ABSTRACT

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Citizen science projects involve members of the public in the process of science. These joint efforts between scientists and the public have benefited scientific understanding, especially in fields like ecology and environmental science that investigate broad geographic and temporal scale phenomena, as well as social benefits like increases in scientific literacy for volunteers. While citizens have contributed to our scientific understanding of the natural world for centuries, researchers have only been conducting studies on citizen science processes and outcomes for the past couple of decades. As the field of citizen science research is relatively new, there is a need to better understand the communication, structures, and practices of the discipline. The studies in this dissertation focus on various aspects of communication in the field of citizen science.

Chapter 2 describes a content analysis of citizen science project descriptions on CitSci.org and hyperlinked websites to better understand how project leaders describe volunteer tasks and project benefits. Specifically, we were interested in the links between different types of engagement in citizen science and learning outcomes. Citizen science projects often struggle to retain volunteers, so understanding how volunteer tasks align with their motives for participation is informative. We conducted a content analysis of CitSci.org project descriptions (n = 152) along with project descriptions found on hyperlinked websites (n = 23), analyzing volunteer tasks according to cognitive order as defined by Bloom's Taxonomy, an educational framework designed to classify an individual's depth of knowledge. We also considered who benefits from

the tasks that volunteers performed. We found that most projects described volunteers as performing (low order) tasks and described the benefits to citizen science projects. Our analysis indicates that project managers described the scientific process in a limited capacity, which has implications for volunteer scientific literacy. We concluded that when volunteers have a limited role in the project and described benefits misaligned with volunteer motives for participation, they are better described as citizen technicians than citizen scientists.

In the third chapter, we examined how members of the citizen science community perceive various terms used to brand citizen science. While citizen science projects engage the public in science, they often struggle to recruit diverse participants. Citizen science project leaders are increasingly trying to promote inclusivity by rebranding as “community science” to avoid the term “citizen.” We argue that rebranding efforts, while well-intentioned, are uninformed by research. To address this knowledge gap, we distributed a survey to those who participate in citizen and community science (n = 180). We found differences in how well known and accepted the terms are, who is perceived as initiating and benefiting from the projects, and associated levels of inclusivity. Our findings suggest that projects seeking to increase and diversify their volunteer participation should consider what branding they use.

Chapter 4 describes the experiences of citizen science project leaders as they balance multiple project goals. Project leaders often have to manage different goals and the competing interests of scientists, volunteers, funding agencies, and community partners. These challenges can diminish project leaders’ capacities to effectively fulfill their roles. We interviewed citizen science project leaders (n = 65) to better understand their perceptions of barriers and opportunities in meeting goals. We found that project leaders who perceived misalignment between their own goals for citizen science projects and what they perceived to be their

organization's goals more frequently reported challenges related to balancing various project interests, convincing colleagues of data trustworthiness and quality, and being part-time staff. We describe important implications for how organizations engaging in citizen science can address these challenges and better achieve goals.

These studies examine communication in citizen science from three vantage points: 1) how volunteer tasks and project benefits are described, 2) how citizen science projects are branded, and 3) how organizations communicate about the goals of their projects. The findings address knowledge gaps in citizen science research related to how people communicate and by documenting the perspectives of those who lead projects.

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CHAPTER 1

INTRODUCTION

What is citizen science?

Citizen science engages people who do not identify as professional scientists but participate in scientific endeavors by asking questions, gathering data, and disseminating findings (Bonney et al., 2009; Shirk et al., 2012). Citizen science projects are increasingly common (Feldman et al., 2021; Pocock et al., 2017) and study a diversity of topics (Kullenberg & Kasperowski, 2016). Most projects center on environmental or ecological phenomena, like water quality monitoring, species migration, cloud cover, and invasive species reporting (Follett & Strezov, 2015). However, other projects are not limited to ecological and environmental fields and include categorizing galaxies (Fortson et al., 2011), determining how proteins are folded (Khatib et al., 2011), and identifying the microbiota of the human belly button (Hulcr et al., 2012).

While the term, citizen science, was only coined in the mid-1990s, non-professionals' contributions to science are as old as Western science itself. Galileo Galilei was a professional draper before he was a physicist and astronomer, Isaac Newton left school at 17 to be a farmer, Charles Darwin sailed on the Beagle unpaid, and Benjamin Franklin was a professional printer and a politician (Tipaldo & Allamano, 2017). Less well known because, as a woman, and therefore not allowed into scientific societies, Mary Anning, an amateur fossil collector and professional fossil guide, revolutionized our understanding of paleontology and evolutionary biology (Torrens, 1995). While many of these earlier "citizen scientists" blurred amateur-professional lines, professional scientists have been engaging the public in data collection for over a century. For example, this past December and January, birders across the world submitted bird biodiversity and abundance data to the Audubon Christmas Bird Count for the 122nd consecutive year (Audubon, n.d.), and water monitoring volunteers have been collecting water quality data on streams and lakes since the 1930s (Lottig et al., 2014).

The credit for coining the term “citizen science” is dually given to both Alan Irwin, from the United Kingdom, and Rick Bonney from the United States. Irwin described citizen science as a form of scientific citizenship in which people engage in democratic decision making (Irwin, 1995), whereas Bonney described citizens who volunteered their time to provide data to scientists (Bonney, 1996). Bonney, a researcher in the Cornell Lab of Ornithology, was referring to the contributions that non-professionals make when providing bird observation data, while Irwin was more broadly interested in natural resource governance and decision making processes. These varying definitions set the stage for citizen science to develop differently in the United States compared to Europe (Riesch & Potter, 2014). In the United States especially, but increasingly in Europe as well, it is well accepted that citizen science refers to members of the public engaged in data collection and analysis (Bela et al., 2016; Dickinson et al., 2010; Groulx et al., 2017; Lin Hunter et al., 2020; Pocock et al., 2017; Silvertown, 2009). While some researchers have argued that volunteer participation should be expanded beyond data collection (Hinojosa et al., 2021), volunteers question their ability to engage in the scientific process beyond data collection (Lewandowski et al., 2017) and sometimes are only interested in helping collect data (Phillips et al., 2019).

Some researchers argue that the field of citizen science is a new unique academic discipline (Jordan et al., 2015) and have developed and adjusted typologies for classifying projects by degrees of volunteer tasks. For example, Danielsen and colleagues (2009) described a typology for environmental monitoring that ranged from no involvement of local stakeholders to projects that were run autonomously by local actors. Bonney and colleagues (2009) developed terminology to describe the range of volunteer tasks described previously. *Contributory* projects are top-down projects run by scientists, in which volunteers primarily collect data. *Collaborative* projects are typically still designed by scientists, but in these projects, volunteers often engage more deeply in the scientific process, but not necessarily the entire process. Finally, *co-created* projects are those in which scientists and members of the public work together at all steps of the project. This typology was then expanded by Shirk and colleagues (Shirk et al., 2012). *Contractual* projects are those in which communities hire scientists to answer questions for them, and *collegial* projects are those in which individuals study scientific phenomena on their own. Thus, there are many different models to classify how citizen science projects operate.

Why participate in citizen science?

Volunteers and scientists have diverse motives for engaging in citizen science projects.

Volunteers' motives

Studies on volunteer motives are needed to understand how to recruit, engage, and retain volunteers through sustained programming (West & Pateman, 2016). Citizen science volunteers have diverse motives for participation. One study of water monitoring volunteers found that, in general, volunteers want to contribute to science or benefit the environment or their community, and that younger volunteers also participated to benefit their careers (Alender, 2016). Similarly, a study of Virginia Master Naturalists found that volunteers were motivated by their interests in nature and local natural resources (Frensley et al., 2017). A study of Galaxy Zoo projects revealed that volunteers were interested in astronomy and wanted to contribute to the understanding of this discipline (Raddick et al., 2013). Furthermore, other studies of volunteers in bee monitoring and water monitoring projects found that people volunteer because they want to learn more (Domroese & Johnson, 2017; Shinbrot et al., 2021).

In general, people's motives for initially volunteering as citizen scientists differs from what motivates them to remain involved. A study of online citizen science participants through Zooniverse indicated that while volunteers were initially motivated by curiosity, interests in science, and their desire to contribute to research, they stayed engaged when the projects maintained their interest through new opportunities to learn and engage in different aspects of their project (Jennett et al., 2016). Rotman and colleagues (2014) found that citizen scientists across three countries volunteered because they found projects interesting and wanted to self-promote and their involvement was sustained after building trust and relationships with partnering scientists. Thus, volunteers' motives are diverse and often differ across the length of their participation in the project.

While there is a limited amount of research on volunteers who did not maintain their engagement, some studies have examined factors that decrease motivation to participate. Some volunteers leave projects because they do not have time or knowledge of the technology needed to complete project tasks (Rotman et al., 2014). Retention is also limited by volunteers' perceptions of the project's relevancy to the needs of the local community (Shinbrot et al., 2021). Furthermore, when volunteers do not observe tangible impacts of their participation or have limited social interaction with other project participants, they are more likely to leave citizen science projects (Frensley et al., 2017).

Scientists' motives

Only two studies have investigated scientists' perceptions of or experiences with citizen science projects (Golumbic et al., 2016; Riesch & Potter, 2014), suggesting that the perspective of those who develop and lead projects remains understudied. Only one of the two studies examined scientists' motives for leading a citizen science project. Golumbic and colleagues (2016) found that some scientists are motivated to engage citizen scientists because they want to answer research questions and obtain funding. They also concluded that scientists believe that volunteers have a limited capacity to contribute to scientific research and minimal desire to engage with volunteers. Riesch and Potter (2014), however, determined that scientists leading projects were more concerned about their colleagues' perceptions of data quality than they were themselves. In addition, these scientists indicated ethical dilemmas about how to meaningfully give credit and benefits to volunteers. Because these two studies arrived at different conclusions, it is likely that scientists' perceptions about the volunteers on whom they depend is as diverse as the citizen science projects are.

What are the benefits of citizen science?

Scientific outcomes

Early citizen science research focused on scientific outcomes to ensure that engaging in such practices were scientifically worthwhile. Studies demonstrating the rigor of volunteers' sampling skills were common. When tasks are more difficult the level of volunteer education is an important factor for ensuring data quality (Delaney et al., 2008). Furthermore, Fitzpatrick and colleagues (2009) showed that volunteers collect data more accurately when accompanied by experienced professionals. Moreover, as volunteers spend more time on the project, their abilities and productivity in wildlife monitoring increases (Jiguet, 2009; Sauer et al., 1994), making them better data collectors (Dickinson et al., 2010). Other studies have shown that more experienced volunteers are more likely to report rarer species that might be missed by new ones (Kelling et al., 2015; Weir et al., 2005). Further studies have shown that recreational divers can effectively help monitor marine biodiversity, but that their data may be biased towards reporting species in which they are personally more interested (Meschini et al., 2021). Thus, with sufficient training and data quality and assurance plans, citizen science volunteers are often capable of collecting data of sufficient quality to make trade-offs between data quality and quantity are often worthwhile (Kosmala et al., 2016; Schmeller et al., 2009).

Because citizen science programs require resources to recruit, train, and support volunteers, some researchers have examined whether these are financially worthwhile endeavors. One study showed that given the same financial investment, citizen science monitoring initiatives in a protected area in the Philippines led to more conservation interventions and policy impacts than traditional monitoring efforts (Danielsen et al., 2007). Another study showed that volunteer efforts in Project FeederWatch out of the Cornell Lab of Ornithology equated to $3 million worth of labor annually (Dickinson et al., 2010). That said, Fauver (2016) claimed that, unless there is a large amount of data collected by volunteers, investments in training and relationships with volunteers may not be worthwhile. Citizen science initiatives can be more cost-effective if projects can get over the initial financial barrier of starting a project and engage in sustained, long-term monitoring using fixed protocols at fixed sites (Tulloch et al., 2013). Thus, in many cases, especially when researchers anticipate high amounts of data or lower training needs, citizen science programs can be a financially beneficial approach to answering research questions.

Researchers are increasingly publishing studies on the contributions of citizen science projects to science. One review of studies that used volunteer-collected data demonstrated that citizen science data have expanded the geographic scale at which researchers can work, allowing for macroecological studies on species distribution and landscape-level studies on habitat loss and fragmentation (Dickinson et al., 2010). Citizen science data have also contributed to our long-term understanding of scientific phenomena. For example, volunteers have been contributing water quality data since the 1930s (Lottig et al., 2014). It is clear that citizen science projects have expanded both the geographic and temporal scale at which scientific investigations can occur.

Citizen science projects contribute to our knowledge of specific species and habitat types. It is estimated that citizen science data are prevalent in up to 77% of studies on birds, regardless of whether or not the use of volunteer-collected data is mentioned (Cooper et al., 2014). Furthermore, citizen scientists' contributions to stream and lake monitoring more frequently allow for repeated monitoring over time, when compared to data collected by professionals (Poisson et al., 2020). For example, while about 50% of sites monitored for water clarity 1-5 times were monitored by professionals, only about 5% of sites monitored more than 15 times were done so by professionals. While the majority of citizen science projects are environmental or ecological (Follett & Strezov, 2015), citizen science-supported research is published in journals related to computer science, history, astronomy, and public health (Kullenberg & Kasperowski, 2016). There are also increasing calls for citizen social science (Tauginienė et al., 2020).

While the majority of citizen science projects are ecological and environmental in nature, their capacity to contribute directly to conservation and management remains to be seen. Some researchers argue that while there can be some direct benefits to conservation and management of species and habitats, most conservation benefits are indirect through research in service to conservation and social outcomes like learning and policy changes (Ballard, Robinson, et al., 2017; Ballard, Phillips, et al., 2018).

Social outcomes

Social outcomes include learning, policy, and other social outcomes.

<u>Learning outcomes</u>

As the field of citizen science developed as an academic discipline (Jordan et al., 2015), research on social outcomes has become more common, especially investigating social outcomes related to volunteer scientific literacy (Peter et al., 2019). One study of volunteers in an invasive plant citizen science project found that volunteers both gained knowledge and reported that they had changed their behaviors as a result of participating, though most behavior changes were related to noticing more invasive plants and speaking with others about them (Jordan et al., 2011). Another study of a turtle monitoring project revealed similar gains in knowledge and behavior change of volunteers related to awareness of turtles on the road (Santori et al., 2021). A study of volunteers in the Great Pollinator Project and Earthwatch Coyote Project revealed little change in conservation attitudes and behaviors, likely because volunteers in projects like these self-select for those who already have high conservation attitudes and behaviors (Toomey & Domroese, 2013). While researchers have suggested that participation in citizen science projects can promote a science identity, or the perception that people see themselves as scientists (Ballard, Harris, et al., 2018), these results have not been confirmed. Thus, while it does appear that engaging in citizen science programs can result in volunteer knowledge gains, further investigations into attitude change, behavior change, and science identity are needed to more confidently understand how they are impacted by engagement in citizen science projects.

The National Academies of Sciences, Engineering, and Medicine (2018) has called for intentional design related to developing projects uniquely designed to promote educational outcomes like behavior change. One framework for incorporating learning outcomes into projects include volunteer interests and motivations, their perceived self-efficacy to participate, knowledge of science concepts and practices, scientific skills, and behavior change (Phillips et al., 2018). Explicit consideration of desired learning outcomes is important because certain tasks are associated with greater increases in scientific literacy (Lin Hunter et al., 2020) and, as already addressed, common volunteer motives for participating include learning more about the social-ecological system being studied (Domroese & Johnson, 2017; Shinbrot et al., 2021).

Finally, there is an increasing body of research discussing the learning outcomes of engaging in citizen science projects within a formal classroom setting. In postsecondary classrooms, professors engage students in citizen science research to increase experiential learning and participation in authentic inquiry (Vance-Chalcraft et al., 2022). These efforts have yielded several anecdotal accounts of student learning but evaluating outcomes of citizen science engagement within college classes remains understudied. More commonly, citizen science projects have been integrated into K-12 curricula. Some studies have demonstrated that elementary students (Kermish-Allen et al., 2019) and high school students (Grossberndt et al., 2021) increased their content knowledge after engaging in citizen science projects. Participating in citizen science endeavors can also help students achieve agency as they take part in conservation actions (Ballard, Dixon, et al., 2017). Furthermore, middle school teachers who engaged their students in a local camera trap citizen science projects through place-based education lessons achieved curricular agency, a precursor to continuing to use such lessons (D. S. Wright et al., 2021). Other studies demonstrated that students were capable of collecting high quality data that contribute to research (Saunders et al., 2018; Schuttler et al., 2019), though some have indicated that more challenging tasks may require participation by older students (Delaney et al., 2008).

Policy outcomes

Citizen science outcomes related to policy are increasingly common (Shanley et al., 2019). One study showed that citizen science data have contributed to various aspects of the policy process, from helping define problems, through policy formation, implementation, compliance assurance, and policy evaluation (Turbé et al., 2019). More local scale case studies have shown specific policy outcomes have been achieved. Data collected by Master Gardeners in Washington served as a catalyst for changes in policy that allowed for better management of roadside weeds and helped increase the trust that local stakeholders had in policy decisions (Rome & Lucero, 2019), and data collected by recreational anglers in the Puget Sound watershed allowed for the delisting of canary rockfish from the Endangered Species Act and the expansion of the yelloweye rockfish's protected habitat (Andrews et al., 2019).

Others have discussed the potential outcomes of citizen science projects to impact policy at larger scales. Roger and colleagues (2019) examined a citizen science project's capacity to shape environmental policy in New South Wales, Australia. Groom and colleagues (2019) provided recommendations for technology infrastructure to decrease the amount of time between data collection and use by policymakers at a global scale. Some scholars have investigated how the phenomenon of citizen science is conceptualized in policy documents and concluded that most describe it as a tool for science rather than policy (Hecker et al., 2019). Further research is needed to better understand tangible citizen science outcomes for larger scale policies.

Other social outcomes

The majority of the social outcomes discussed thus far have resulted in top-down, contributory citizen science projects. Other outcomes that have been reported are primarily found in bottom-up, grassroots projects, many of which go by other terms than citizen science like community science (Charles et al., 2020), community-owned and managed research (Heaney et al., 2007), civic science (Jordan et al., 2019), community-based management or monitoring (Conrad & Hilchey, 2011). The Louisiana Bucket Brigade was a grassroots citizen science initiative to address environmental injustice related to poor air quality that disproportionately affects African American and low socioeconomic communities (Ottinger, 2010). Citizen science projects have also been described as helping build local capacity within the communities in which it takes place (Balestrini et al., 2021). A review of citizen science programs showed that they can contribute to democratized science, social learning, incorporation of local and indigenous knowledge into science, gains in social capital, empowerment of local communities, and livelihood improvements (Walker et al., 2021), though the majority of papers cited did not identify as citizen science (Bliss et al., 2001; Gérin-Lajoie et al., 2018; Mullen & Allison, 1999; Pollock & Whitelaw, 2005; Whitelaw et al., 2003; Wiseman & Bardsley, 2016). It is possible that there is an underrepresentation of these other types of goals for projects that self-identify as citizen science because scientific outcomes like peer-reviewed publications are less commonly the goals of bottom-up initiatives (Heaney et al., 2007). It is also possible that studies with other outcomes may not have ended up in this review if they go by other names, as the goal was to review the literature on citizen science.

What are the current challenges?

There are several current challenges in the field of citizen science related to diversity and inclusion, terminology, and democratization of science.

Diversity and inclusion

Citizen science endeavors depend on the volunteers, but volunteering is a privilege, requiring capacity and resources to do unpaid labor (Wilson, 2000). Furthermore, while the majority of citizen science projects are environmental and ecological (Follett & Strezov, 2015), in the United States, there is a history of exclusion of people of color from the outdoors (Whitesides, 2016). US environmental norms were established from the perspectives of wealthy, white, men (Gibson-Wood & Wakefield, 2013). Survey instruments measured their norms, leading to the perspective that people of color had low environmental attitudes (Outdoor Recreation Resources Review Commission, 1962). Lack of survey recruitment of people of color and differences in recreation activities from white people led to the notion that they were absent from outdoor spaces altogether (Floyd, 1999; Jones, 2002). On this backdrop, amateur naturalists laid the groundwork for citizen science endeavors (Liebenberg et al., 2021). As a result, citizen science projects struggle to engage diverse participants (Pateman et al., 2021).

Citizen science volunteers tend to be white, wealthy, and well-educated. One study found that when compared to a nationally representative sample from the United Kingdom, people who were older, white, and more wealthy were more likely to repeatedly participate in citizen science projects, and that full-time employed men were more likely to participate at least once (Pateman et al., 2021). Overall, these demographic factors align with samples of volunteers in other studies. For example, one study in South Africa tested a psychometric survey on citizen science volunteers' motivations in a sample that was 99.5% white and 72.4% male, of which 65.4% had a graduate degree and 61.0% were found to be in the highest income bracket (D. R. Wright et al., 2015). Another study showed that bee monitoring volunteers were 89% white, 76% female, and 64% over the age of 50 (Domroese & Johnson, 2017). While the majority of demographics appear consistent across studies, there does appear to be inconsistency in participation between gender (Pateman et al., 2021). Furthermore, the experiences of the lesbian, gay, bisexual, transgender, and queer plus (LGBTQ+) community in citizen science projects remains unstudied.

Lack of participant diversity is problematic for two primary reasons. The first is that the benefits of participating in citizen science projects are unequally distributed. Because it is known that volunteers are often initially motivated by personal interests (Rotman et al., 2014), like learning more about a phenomenon, or in the case of younger volunteers, furthering a career (Alender, 2016), if only some community members seek these opportunities, there may be a growing divide within communities. Some community residents may increase their content knowledge and capacity to be engaged as change agents around environmental issues, while others are on the sidelines (Pateman et al., 2021). This is also problematic because, as citizen science is a new and developing academic field (Jordan et al., 2015), there is a growing body of research on its practices and outcomes (Hajibayova, 2020) that fails to represent diverse perspectives.

Researchers suggest project leaders consider inclusivity at the start of projects (Paleco et al., 2021). By co-creating citizen science projects with community members, Pandya (2012) suggested that citizen science programs can: 1) align projects with community goals, 2) share leadership with communities, 3) work with communities throughout the entire project, 4) incorporate diverse knowledge systems, and 5) share findings broadly. One issue with this framework is that it limits the capacity of large scale, scientist-driven citizen science projects to address inclusivity challenges; however, by “centering in the margins,” or designing projects specifically for those who have been historically excluded, it has been suggested that citizen science projects can be designed to be inclusive for marginalized communities (Cooper et al., 2021, p. 1388). They suggest a focus on environmental justice or projects that had clear benefits to marginalized communities. When compared with more traditional recruitment strategies, targeted recruitment of people with diverse identities has been shown to broaden the reach of citizen science projects related to drinking water in the Netherlands (Brouwer & Hessels, 2019). Others strategies for promoting inclusivity include compensating participants for their work (West & Pateman, 2016) and translating materials into languages besides English (Sanz García et al., 2021). However, citizen science projects overall, especially those that occur at larger scales, tend to have issues with inclusivity that result in limited participant diversity.

Terminology

The field of citizen science is increasingly struggling with how to describe and define itself (Bonney, 2021). One study of people's conceptions of citizen science projects revealed that there were multiple different ways to define and perceive projects (Haklay et al., 2021). Furthermore, as citizenship has become politicized, especially within the United States, projects are increasingly questioning the inclusivity of the term citizen and rebranding as community science to address the diversity issues discussed above (Lin Hunter et al., in revision). However, this can be problematic as it ignores pre-existing, bottom up definitions for community science and fails to address inclusivity issues in citizen science (Cooper et al., 2021). When the term citizen science was coined, citizen scientists were intended to mean "citizen[s] of the world" but as language has shifted over time, the term citizen science is increasingly perceived to be "problematic or even demeaning" (Bonney, 2021, p. 4). This has led to calls to better define terminology in the field and debates within peer reviewed literature about definitions (Auerbach et al., 2019; Eitzel et al., 2017; Heigl et al., 2019a, 2019b; Heigl & Dörler, 2017). To avoid use of the term citizen others have suggested alternative names like tracking science (Liebenberg et al., 2021). The next conference for the Citizen Science Association has been dubbed a "C*Sci" conference to avoid use of the term citizen and avoid co-option of the term community science (Citizen Science Association, 2021), and North Carolina State University describes citizen science as "Public Science" (NCSU, 2022), though there is no peer reviewed literature on either of these terms.

Another issue relates to other terms that are often conflated with citizen science. There are several transdisciplinary approaches that engage the public to varying degrees (Knapp et al., 2019). While community science is the most commonly conflated with citizen science, community based environmental monitoring (Conrad & Hilchey, 2011), public participation in scientific research (Bonney et al., 2009; Shirk et al., 2012), civic science (Jordan et al., 2019), among others are often equated with citizen science, as was the case in the review on outcomes in citizen science discussed above (Walker et al., 2021). Thus, there is also a need to clarify how these different terms relate to citizen science.

Democratizing science

Citizen science projects are often described as democratic science (Bäckstrand, 2003), but some have argued that it may not be as successful at meeting this ideal (Kinchy, 2017; Strasser et al., 2019). Democratization involves a shift in how we perceive the role of the public from that of consumers of science to partners, problem solvers, and leaders (Boyte, 2005). However, some have simply equated it with increasing the accessibility and inclusivity of science and thereby broadening volunteer diversity (Kullenberg & Kasperowski, 2016; Walajahi, 2019). Carolan suggests that research can never be democratic because it operates within the current paradigm of science in which the scientists' expertise will be privileged over that of the public (2006). Democratized science, on the other hand, requires bridging a plurality of expertises (Nowotny, 2003). Because the majority of citizen science projects are contributory in which scientists drive the research, have ownership over funding, and define project outcomes (Bela et al., 2016; Dickinson et al., 2010; Groulx et al., 2017; Lin Hunter et al., 2020; Pocock et al., 2017; Silvertown, 2009), most projects may not meet such criteria for democratic science.

Issues related to whose voices are considered and volunteer participation limit the democratization of science. Because citizen science leaders are key for the success of citizen science projects, it is imperative that their perspectives, decisions, and intentions are examined since their actions will help shape the success and sustainability of projects. Yet only two studies have examined their perspectives (Golumbic et al., 2016; Riesch & Potter, 2014), suggesting that this might not be the case. When certain groups are not included in citizen science projects this reduces the democratic quality of the science because it is less accessible (Kullenberg & Kasperowski, 2016; Walajahi, 2019). Furthermore, people may decide to join projects because of the benefits to them, and as a result, this affects the quality of volunteer participation (Shirk et al., 2012). For example, if projects recruit volunteers by advertising it as a way to increase content understanding of an issue yet only engage them in data collection, projects may not meet volunteers' goals as limited engagement in data collection may be insufficient to increase volunteer scientific literacy (Lin Hunter et al., 2020). Thus, if projects fail to address volunteer interests there are not only implications for volunteer retention (West & Pateman, 2016), but also the democratic potential of a project.

How this dissertation addresses these challenges

In Chapter 1 I review research on citizen science and identify several current challenges in the field including limited engagement by diverse participants, issues related to defining the field, and limitations in the capacity of citizen science projects to democratize science. Each subsequent research chapter addresses one or multiple of these challenges by identifying misalignments in the field of citizen science that prevent it from reaching its full potential.

There are two primary uniting factors across the research chapters in this dissertation. First, each of the studies addresses the clear gap in research on the perspectives of people who lead projects by studying how they communicate and their perceptions of their experiences as project leaders. Secondly, each of the chapters identifies various misalignments in citizen science practice. One of the two studies on citizen science leaders describes their experiences in the title as being “Between vision and reality” (Golumbic et al., 2016, p. 1). The misalignments identified in each of the studies prevents the field of citizen science from reaching its full potential.

Chapter 2 describes a content analysis of citizen science project descriptions on CitSci.org and websites hyperlinked within project descriptions. It has been published in *Citizen Science Theory and Practice*. We were interested in better understanding how project leaders described the tasks the volunteers were asked to perform and who was described as benefiting from these tasks. Bloom’s taxonomy of cognition classifies different skills that support the development of scientific literacy from memorization to the ability to create knowledge (Bloom, 1956). We used Bloom’s taxonomy of cognition to connect the tasks that volunteers were asked to complete with associated levels of scientific literacy. We found that volunteers were often described as having limited engagement in the process of science and that described benefits often misaligned with volunteers’ motives for participating. When volunteers have limited engagement in science, this can limit increases in scientific literacy, another common volunteer motivator (Domroese & Johnson, 2017; Shinbrot et al., 2021). Our study identified limitations in the capacity of citizen science projects to engage in democratic science because it suggests that volunteers' goals may misalign with project tasks. Furthermore, it expanded the scope of discussion on terminology to consider not just how we describe the field of citizen science, but how we communicate about the process of citizen science. Ultimately, we concluded that when citizen scientists have limited engagement in the process of science and unmet goals for participation, they are better described as citizen technicians.

Chapter 3 describes a survey study of those engaged in citizen and community science. The goals were to identify differences in perceptions of the terms citizen science and community science in light of recent discussions about terminology. Citizen science practitioners are increasingly rebranding their projects as community science to avoid the potentially exclusive nature of the term citizen, in hopes of appearing more inclusive. Because these rebranding efforts are often uninformed by research (Bonney, 2021; Cooper et al., 2021; Lowry & Stepenuck, 2021), we conducted a survey study of those involved in citizen and community science to characterize their perceptions and motives for branding projects as citizen science or community science. Survey respondents perceived the terms to differ in their definitions, their perceptions of how well-known and accepted and how inclusive they were, as well as perceptions of who initiated projects. Thus, we identified a misalignment between practitioners' behaviors and their perceptions. While they perceived that the terms were not the same, their behaviors in choosing to change names indicated that they were. This study addresses challenges of selecting inclusive terminology by providing evidence-based recommendations. We concluded that top-down, scientist-run projects should avoid rebranding to community science and should address inclusivity issues beyond simple name changes. This chapter is in revision in *Frontiers in Ecology and the Environment*.

Chapter 4 describes a phenomenological study of project leaders' experiences leading citizen science projects. The goal of the study was to document how project leaders decide to balance various project goals. We used social-ecological systems theory to inform our analysis because citizen science projects often have both social and ecological goals. We found that project leaders perceived multiple goals. They had both personal goals that they wanted to achieve and perceptions of their organization's goals. Goals were classified as scientific (e.g., answering research questions), social (e.g., education), and citizen science goals (e.g., project sustainability). When project leaders' personal goals aligned with their perceptions of their organization's goals, they balance different goals of the project and incorporate collaborators' interests. However, when their personal goals misaligned with their perceptions of their organization's goals, they described spending time managing their organization at the expense of meeting goals. For example, they were more likely to have to convince their colleagues of data quality and balance project interests with incongruent organizational goals. This study identifies other organizational dynamics that need to be considered for the field of citizen science to reach its democratic potential of engaging diverse community members. We concluded that if citizen science projects want to accomplish their goals most effectively, they should be more explicit about the types of project goals, as well as the alignment of project leader's personal goals and those of their organization. We intend to submit this chapter to *Conservation Biology* as a research manuscript.

The goal of this dissertation was to better understand how citizen science practitioners communicate about and engage in activities around primarily social-ecological issues. Based on the results of this dissertation, I am well positioned to provide recommendations to citizen science practitioners seeking to meet their organizational and personal objectives. I hope that, if I can share these results with citizen science project leaders, they will be better equipped to lead successful and sustained projects. In the final chapter, I summarize research findings and present implications for potential future research.

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CHAPTER 2

CITIZEN SCIENTIST OR CITIZEN TECHNICIAN: A CASE STUDY OF COMMUNICATION ON ONE CITIZEN SCIENCE PLATFORM[1]

Introduction

Citizen science efforts involve the general public in various aspects of the scientific process (Bonney, Ballard, et al., 2009). However, there are different degrees to which volunteers can participate (Shirk et al., 2012). Citizens hire scientists to answer local questions in contractual projects, whereas volunteers collect or analyze data for professional scientists in contributory ones. In collaborative projects, volunteers and project managers work together on certain parts of the project, whereas co-created projects involve collaboration between volunteers and project managers throughout the entire project (from asking scientific questions to sharing results). Finally, in collegial projects, citizen scientists perform research independent of professional scientists. While many papers have anecdotally noted that most projects tend to be top-down, contributory projects (e.g., Pocock et al., 2017), few have documented this through research (Bela et al., 2016; Groulx et al., 2017)

Volunteers have many diverse motives for participating in citizen science. Studies have investigated motivation for participation in individual projects (Domroese & Johnson, 2017; Raddick et al., 2013) and across multiple projects (Alender, 2016; Geoghegan et al., 2016). Both types of studies indicate participant motives that include contributing to science, to conservation efforts, or to the community; connecting with nature or with a specific place; socializing; furthering a career; exercising; having fun; and learning. The quality of overall volunteer

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participation in citizen science is defined by how well project outcomes align with volunteer needs and motives (Shirk et al., 2012).

Participating in citizen science programs can result in various outcomes, but one that has received attention in the literature is learning. Multiple citizen science stakeholders, including volunteers, community members, and scientists, can learn about scientific inquiry and environmental issues when engaging in citizen science projects (National Academies of Sciences, Engineering, and Medicine (NASEM), 2018). This paper focuses on learning outcomes of volunteers specifically. Participating in citizen science can increase volunteer scientific literacy (Bonney, Cooper, et al., 2009). Knowledge gains, engagement in inquiry-based reasoning, and changed conservation attitudes and environmental behaviors are all documented learning outcomes in citizen science (Jordan et al., 2011; NRC, 2000; Toomey & Domroese, 2013; Trumbull et al., 2000). Scientific literacy has important benefits for both individuals and society (Laugksch, 2000). Here, we define the highest level of literacy as the ability to make an evidence-based decision that alters one's behaviors (Balgopal & Wallace, 2009; UNESCO, 1978). Individuals empowered to engage in scientifically informed behaviors can make decisions in their personal lives that also result in economic or environmental benefits to society (Laugksch, 2000). While changed behaviors may be considered the idealistic epitome of scientific literacy, the two are often not correlated (Nisbet & Scheufele, 2009).

Although education research has focused on the disparity between scientific literacy and scientifically informed decision-making, this is an area that is under studied in the field of citizen science. A recent report by NASEM (2018) revealed that there was little to no research on how the design of citizen science projects may result in learning outcomes. In fact, there is little research on how scientists and project managers generally choose to design projects. This prompted our inductive investigation of how project managers and scientists describe their projects on an online platform for citizen science. Our objectives were to characterize 1) the tasks that volunteers were asked to perform and 2) who was described as benefitting from the tasks. Volunteer tasks are important because how citizen science volunteers are engaged in projects may affect opportunities for them to increase their own scientific literacy (Bonney et al., 2016). Furthermore, we analyzed described project outcomes because learning is more likely to occur when projects align with volunteer motivations and interests (NASEM, 2018).

Theoretical Framework

Science literacy is a complex concept that describes people's understanding and applications of scientific knowledge (Laugksch, 2000). Although scientific literacy has historically been described as an endpoint of learning about and understanding scientific concepts, it is probably more accurately described as a continuum (Uno & Bybee, 1994). A person becomes increasingly scientifically literate as they learn more about science content and the scientific process by which this information is generated (NRC, 2012). The notion that scientific literacy is dependent not only on content knowledge but also critical thinking and scientific skills has a long history in education research (Sanderson & Kratochvil, 1971). These components of scientific literacy have been classified as basic and integrated processes. Basic processes involve "observing, classifying, using numbers, measuring, using space/time relationships, communicating, predicting, inferring," whereas integrated processes include "defining operationally, formulating hypotheses, interpreting data, controlling variables, experimenting" (Sanderson and Kratochvil, 1971, p. 13). Engaging in basic processes has been linked to low-order thinking, and integrated processes are associated with high-order thinking (Lewis & Smith, 1993). More recently, communicating results and educating others have been associated with demonstrating high-order thinking because these skills involve critically understanding and thinking about science content knowledge (NASEM, 2018). The classification of thinking as low and high has been expanded to include medium-order thinking (Jensen et al., 2014).

Low-, medium-, and high-order thinking have been connected to Bloom's taxonomy of cognition, a psychological framework used by educators to classify levels of thinking or learning objectives (Jensen et al., 2014; Miri et al., 2007). Bloom's taxonomy classifies different cognitive skills that support the development of scientific literacy. On one end of the continuum is the ability to remember or memorize information. As scientific literacy increases, individuals demonstrate abilities to understand, apply, analyze, evaluate, and create knowledge (Bloom, 1956). Jensen et al. (2014) defined low-order cognition as being able to remember and understand knowledge, medium-order cognition as the ability to apply knowledge, and high-order cognition as the ability to analyze, evaluate, and create knowledge. Because Bloom's taxonomy is most often used in educational settings and not in citizen science contexts, we slightly modified the three levels, expanding the medium-order category to include understanding and analyzing because application of knowledge is uncommon in citizen science (Figure 2.1).

Methods

In this study, we sought to investigate how project managers communicate about volunteer tasks on an open-access digital platform for citizen science projects called CitSci.org. We conducted a content analysis of the different tasks that volunteers are described as performing and considered how they are related to tasks associated with increased scientific literacy.

Positionality statements

Our team comprises three experts in environmental social science: a graduate student studying conservation social science, an ecologist who studies citizen science programs, and a social scientist who studies ecological and scientific literacy. Our team has collaborated for the past three years and knows that our individual perspectives have helped shape the analysis of this study. All three of us are formally trained in ecology and have worked at some point in our lives as research assistants (or technicians) and as citizen science volunteers. Our research experience in discourse analysis varies, but we have worked collaboratively throughout the research process to ensure that we adhere to the standards of research practices.

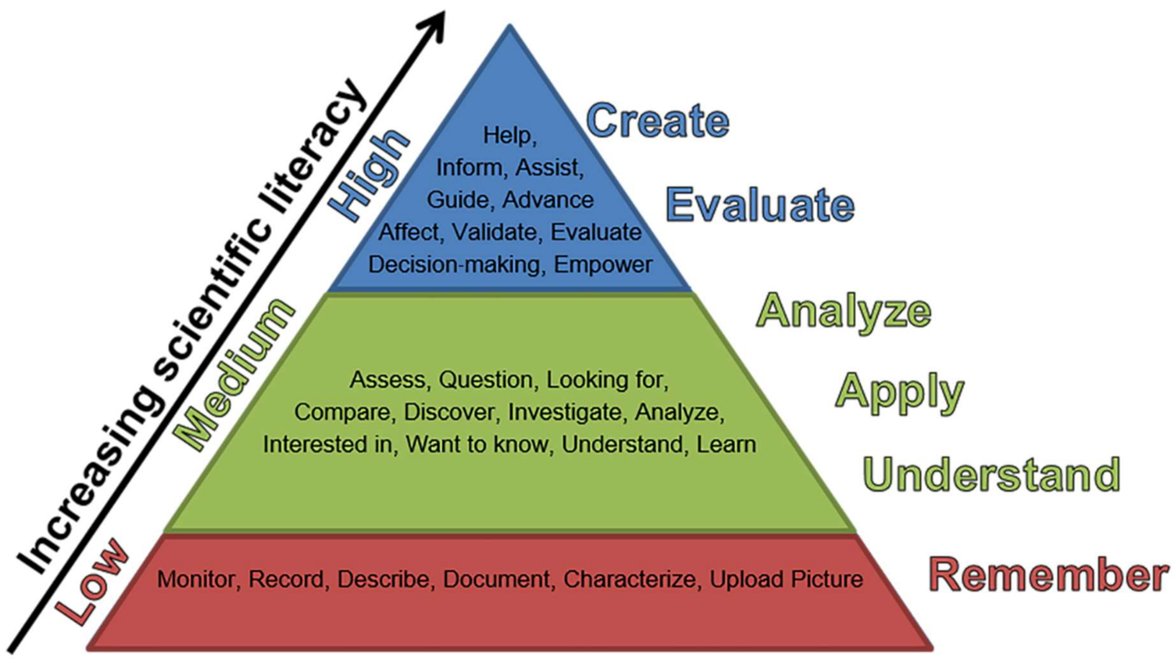

Figure 2.1: Bloom's Taxonomy: an educational framework used to classify the depth of knowledge as low, medium, and high. The words and phrases above represent the tasks of the citizen science projects on CitSci.org (modified from Bloom, 1956).

Research setting

CitSci.org is an online platform that supports citizen science projects (Newman et al., 2012). It is a free resource and therefore helps to alleviate some of the financial difficulties that citizen science projects often face by providing cost-effective data management, documentation, and sharing (Wang et al., 2015). It has been used by more than 750 projects since it was first developed in 2007. Project managers create project pages where they provide a general overview of the project and define goals and tasks. They can also add links to other webpages that often further describe projects. Project managers can recruit and communicate with volunteers on CitSci.org. There is also a means by which data collection protocols can be developed and shared with other citizen science projects. Once a volunteer joins a project, they upload data to CitSci.org using the protocols developed by the project managers. Project managers and volunteers can also perform preliminary analyses of their data on CitSci.org. Because CitSci. org has these different functions and governance capabilities, it can support a diverse array of projects (Lynn et al., 2019) and in turn can collect metadata across projects to conduct informative meta-analyses (Newman et al., 2012). CitSci.org is an appropriate platform for such a study because it can support studies across an array of projects with different types of volunteer tasks.

Data collection

In this study we included environmental and ecological projects on CitSci.org that were active between June 2016 and June 2018. Any project that temporarily ceased activity between these dates but resumed after data were extracted for the study was excluded. This resulted in 165 projects that were included in our analysis. Of these 165 projects, some projects were created under the same umbrella organization and shared the same descriptions. In these instances, they were counted as a single project. This reduced our total number of unique project descriptions to 152. Each project on CitSci.org has a profile page on which a primary project description is provided by the creators. Project managers also have the option to provide defined metadata attributes such as goals, tasks, external website, study extent, status, privacy, sampling design, QA/QC (quality assurance/quality control), QA/QC description, and organization. Project descriptions and described metadata attributes were extracted for analysis.

Some projects include hyperlinked external websites that further describe relevant metadata attributes of the project; these were included in our analysis. Only websites that were hyperlinked in the main project descriptions or within the metadata attribute fields described above were included. Websites often contain information other than what pertains to the project, so only information about the project within the hyperlinked domain was included. Although some websites provide links to other website domains with more information on the project, these were excluded from analysis. Within the website domain, specific data collection protocol documents and data portals that require a login were also excluded. Of the 165 projects in the study, 34 had website links that met the criteria for additional inclusion. Again, the projects that shared the same website were analyzed as a single project. This resulted in a total of 23 unique external websites that were included in our analysis.

Data analysis

We used an inductive coding process to identify emergent themes, while using Bloom's taxonomy as a sensitizing concept (Bowen, 2006; Charmaz, 2006). In other words, we recognized that citizen science tasks could be classified by levels of cognition using Bloom's taxonomy; however, we did not anticipate all the tasks that would be described, nor how often they would appear in our analysis. We started by identifying potential codes for random subsets of 10% of the project descriptions. As we considered these data, it became clear that tasks for volunteers varied across levels of cognitive expectations, warranting the use of Bloom's taxonomy to inform further coding (Bloom, 1956). Project descriptions on CitSci.org and text of hyperlinked websites were analyzed through qualitative content analysis (Elo & Kyngäs, 2008).

Volunteer tasks, as described by project managers, were coded by cognitive level as low-, medium-, and high-order tasks (Figure 2.1). High-order tasks were those that were intended to benefit or enact change on the environment (e.g., to take actions to reduce erosion or to help something). Medium-order tasks were those that intended to help volunteers understand the environment (e.g., understand or question). Finally, low-order tasks were intended to ask volunteers to describe or otherwise measure aspects of the environment (e.g., upload a photo or measure the pH of water). Some projects asked for public opinion only, rather than for any other task to be performed. We restricted our coding of each project description to a single code consisting of either low, medium, or high. If project descriptions described multiple levels of tasks, we coded them to be at their highest level of Bloom's taxonomy. Therefore, a project description that described both low and medium tasks was coded only as medium.

Coding also distinguished between an intended task and a performed task. Often, project descriptions included related actions for which the intended task had a larger scope with fewer explicit actions. The performed task was the means by which the intended task could be accomplished; this usually included specific action steps. In other words, the volunteer was expected to accomplish the intended task by doing the more specific performed task. For example, a volunteer might *help* by *collecting* water-quality data. In this case, it is intended that the volunteer *helps*. The specific task that they are expected to perform to accomplish this is *collecting* water quality data. For our analysis, the intended task was labeled as *helping*, and the performed task was labeled as *collecting*. Although the distinctions between intended and performed tasks may at first appear to be subtle, they are important because some tasks are related to others. This coding process was necessary to distinguish between what project managers expect citizen science volunteers to accomplish (the intended task) and how they are expected to accomplish it (the performed task). This distinction is rooted in educational psychology research that considers both intended learning outcomes and performed tasks (Anderson & Krathwohl, 2000).

Volunteer tasks are meant to help the project, but all projects differ in their intended outcomes. We therefore considered who or what was benefitting from the indicated volunteer tasks. Each time a new beneficiary code was identified, all projects and website materials were re-coded. Benefits identified included: no described benefit, the environment, social ecological systems, volunteer awareness or knowledge, volunteer empowerment, the citizen science project itself, the community, and the scientific community. The environment and social ecological systems were considered separately because in the citizen science literature, the focus is often on management and policy outcomes rather than on direct environmental benefits (e.g., McKinley et al., 2017; Shirk et al., 2012). Furthermore, social ecological benefits related to management (Shirk et al., 2012) differ from community benefits that can increase local social capital (Conrad & Hilchey, 2011) or promote community health (Den Broeder et al., 2017). By separating the benefits to volunteer awareness/knowledge from the benefits to volunteer empowerment, we sought to tease apart the degree of participation described by volunteer tasks. This distinction is important in the environmental education literature in which empowerment through skills and meaningful participation are viewed as the highest level of environmental education, whereas increasing awareness and knowledge constitute the lowest levels (UNESCO, 1978).

To ensure trustworthiness of our analysis, we engaged in iterative coding and peer and expert debriefing (Creswell & Miller, 2000; Nowell et al., 2017; O'Connor & Joffe, 2020). The first author developed the initial codes and codebook, and engaged in inter-rater coding with the third author, who was trained in how to use the codebook, and independently coded a randomly selected 20% of the extracted content (as suggested by O'Connor and Joffe, 2020). The initial inter-rater coding reliability was 89%, but after expert debriefing, the codebook was revised (Appendix A), and 100% agreement was obtained between two coders. Three months after the initial round of coding took place, the first author re-coded the project descriptions and websites to ensure the reliability of the codes through intra-rater coding, and 93% agreement was found. Each discrepancy was double-checked and evaluated through peer debriefing until our team reached consensus.

Results

We found that most projects on the CitSci.org platform described volunteers as performing tasks that we classified as low order and described benefits to citizen science projects. Our analysis suggests that project managers describe citizen science activities as those that engage volunteers in limited participation in the scientific process.

Volunteer tasks

Descriptions of volunteer tasks were categorized as intended and performed and were calculated across tasks found in CitSci.org project descriptions (n = 152) and hyperlinked website materials (n = 23; Table 2.1; Figure 2.2). Low-, medium-, and high-order tasks were intended respectively in 74, 17, and 52 of the 152 projects on CitSci.org. Two projects described volunteer opinions. When performed tasks were considered, low-, medium-, and high-order tasks were found in 136, 1, and 5 projects of the 152 projects on CitSci.org. Two of the projects were coded as a solicitation of volunteers' opinions. No intended tasks were found in seven of the projects, and no performed tasks were found in eight of the projects. One project suggested that volunteers could

Table 2.1: Intended and performed tasks

Task Code	CitSci.org				Website				Example
	Intended count	Intended percent	Performed count	Performed percent	Intended count	Intended percent	Performed count	Performed percent	
Low order	74	48.7%	136	89.5%	5	21.7%	15	65.2%	“Observe and record flora” “Take a photo of the landscape” “Monitor local intermittent stream channels”
Medium order	17	11.2%	1	0.7%	0	0.0%	0	0.0%	“Evaluate the status of the species” “Assess the success of restoration efforts” “Compare creek flow season to season”
High order	52	34.2%	5	3.3%	17	73.9%	7	30.4%	“Help inform future tree planting” “To clean up [location] and all streams that flow through [location]” “Improve sections of wetlands, rivers, lakes, or estuaries”
Opinion	2	1.3%	2	1.3%	0	0.0%	0	0.0%	“Fill out our survey” “Gathering citizen science inputs on what ecosystem attributes are valued”
No task	7	4.6%	8	5.3%	1	4.3%	1	4.3%	“[Project name], [location]”

help the project, a high-order intended task, but did not explain how it should be done; hence the project was coded as having a high-order intended task but with no performed task.

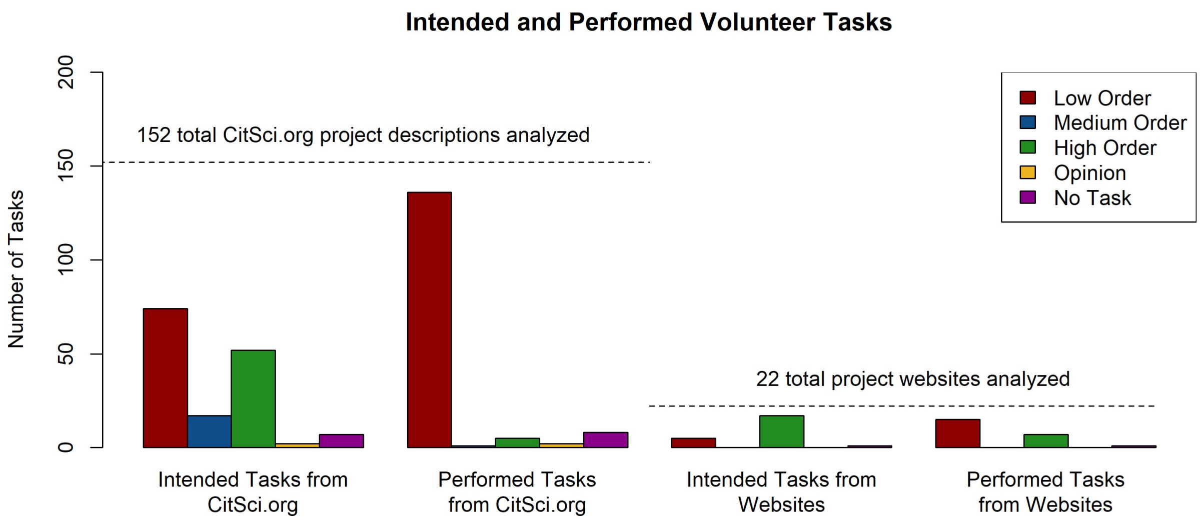

Figure 2.2: Intended and performed volunteer tasks. Presented according to cognitive level (low, medium, and high-order tasks), the solicitation of an opinion, or no task expectations.

Intended and performed tasks were also identified in websites that were hyperlinked on CitSci.org project pages. Low-, medium-, and high-order tasks were intended respectively in 5, 0, and 17 of the 23 project websites. No projects asked volunteers to record their opinions. However, 15, 0, and 7 of 23 project websites asked volunteers to perform low-, medium-, and high-order tasks, respectively. None of the websites asked for an opinion. Of the 23 hyperlinked website materials, only one had no discernable task described.

We analyzed the breakdown of intended tasks by performed tasks on CitSci.org and hyperlinked websites according to cognitive level, the solicitation of just an opinion, and no task expectation (Figure 2.3). On CitSci. org, all the project descriptions that were coded as intending low- or medium-order tasks were coded as performing low-order tasks. Of the 52 intended high-order tasks, 45 were coded as low-order performed tasks, 1 was coded a medium-order performed task, 5 were coded high-order performed tasks, and 1 had no performed task. The two projects that requested opinions from volunteers and the seven projects that had no intended task had alignment between intended and performed tasks.

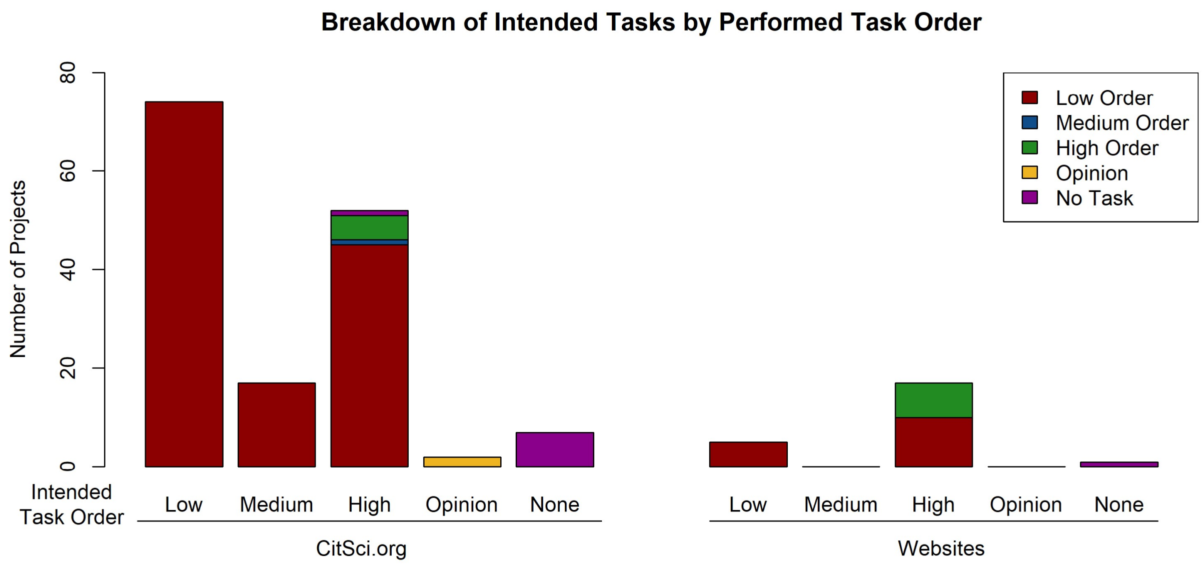

Figure 2.3: Breakdown of intended tasks by performed task order. Misalignment of intended and performed tasks expected of citizen science volunteers.

We conducted a similar analysis on the text obtained from hyperlinked websites. All five of the project websites that intended low order tasks were also coded as having low-order performed tasks. Of the 17 websites that intended high-order tasks, 10 were coded as having volunteers perform low-order tasks and 7 were coded as having volunteers perform high-order tasks. The one project that had no intended task was also coded as having no performed task. There were no intended or performed tasks coded as medium order or asking for an opinion on the websites.

Beneficiary of tasks

We recorded who or what benefitted from the tasks that volunteers performed for each project using one of eight codes: the citizen science project, the environment, the social ecological system, the scientific community, volunteer awareness or knowledge, volunteer empowerment, the local community, or no described benefit (Table 2.2; Figure 2.4). Of the 152 project descriptions on CitSci.org, 80 are described as benefitting the citizen science project, 25 as benefitting the environment, and 24 as benefitting social ecological systems. Benefits to the scientific community are described in 17 project descriptions. Volunteer awareness or knowledge and volunteer empowerment are described as benefits in 11 and 7 projects respectively. Benefits to communities are described in 7 projects, and 16 projects have no described benefit.

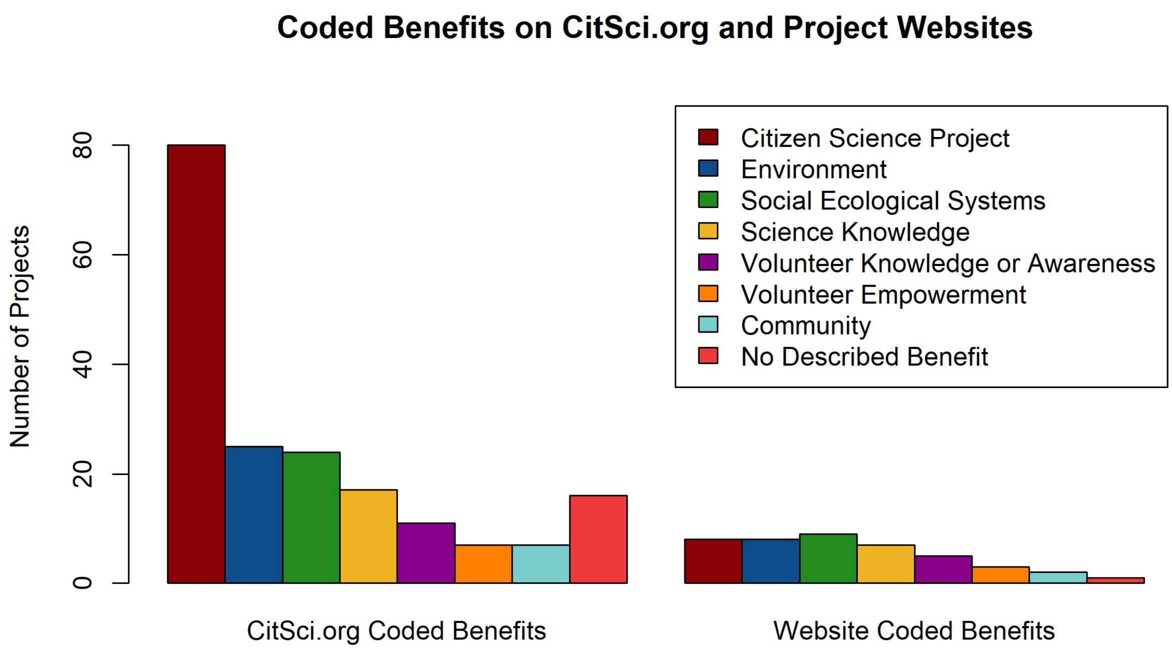

Figure 2.4: Coded benefits on CitSci.org and project websites. A comparison of who or what benefits from volunteer tasks according to project descriptions on CitSci.org and associated project websites.

Project beneficiaries were identified and coded from hyperlinked websites. Eight of the 23 websites describe benefits to the citizen science project, eight describe benefits to the environment, and nine describe benefits to the social ecological systems. Seven websites describe the benefits of the project to the scientific community. Volunteer awareness or knowledge is described as a

Table 2.2: Benefits codes

Benefit Code	CitSci.org		Websites		Example
	Count	Percent	Count	Percent	
Citizen science project	80	52.6%	8	34.8%	"You can help us understand whether this seaweed has a negative or positive impact on our [location] coastal ecosystems."
Environment	25	16.4%	8	34.8%	"This project supports aquifer recharge, rainwater harvesting, and salmon recovery in [watershed]."
Social ecological systems	24	15.8%	9	39.1%	"Baseline studies, like [project name], of populations are crucial for management decisions."
Scientific community	17	11.2%	7	30.4%	"These samples will help small game biologists better understand age and sex demographics of game bird populations."
Volunteer awareness or knowledge	11	7.2%	5	21.7%	"Increase public awareness of ecological value of maintaining healthy vernal pools."
Volunteer empowerment	7	4.6%	3	13.0%	"[Project] is a water quality data collection and education program that seeks to increase awareness about the importance of water quality and promote stewardship of [location's] aquatic resources."
Community	7	4.6%	2	8.7%	"They sought to ... improve city planning, management, and human health."
No described benefit	16	10.5%	1	4.3%	"[Project name], [location]"

benefit in five projects, while three websites describe volunteer empowerment as a benefit. Two websites describe benefits to the community, and on one of the websites there are no described benefits.

Discussion

Our content analysis revealed that only a small proportion of the environmental and ecological projects on the CitSci.org platform expect volunteers to engage in higher-order tasks. Instead, most of the projects we examined describe low-order tasks for their volunteers to perform. We argue that our analysis provides an opportunity for citizen science managers and researchers to further examine claims about the value of participation on volunteer scientific literacy.

Characteristics of higher-order tasks

On CitSci.org, five of the 152 total projects (3%) expect volunteers to perform high-order tasks compared with seven out of 23 websites (30%). Only one project is coded as describing high-order tasks on both their CitSci.org project description and their website; this project asks volunteers to educate the public about what they learned. Our findings are corroborated by two recent studies. A survey of 77 citizen science project managers reported that volunteers were mostly data collectors who rarely engaged in stewardship or communication activities (Wiggins & Crowston, 2015). Another study of volunteers from six different citizen science projects revealed that while general communication about participating in the project was common, communication about findings of the research was uncommon (Phillips et al., 2019).

There were two noteworthy characteristics across the 11 projects (4 from CitSci.org, 6 from websites, and 1 from both) with expectations that volunteers perform a higher-order task. First, projects that engage volunteers in performing high-order tasks are more likely to describe volunteers as having a more direct sphere of influence on the discussed outcome. Eight describe benefits to the environment directly, four of which also describe benefits to social ecological systems. Citizen science is often described as benefitting social ecological systems like management and policy as opposed to benefitting the environment directly (McKinley et al., 2017; Shirk et al., 2012). When social ecological benefits are described, however, volunteers are described as one step removed from their actions benefitting the environment. Their actions might benefit (support) management or policy, which then goes on to benefit the environment, but are not described as engaging in actions that directly benefit the environment. That said, benefitting the environment is a common motive for volunteers in environmental citizen science (Alender, 2016; Geoghegan et al., 2016).

Furthermore, none of the 11 projects suggest benefits to the citizen science project itself, the most commonly described benefit. Benefits to the citizen science project may have an eventual impact on other outcomes, but the language used to describe volunteer tasks does not directly suggest these outcomes. When projects describe volunteers as indirectly imparting outcomes, they maintain the primary discourse related to public participation in environmental issues: green governmentality (Lassen et al., 2011). Green governmentality maintains top-down structures in that the public provides help to experts, who then go on to enact change. However, civic environmentalism is a less common discourse in which members of the public drive decision-making and enact change on their own (Bäckstrand & Lövbrand, 2006). Although project managers assigning tasks for volunteers will naturally maintain top-down green governmentality, when direct benefits are described, discourse shifts toward civic environmentalism because volunteers more directly impart project outcomes.

Second, these projects describe not only higher-order tasks, but also higher-level benefits to volunteers. Four of the eleven projects describe benefits to volunteer empowerment, while none of them describe increasing volunteer awareness or knowledge. This distinction is rooted in environmental education literature. The Tbilisi Declaration was drafted at the first Intergovernmental Conference on Environmental Education to outline the role and importance of environmental education for sustainability. Increasing awareness and gaining knowledge were viewed as the lowest levels of environmental literacy. However, learning the skills to solve environmental problems and thorough participation in environmental problem solving have been, and still are, viewed as the highest level of environmental literacy (McBride et al., 2013; UNESCO, 1978). Therefore, several of the projects that engage volunteers in higher-order tasks also, whether purposefully or inadvertently, describe activities that are in alignment with more holistic and comprehensive forms of environmental education.

The 11 projects that ask volunteers to perform higher-order tasks may intend to empower volunteers, yet this cannot be claimed without follow-up interviews with the project leaders. However, a cross-case analysis of five volunteer biological monitoring projects revealed that level of participation and empowerment were not connected (Lawrence, 2006). Volunteers participating in contributory projects were empowered to collect data more independently and more rigorously, and participants in a contractual project were empowered to protect local economically and culturally important resources. While projects on CitSci.org that intend higher-order tasks may involve volunteers in diverse participation and use language that more directly describes benefits, we cannot speculate about whether this is purposeful or if empowerment of volunteers actually occurs. Further research is needed to understand how language may affect volunteer empowerment.

Low-order tasks in citizen science

Low-order tasks are those that ask volunteers to describe or otherwise measure the environment, often through activities such as monitoring the presence or absence of a species, collecting samples, or uploading a picture. Because each of these tasks involves collection, most of the projects on CitSci.org are considered contributory (Shirk et al., 2012). These findings are supported by other studies that indicate that citizen science is primarily contributory (e.g., Bela et al., 2016; Pocock et al., 2017) and focuses on data collection (Phillips et al., 2019). It is important to note the distinction between task complexity and task order as per Bloom's taxonomy (NASEM, 2018; Wiggins & Crowston, 2015). Performed tasks may be complex (e.g., identifying hard-to-identify species or taxa, measuring transects or nested plots, and measuring and collecting verification samples for subsequent laboratory analysis) yet still be coded as low order, given that they require volunteers to describe or measure the environment rather than analyze data or otherwise critically reflect on the meanings or interpretations of results.

Previous research on contributory citizen science suggests that these projects may not increase public scientific literacy compared with those projects that engage volunteers in deeper degrees of participation (Bonney et al. 2016). In fact, a content analysis of 327 project websites revealed that if volunteer learning objectives were defined, they were usually low order (Phillips et al., 2018). This is important because environmental education research indicates that participation in low-order tasks alone is insufficient to motivate pro-environmental behaviors changes (Balgopal and Wallace, 2009) that make up the highest level of scientific literacy (Bloom, 1956; UNESCO, 1978). Because many volunteers tend to be college educated, or even retired scientists (Geoghegan et al., 2016), they exhibit high levels of scientific literacy prior to participating (Martin, 2017). There are different types of scientific literacy that can be improved upon; for example, one can have high ornithology literacy but low watershed literacy (Uno and Bybee, 1994). Therefore, individuals who are generally scientifically literate can still benefit from engaging in citizen science activities. Consideration of how project design affects scientific literacy is also important because learning is another common motive for participation (Domroese & Johnson, 2017).

Contributory citizen science and engagement in low-order tasks can result in positive outcomes for both volunteers and the scientific community (Shirk et al., 2012). For example, volunteers often report high satisfaction and learning as a result of participation (e.g., Trumbull et al., 2000; Wright et al., 2015). Volunteers sometimes do not want to engage in more than data collection, suggesting that they are satisfied with engaging in low-order tasks (Lewandowski et al., 2017; Martin et al., 2016; Phillips et al., 2018). Furthermore, contributory citizen science has benefited the scientific community through expanded temporal and geographic sampling scale (Cooper et al., 2007), cost-effective data collection and analysis (Dickinson et al., 2010), and peer-reviewed publications, whether explicitly mentioned (Kullenberg & Kasperowski, 2016) or not (Cooper et al., 2014). We, by no means, intend to undervalue the contributions of contributory citizen science or its dedicated volunteers.

We do, however, wish to push the field of citizen science to consider two critiques that can be learned from political theory and from participatory democracy. First, common discourse often serves to perpetuate current norms and values, meaning that how we communicate about a phenomenon today affects how the phenomenon will occur in the future (Young, 2001). Therefore, it is possible that describing low-order tasks now might affect how future citizen science projects are planned and designed. We recognize that our analysis is limited in that we studied projects only on CitSci.org and therefore cannot generalize to the greater state of communication regarding citizen science. However, this serves as a first step toward interesting questions for future citizen science and communication researchers to consider. Second, programs— in this case, citizen science projects—should be designed with non-dominant groups in mind (Kadlec & Friedman, 2007; Sanders, 1997). Therefore, even if most citizen science volunteers tend to be generally scientifically literate, project design should focus on how it can benefit and be accessible to individuals with lower or different types of scientific literacy (NASEM, 2018). Only then can we expand the stakeholders who benefit from engaging in citizen science.

Project managers and volunteers work together in citizen science communities of practice. There are different models to evaluate the degree to which they work together (Shirk et al., 2012). In more traditional scientific communities of practice, scientists ask and answer research questions, while technicians perform tasks that help answer the scientists' research questions and accomplish the scientists' goals (Doing, 2004; Shapin, 1989). Hence, when the project managers describe low-order tasks for volunteers to perform in contributory projects and define project benefits that may misalign with volunteer motives for participation, they are described as citizen technicians rather than citizen scientists.

Limitations

First, we did not confirm the findings of this research with project managers through interviews; we relied on content analysis only. It is possible that the citizen science projects in our analysis have volunteers perform higher-order tasks than were described. Second, although the coding in this content analysis was based on initial agreement using over 20% of the data, rather than 100%, as is suggested by Krippendorff (2004), we followed the protocols advocated by O'Connor and Joffe (2020). Third, our analysis was designed to assume that the person who created a CitSci. org project page was the project manager; however, members of the public may have developed their own collegial projects on CitSci.org, indicating that they are engaging in more parts of the scientific process than just data collection, as our results may suggest. Fourth, CitSci.org does not vet projects, meaning that there are no minimum qualifications for people to create projects. While the lack of a vetting process is appealing to newcomers and is inclusive, especially to those involved in projects with few resources, it may also result in busy, time-constrained project managers paying less attention to the ways in which they describe their projects. Fifth, project managers may spend very little time describing their projects on a platform because they have already described their projects in detail elsewhere. Although we examined external website content descriptions to avoid this bias, detailed project descriptions external to CitSci.org descriptions may still exist that we were unable to obtain. Finally, we recognize that the citizen science projects used in our analysis may not be representative of all citizen science projects.

Conclusions

Despite some limitations, our findings suggest that the ways citizen science projects on CitSci.org communicate about the tasks their volunteers perform tend to describe citizen scientists as citizen technicians and tend to categorize most projects as contributory. Although those engaged in citizen science projects may informally discuss the limited role that volunteers play in scientific inquiry, we are unaware of other systematic analyses of online citizen science materials. We reiterate that CitSci.org is just one citizen science platform and is not representative of the entire citizen science community. Yet, this study is a first step in understanding how people communicate about citizen science. Further research is necessary to understand the broader scope of communication about citizen science and to support or refute these findings by validating these results with project managers and volunteers. There is a need to better understand how described benefits affect volunteer recruitment, retention, or future project design modalities (e.g., citizen science projects remain focused on a contributory model). These findings suggest that there may be a missed opportunity to increase volunteer scientific literacy in citizen science and that improved science communication skills among managers describing these endeavors may play an important role in shaping the citizen science community of practice. We conclude that communication on CitSci.org is one that largely describes projects as contributory, describing low-order tasks for volunteers. How citizen science project managers communicate about their projects may have implications for current and future volunteer engagement, volunteer agency to enact environmental change, and perceptions of citizen science broadly. These implications can hinder public scientific literacy and therefore public engagement in behaviors that would ultimately be beneficial to the environment.

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CHAPTER 3

WHAT'S IN A NAME? THE PARADOX OF CITIZEN SCIENCE AND COMMUNITY SCIENCE[2]

Introduction

Both environmental science and society benefit when the public is engaged in environmental research and monitoring endeavors (Adler et al., 2018; Cooper et al., 2007; Kosmala et al., 2016). Over the past two decades, citizen science has developed as a model for accomplishing this. Citizen science refers to initiatives that involve members of the public in any part of scientific investigations but most commonly in the collection of data (Lin Hunter et al., 2020). The term "citizen science" was separately coined by Alan Irwin in the United Kingdom to describe engaged citizenry and by Rick Bonney in the United States, referring to members of the public collecting data on behalf of scientists (Bonney, 1996; Irwin, 1995). Though the term was initially intended to describe a citizen scientist as a "citizen of the world" (Bonney, 2021, p. 451), in an age of heightened discussions on diversity, equity, and inclusion, some researchers and practitioners have recently challenged whether using the word, "citizen," is inclusive (Cooper et al., 2021).

This discussion stems from confusion on how to describe the field, its participants, and their practices (Auerbach et al., 2019; Eitzel et al., 2017; Heigl et al., 2019) from which a "plurality and diversity" of conceptions of citizen science has emerged (Haklay et al., 2021, p. 22). Project leaders that engage members of the public that are not citizens in the country where

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the project takes place may, for example, feel uncomfortable referring to their project as a *citizen science* project and their participants as *citizen scientists*, echoing debates from the field of citizen journalism (Campbell, 2015). To deviate from the potentially exclusionary nature of the term *citizen science*, many project leaders have rebranded their activities as *community science* (Bonney, 2021; Cooper et al., 2021; de Lange et al., 2021).

A key limitation of this discussion is that most papers on terminology and rebranding are opinion pieces, essays, and commentaries that are not informed by empirical research (Bonney, 2021; Cooper et al., 2021; de Lange et al., 2021; Eitzel et al., 2017; Heigl et al., 2019). This prevents citizen science project leaders from being able to make evidence-based decisions about how to describe their projects. Over the past few decades, calls for evidence-based practice, especially in conservation fields, have been common (Sutherland et al., 2004), and natural science research is increasingly available to and used by managers making decisions (Sutherland & Wordley, 2017). Yet the same links between research and practice have not been as common for social science work (Bennett et al., 2017) nor for semantically important terminology decisions. The current rebranding effort is a clear example of this disjuncture. To address the need to understand perceptions about (re)branding citizen science, we surveyed those engaged in projects branded as both citizen and community science programs to determine if there is, indeed, a conflict of perceptions. Our goals were to describe how survey respondents perceive project outcomes and citizen and community scientists' tasks associated with the different terms, as well as their motivations for describing a project with a certain name.

Methods

Survey development and reliability

We developed a survey using Likert scale questions about perceptions of project outcomes and tasks associated with the terms, citizen science and community science. We recruited individuals (n = 20) from the citizen and community science community to pilot the survey in our efforts to ensure survey construct and content validity. In addition, to test the reliability of the survey instrument, these individuals took the same survey a second time, a week after taking it the first time (Vaske, 2008). Most outcome variables had a high level of internal consistency and items that reduced internal consistency were removed from the final version of the survey (Table 3.1). Items that were not internally consistent were altered, re-piloted, and included only after they were found to be reliable. We calculated Pearson correlations and found that there was high response reliability (Table 3.1). The survey instrument is available in Appendix B.

Table 3.1: Survey reliability. The first pilot survey had n = 20 participants. Items that were not reliable were reworded in a second pilot (*) of n = 10 participants.

Variable	Pilot Cronbach's α	Pilot Pearson's correlation (*p*)	Pilot Pearson's correlation (*r*)	Final survey Cronbach's α
Answer research questions	0.73	<0.001	0.79	0.75
Increase participant scientific literacy*	0.90	<0.001	0.92	0.89
Inform conservation	0.75	<0.001	0.75	0.91
Inform management	0.75	<0.001	0.84	0.90
Inform policy*	0.90	0.001	0.88	0.92
Produce trustworthy data	0.79	<0.001	0.88	0.86
Promote collaboration	0.78	<0.001	0.72	0.85
Promote inclusion*	0.89	0.007	0.79	0.90

Survey distribution and study population

The survey was distributed to groups engaged in citizen science, community science, or other types of science that engage members of the public across 10 weeks, from February 17th to April 30th, 2021. We shared the survey on the Citizen Science Association listserv, in the CitSci.org newsletter, and through Twitter and asked respondents to share the link with their networks. Participants (n = 180) were involved in various and often multiple aspects of citizen and community science and included 85 project coordinators, 69 scientists who use data collected by citizen and community scientists, 57 citizen and community science participants, 33 trainers of project coordinators, and 40 scientists who research the science of citizen science. Most participants identified as white (139), while 11 identified as people of color. The majority of participants were women (107), while 40 identified as men, and four as nonbinary. In this paper, to reduce confusion, we use the phrase “citizen and community science participants” when referring to citizen or community scientists and the term “survey respondent” when describing those from whom we collected survey data.

Data analysis

We repeated the reliability analysis on the quantitative outcome variables of survey responses to ensure internal reliability. All items were reliable for each variable except for *promoting inclusion*, but by removing one item, we ensured internal reliability of all constructs (Table 3.1). We conducted independent-samples Kruskal Wallis tests for nonparametric data to analyze the differences between *citizen science* and *community science* and perceptions by various demographic groups.

We conducted a content analysis on open-ended responses (Elo & Kyngäs, 2008). Emergent themes included how well known each term was, who initiated the project, whose goals were addressed, who the citizen and community science participants were, level of citizen and community science participant involvement, and the inclusivity of the term. To ensure the trustworthiness of our analysis, we evaluated intercoder reliability. We coded a random subsample of 25% of the data separately, resulting in 97.32% inter-coder agreement. Differences were addressed, and the codebook was updated accordingly (O'Connor & Joffe, 2020). The final codebook was used to code the remainder of the data (Appendix C). Final codes were tallied and analyzed using chi-squared tests.

We recognize that our views and identities affect how we interpret the data, but we have tried to limit our biases through peer and expert debriefing. The first author is a graduate student studying citizen and community science. The second author is a citizen and community science researcher and the founder and director of CitSci.org, which supports both top-down and bottom-up citizen and community science efforts. The third author uses discourse analysis and participatory action research to study environmental literacy. The first and third authors are daughters of naturalized immigrants to the United States, which may have shaped our perceptions of whether the term "citizen" is problematic or not.

Results

Familiarity and acceptance of terms

People described higher familiarity with and acceptance of the term, *citizen science,* than *community science* (Figure 3.1A). Specifically, people were more likely to call a project *citizen science* because the term was better known and accepted by others than *community science* ($X^2(1) = 58.025$, $p < 0.001$, $\phi = 0.831$). Furthermore, survey respondents were also more likely to call a project *citizen science* than *community science* because of their own familiarity or unfamiliarity with the various terms ($X^2(1) = 34.000$, $p < 0.001$, $\phi = 1.000$). *Citizen science* was also described as being more well known and accepted by funding agencies ($n = 4$), government agencies ($n = 4$), the scientific community ($n = 7$), and outside of the citizen science community ($n = 2$). *Community science* was only described as being well known and accepted by the scientific community by one person.

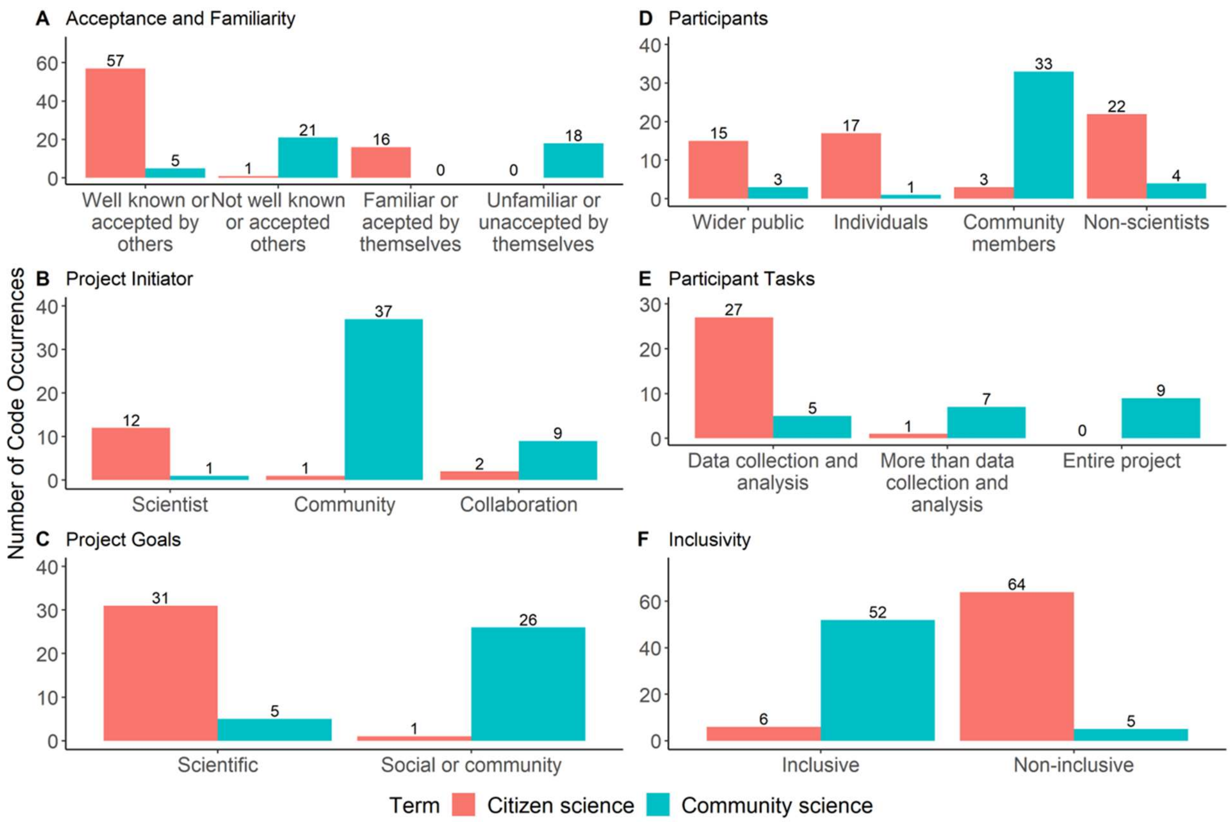

Figure 3.1: Content analysis results for (A) how well known and accepted *citizen science* and *community science* are, (B) who initiates the project, (C) what types of goals are addressed, (D) who the volunteers are, (E) what the volunteers do, and (F) the perceived inclusivity of the term.

Top down and bottom up

Citizen science was more likely to be described as a top down, scientific initiative, while *community science* was more likely to be described as a bottom up, grassroots initiative. Survey respondents indicated that they were more likely to describe a project as *citizen science* when it was initiated by a scientist and *community science* when initiated by a community ($X^2(2) = 42.736$, $p < 0.001$, $\phi = 0.830$; Figure 3.1B). Survey respondents were more likely to describe a project as *citizen science* if it had scientific goals like answering research questions, whereas projects with community or social goals, like solving social ecological problems, were more likely to be described as *community science* ($X^2(1) = 41.921$, $p < 0.001$, $\phi = 0.816$; Figure 3.1C). The citizen and community science participants of the various projects were also described differently (Figure 3.1D). *Citizen science* participants were described as being involved on an individual basis or being part of the wider public or non-scientists, while *community science* participants were described as community members ($X^2(3) = 58.634$, $p < 0.001$, $\phi = 0.774$).

These findings were supported by an analysis of Likert scale questions and open-ended responses about participant tasks. Survey respondents perceived that asking research questions ($H(1) = 6.806$, $p = 0.009$) and developing hypotheses ($H(1) = 7.230$, $p = 0.007$) were more associated with *community science*, while analyzing data ($H(1) = 4.191$, $p = 0.041$) and analyzing samples ($H(1) = 4.262$, $p = 0.039$) were more associated with *citizen science*. Citizen science was also more associated with the outcome of answering new research questions ($H(1) = 7.806$, $p = 0.005$). Open-ended responses revealed that *citizen science* was more associated with data collection and analysis only, while projects that involved the public in more than data collection and analysis or the entire project lifecycle were more likely to be called *community science* ($X^2(2) = 28.201$, $p < 0.001$, $\phi = 0.759$; Figure 3.1E). In other words, it appears that *citizen science* was associated with determining the results of a project, while *community science* was associated with co-creating a project. Finding background information, designing methods, collecting data or samples, interpreting data, drawing conclusions, disseminating findings, and designing follow-up studies were all found to be non-significant. That said, those who had already rebranded or who were considering rebranding were equally likely as those who had not, to perceive *citizen science* as top down ($X^2(1) = 2.363$, $p = 0.124$, $\phi = 0.234$) and *community science* as bottom up ($X^2(1) = 0.006$, $p = 0.936$, $\phi = 0.010$).

Even though there appeared to be a clear distinction between the purpose of projects with these different names, survey respondents perceived overlaps between the two. Most commonly, survey respondents cited *community science* as being a type of *citizen science* (n = 14). Some described the terms as interchangeable or synonymous (n = 7). Very few people described that the two terms were completely different entities (n = 4) or that *citizen science* was a part of *community science* (n = 3).

Inclusion

Community science was perceived to be a more inclusive term than *citizen science* ($X^2(1) = 86.508$, $p < 0.001$, $\phi = 0.825$; Figure 3.1F). Those who gave a reason often cited immigration issues and the political nature of the word *citizen* as justification. Promoting inclusion was one of the only Likert scale outcome variables for which there was a significant difference. Informing management, informing conservation, informing policy, promoting collaboration, producing trustworthy data, and increasing scientific literacy were all non-significant variables when comparing differences between *community* and *citizen science*. *Community science* was perceived to more likely result in "inclusion in science" than *citizen science* ($H(1) = 4.345$, $p = 0.037$). Furthermore, all of the survey respondents who were part of rebranded projects were more likely to call a project *community science* ($X^2(3) = 49.630$, $p < 0.001$, $\phi = 0.547$), and those who had rebranded or were considering it were more likely to perceive project inclusivity outcomes than those who had not considered rebranding ($H(1) = 106.521$, $p < 0.001$). However, while this perspective was lost in statistical analyses, five survey respondents described *community science* as more exclusionary than *citizen science* because they perceived participation as requiring membership in a community.

Discussion

Conversations on the merits of the terms *citizen science* and *community science* have been centered in opinion pieces and commentaries, preventing project leaders from making evidence-based decisions on how to brand their projects. We sought to address this gap by surveying those involved in citizen and community science projects. We found that survey respondents perceived *citizen science* as being more well known and accepted, less inclusive, and driven by goals of answering scientific questions. *Community science*, on the other hand, was perceived by survey respondents as being less well known and accepted, but more inclusive, and driven by community desires to solve problems. Despite these seemingly opposite perceptions, survey respondents most commonly described *citizen science* as being an umbrella term encompassing *community science* (Figure 3.2).

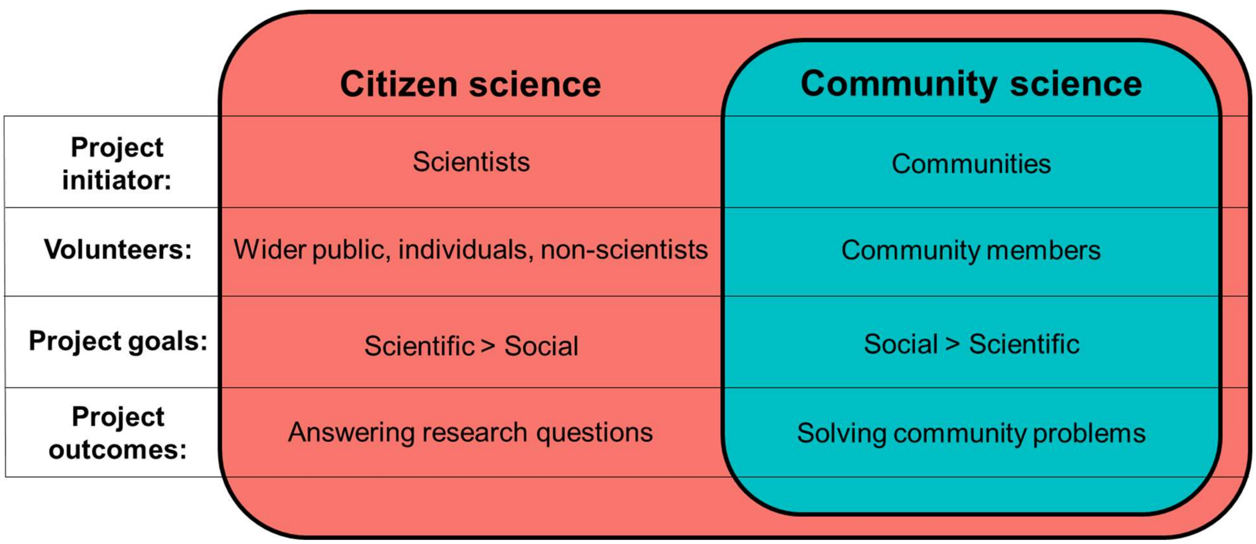

Figure 3.2: Differences and connections between *citizen science* and *community science*

Unlike much of the recent discourse about these terms (Bonney, 2021; Cooper et al., 2021; de Lange et al., 2021), our findings provide empirical evidence of perceptions of those engaged in either citizen or community science. The increasing number of publications using citizen science data (Cooper et al., 2014), academic journals dedicated to citizen science research, and professional societies established to share citizen science research and best practices, as well as the legal protections for citizen science (Cooper et al., 2021) are all indicative that citizen science is increasingly common and accepted. While some scientists are still skeptical of citizen science data (Kosmala et al., 2016), responses to open-ended questions indicated concerns that the field of citizen science would lose credibility if it was rebranded completely as community science. Yet, our data indicated that survey respondents did not perceive a difference in the scientific capacity of both types of projects to inform management, conservation, or policy. This suggests that survey respondents perceive that community science projects have similar capacity for scientific rigor as citizen science projects. Perhaps as scientists have more time to witness the positive social and scientific outcomes of community science, perceptions of rigor will match perceptions of potential.

Public participation in scientific research (PPSR) was the previous umbrella term for public engagement in science (Bonney et al., 2009). Previous frameworks for PPSR have described top-down and bottom-up initiatives (Shirk et al., 2012). The top-down nature of *citizen science* aligns with Bonney's original definition for engagement in data collection (1996), while the bottom-up nature of *community science* we identified in our analysis aligns with pre-existing frameworks on community science (Charles et al., 2020). That said, community can take on many forms, be it those living within physical proximity to one another, or those in a shared virtual space (Liberatore et al., 2018). Eitzel and colleagues indicated that *citizen science* may be replacing PPSR as the new umbrella term (2017). This aligns with the perception identified in our analysis that *community science* should be considered a distinct, subcategory of *citizen science*, and is supported by several, recent papers (Bonney, 2021; Cooper et al., 2021).

Citizen and community science practitioners are wrestling with the potentially exclusionary nature of the word "citizen" (Bonney, 2021; Cooper et al., 2021; Lowry &

Stepenuck, 2021). Thus, it is unsurprising that *community science* was perceived to be more inclusive than *citizen science*. Some warn that rebranding as *community science* ignores the previously existing, bottom-up perception of community science as a grassroots initiative (Bonney, 2021; Cooper et al., 2021). Regardless of whether survey respondents had rebranded, were rebranding, or were not considering rebranding, they all perceived that citizen science endeavors are top down, while community science endeavors are bottom up. What is unclear, though, is whether programs have chosen to rebrand as community science even though they maintain a top down structure.

While other terms like *public science* and *tracking science* have been suggested (Eitzel et al., 2017; Liebenberg et al., 2021) inclusivity issues in citizen science should be addressed beyond terminology. Intentional design, especially for underrepresented audiences, targeted recruitment, incorporating diverse knowledge systems, compensating citizen and community science participants, and sharing findings broadly are strategies that have been identified to address deeper inclusivity issues (Table 3.2; Cooper et al., 2021; Lowry & Stepenuck, 2021; Pandya, 2012; Pateman et al., 2021). Given that all the survey respondents who were part of rebranded projects switched from *citizen science* to *community science*, it will be interesting to see how such projects address increasing criticisms towards rebranding.

Table 3.2: Strategies for increasing inclusivity in citizen science beyond name changes
Co-create. A common strategy recommended for increasing the inclusivity of projects for those that are typically left out of projects is co-creation (Pandya 2012). Pandya developed a framework for diverse citizen science, suggesting that it required: 1) aligning projects with community goals, 2) shared leadership with communities, 3) working with communities throughout the entire project, 4) incorporating diverse knowledge systems, and 5) sharing findings broadly (2012).
Focus on the margins. Cooper and colleagues suggested that projects try "centering in the margins," or that they design projects specifically to be inclusive for marginalized communities (2021, p. 1388). They suggest a focus on environmental justice or projects that

had clear benefits to marginalized communities. This would also include targeted recruitment, especially for people of color and people with disabilities, compensating volunteers, and translating resources in languages other than English (Paleco *et al.* 2021; Pateman *et al.* 2021; Lowry and Stepenuck 2021).
Integrate social outcomes. Considering not only the scientific outcomes, but the social ones for volunteers and involved communities is important (Pateman *et al.* 2021). Up-front considerations of what communities hope to get out of a project and how they will benefit is key to working with diverse groups (Pandya 2012; Cooper *et al.* 2021).

Moreover, it is interesting that the majority of people questioned the inclusivity of the term *citizen* on the grounds of immigration specifically. Citizenship has historical roots that transcend modern immigration politics, which has excluded “women; the landless; the low-caste; or racial, religious, and ethnic minorities” from democratic participation in society (Jasanoff, 2004, p. 92). Moreover, Fan and Chen suggested that by using the term “citizen” specifically, that the field of citizen science invokes and must grapple with this historical political context (2019). That said, to our knowledge, no research on immigrants’ volunteer experiences has critiqued the term *citizen science*. What is known is that immigrant populations are most likely to volunteer for literacy and advocacy organizations (Nesbit, 2017; Perez et al., 2010; Sundeen et al., 2009). More research is needed on immigrant choices to volunteer for scientific or environmental organizations.

A major limitation of the study is associated with sampling. Due to challenges with recruitment, we are unable to confirm if our survey respondents are representative of the greater citizen and community science community. Given the demographics of survey respondents and the over-representation of white women, we assume that our sample may not be. Even though survey sampling through social media like Twitter can increase the number of survey respondents, sampling is often biased due to inability to reach all members of the desired population (Brick, 2011; Toepoel, 2012). Thus, some may question the generalizability of our results. However, given high chi square effect sizes indicating strong ($0.60 > \phi > 0.80$) and very strong ($0.80 > \phi > 1.00$) associations, at least within the population that was sampled, the findings are consistent (Kotrlik et al., 2011). We argue, therefore, that these results are important contributions to research on citizen and community science and have important implications for practitioners seeking to describe their projects. Because we did not ask survey respondents about whether they identified as a citizen of the country in which they participated in citizen and community science we can only speculate about the actual perceptions of non-citizens and pull from other studies on immigrants. Future studies may want to investigate this perspective more.

Conclusions

Interestingly, citizen and community science practitioners are increasingly rebranding projects from *citizen science* to *community science*. Such rebranding efforts suggest that the terms would be viewed as interchangeable since many projects change in name alone. Yet, our findings indicate that there are clear distinctions in how those who lead and participate in citizen and community science perceive the two terms. Specifically, they differ in perceptions of the familiarity and acceptance, the purpose and goals of the projects, and the inclusivity of the terms. This has created a paradox for those involved in citizen and community science in which actions fail to align with perceptions. Thus, there is not a conflict of perceptions, but there is a conflict between perceptions and practice. Yet, because of the lack of empirical data on the matter, citizen science project leaders have been incapable of making evidence-based branding decisions.

Based on our findings, we suggest that the term *citizen science* be used to describe projects that benefit scientists, while the term *community science* be reserved for grassroots projects that benefit community members. Rebranding the entire field of citizen science as community science could come with dire costs to the hard-earned credibility of citizen science initiatives, and those interested in addressing inclusivity issues should do so more thoroughly by changing more than their name alone (see Table 3.2 for examples). Finally, we suggest that *community science* be viewed as a distinct subcategory of *citizen science*. This will allow community science to benefit from the credibility of citizen science, and for citizen science to benefit from the inclusivity of community science. While they do so through different means, both citizen science and community science have the capacity to increase the accessibility of science. In addition, we recommend that those involved in citizen and community science remain open to the ever-changing nature of the field and terminology within it. We acknowledge that there are other emerging terms like “C science,” “public science,” and “participatory science” and that project leaders have options beyond the terms *citizen* and *community science* when describing their projects. We urge our colleagues to identify and implement practices to increase accessibility of science so that discussions on diversity, equity, and inclusion can become reality.

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CHAPTER 4

GOAL MISALIGNMENT AND THE NEED FOR INTENTIONAL DESIGN IN CITIZEN SCIENCE

Introduction

Citizen science has benefited species conservation and habitat management for diverse fields including marine biology (Kelly et al., 2020), entomology (Oberhauser & Prysby, 2008), and ornithology (Kobori et al., 2016). While some argue that these direct conservation outcomes only occur for a few organisms, like birds and butterflies, and are not equally shared across taxa (Feldman et al., 2021), researchers generally agree that the benefits of citizen science include indirect outcomes achieved through research in service to conservation, education, policy, livelihoods, and capacity building (Ballard et al., 2018). By engaging a cadre of citizen science volunteers, conservation research can expand its scope of study across geographic and temporal scales (Pocock et al., 2014), making possible studies that would otherwise be impossible for any single researcher to complete (Dickinson et al., 2010). There are also a range of positive social outcomes of citizen science. Engaging in citizen science increases participant scientific literacy (Peter et al., 2019), resulting in content knowledge gains and environmental stewardship behaviors (Santori et al., 2021). Additionally, the data collected through citizen science contribute to policy on local to global scales (Shanley et al., 2019), and participation in citizen science can motivate volunteers to engage in environmental advocacy related to local conservation issues (Forrester et al., 2017).

All of these conservation outcomes are important but balancing the many project expectations can be challenging for an individual citizen science project leader. Leaders often answer to a project director or scientist, while at the same time recruit, train, and manage volunteers (Anderson et al., 2020). Therefore, they not only have to balance multiple goals, but also multiple people's interests. This can be especially challenging given that scientists' engagement in citizen science is motivated by the desire to answer research questions (Golumbic et al., 2016). In this paper, we describe the alignment and misalignment of citizen science project leaders' goals and those of the organizations that employ them. By identifying this potential tension, organizations that endeavor to improve conservation and habitat management efforts can more effectively accomplish their goals.

Organizational psychologists use role conflict theory to explain that people experiencing inconsistent expectations in a role may experience stress, dissatisfaction, and limited capacity to carry out the duties of their role (Rizzo et al., 1970). This theory is used to examine the experiences of people who must balance expectations within their profession. For example, role conflict theory has been used to study women in science and how they balance professional and familial expectations (Polkowska, 2014), as well as the experiences of scientists shifting from academic to industry research settings (Sauermann & Stephan, 2013). Role conflict theory has also been used to measure the increase of employee stress and burnout when employers and employees have mismatched job priorities (Adiguzel & Kucukoglu, 2019). Therefore, we found this theoretical framework to be relevant and informative as we designed our study of citizen science leaders who wear multiple hats. Citizen science leaders must balance different groups' interests (e.g., scientists, collaborators, and volunteers) and different types of goals (e.g., scientific goals, social goals, and those related to the project itself).

Methods

We conducted a phenomenological study of citizen science leaders' experiences managing different goals. Phenomenology is a qualitative methodology that documents people's perceptions of a phenomenon through interviews (Khan, 2014). The researcher finds patterns across participant perceptions but does not aim to verify these with additional data. This study was approved by the Institutional Review Board at Colorado State University.

Participants interviewed

We interviewed citizen science leaders (*n* = 65) about perceived barriers and opportunities as they ran citizen science projects. All projects were related to the conservation and management of species and natural resources. Most of the participants were from the United States, though this was not a requirement for participation. Initial research participants were identified from the citizen science platform CitSci.org and then those interviewed recommended others to be contacted for participation through snowball sampling (Naderifar et al., 2017). The final sample included participants with various roles within their organizations who worked with projects covering a range of study topics and project structures (Figure 4.1).

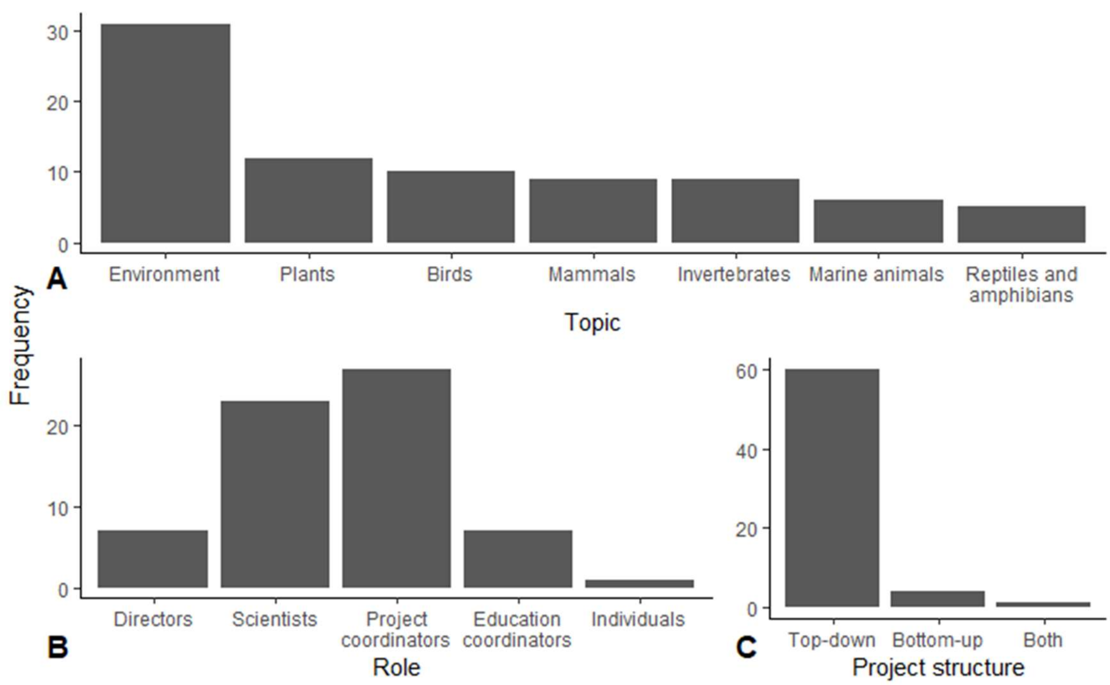

Figure 4.1: Number of interview participants that A) studied certain topics (based on categorization by Follet and Strezov (2015), B) occupied certain roles, or C) engaged in projects with certain structures.

Data collection and analysis

Our semi-structured interviews with citizen science project leaders occurred between March 16 and August 4, 2020. The interview protocol was informed by previous research in citizen science (Jacob & Furgerson, 2012) and included questions on project leaders' experiences with various stakeholders, their goals and how they prioritized and evaluated them, and the challenges they faced and how they addressed them (Appendix D). On average, interviews lasted 40 minutes, for a total of 43.5 hours. Interviews were conducted virtually through Zoom or over the telephone to accommodate a widespread sample and COVID-19 pandemic precautions.

We used an inductive thematic coding process to identify emergent themes within Dedoose (Braun & Clarke, 2006; Dedoose Version *9.0.17,* 2021). We used social ecological systems theory as a sensitizing lens as citizen science projects often have both social and ecological goals (Charmaz, 2006). Two authors iteratively coded the transcribed interviews to identify initial themes within five areas of interest (role, goals, challenges, solutions, evaluation; Appendix E). A deeper analysis of "goals," revealed nine goal-related sub-themes, which were subsequently collapsed into three themes: science goals, social goals, and citizen science goals related to the project itself (Table 4.1). We then looked for alignment between project leader's personal goals and their perceptions of their organizations' goals and categorized them as completely aligned, partially aligned, and misaligned (Table 4.2). While we focused on alignment between themes (i.e., science, social, and citizen science goals), we also looked at alignment within goal-related sub-themes. Finally, project leaders were categorized into cases according to their level alignment to look for patterns in their perceptions of their experiences.

Table 4.1: Thematic hierarchy for determining goals.

Goals codes	Sub-themes	Themes

Answer research questions Collect data Collect high quality data Conserve and manage species or habitat Improve data management Meet grant deliverables Publish papers	Data related goals	Science goals
Engage in decision-making Data use by policymakers Inform organizational advocacy behaviors	Data use	Social goals
Awareness Content knowledge Develop volunteer science identity Engage in advocacy behaviors Engage in stewardship behaviors Increase accessibility of science Scientific reasoning Scientific skills Volunteer communication about science Volunteer communication about project findings	Educational	
Building partnerships, collaborations, and social networks Connect people with nature Connect people with science Connect people with scientists Connect scientists with local or indigenous knowledge	Facilitate connections	
Empowerment Environmental justice Supporting livelihoods Supporting local economy	Other social goals	
Diversifying perceptions of who a scientist is Diversifying volunteer base	Diversify citizen science	Citizen science goals
Acceptance of data quality	Project legitimacy	
Expand the scope of the current project Maintain the project as is Project survival	Project sustainability	
Build community with volunteers	Volunteer management	

Develop volunteer identity with the project or organization Engagement Incorporate volunteer or community interests into the project Recruit volunteers Retain volunteers		

Table 4.2: Definitions and examples for type of alignment in the analysis.

Type of alignment	Definition	Examples for analysis of sub-themes	Example for analysis of themes
Complete alignment	Personal goals are the same as organizational goals or they explicitly mentioned perceiving that their goals aligned with their organization's	*Personal volunteer management goal:* recruit and retain volunteers *Organizational volunteer management goal:* recruit and retain volunteers	*Personal goals:* science and citizen science *Organization's goals:* science and citizen science
Partial alignment	Personal goals included in organizational goals, but organization also has other goals	*Personal data need goal:* collect high quality data *Organizational data need goal:* collect high quality data and conserve endangered species	*Personal goals:* social and citizen science *Organizational goals:* science, social, and citizen science
Misalignment	Personal goals not included in organizational goals	*Personal educational goals:* foster volunteer stewardship and advocacy behavior *Organizational educational goals:* increase awareness	*Personal goals:* science *Organizational goals:* social and citizen science

To ensure the trustworthiness of our analysis, we engaged in iterative coding and peer and expert debriefing (Creswell & Miller, 2000). The first and second authors iteratively co-coded sections of the data to compare agreement over codes (Braun & Clarke, 2006) while debriefing with the third and fourth authors. We co-coded 20 interviews before achieving an intercoder reliability of 90%, after which we clarified our codebook for a final time and re-coded all of the data till there was full agreement (O'Connor & Joffe, 2020).

Results

Our results address three questions: 1) what goals of citizen science efforts are; 2) how goals align for citizen science leaders and their organizations, and 3) what characteristics are of aligned, partially aligned, and misaligned citizen science efforts.

Identified goals

Project leaders described their personal goals for projects as well as their perceptions of their organization's goals. We identified nine goal-related sub-themes that were then collapsed into three overarching themes: scientific goals, social goals, and citizen science goals related to the project itself (Table 4.1). While personal goals for each theme were reported with approximately equal frequency, project leaders perceived that their organizations most commonly had scientific goals, followed by social and citizen science goals respectively (Figure 4.2).

Goal alignment

When examining the goal alignment within each of the nine sub-themes, we found a high level of misalignment (Figure 4.3). Specifically, 77% of project leaders experienced misalignment between their personal goals and their perceptions of their organization's goals within sub-themes. Fewer perceived that goals were partially aligned (n = 12) or completely aligned (n = 3). One project leader of a large-scale water monitoring program perceived that organizational goals were "just increasing scientific literacy [of regional residents] to get more people understanding freshwater issues." However, her own goals were different. "Personally, [...] I think our goal is to actually get communities involved in decision making, getting good data, and being able to advocate for themselves." This project leader believed that she and her organization shared educational goals but that her organization focused on increasing awareness and content knowledge, while she aimed for behavior change.

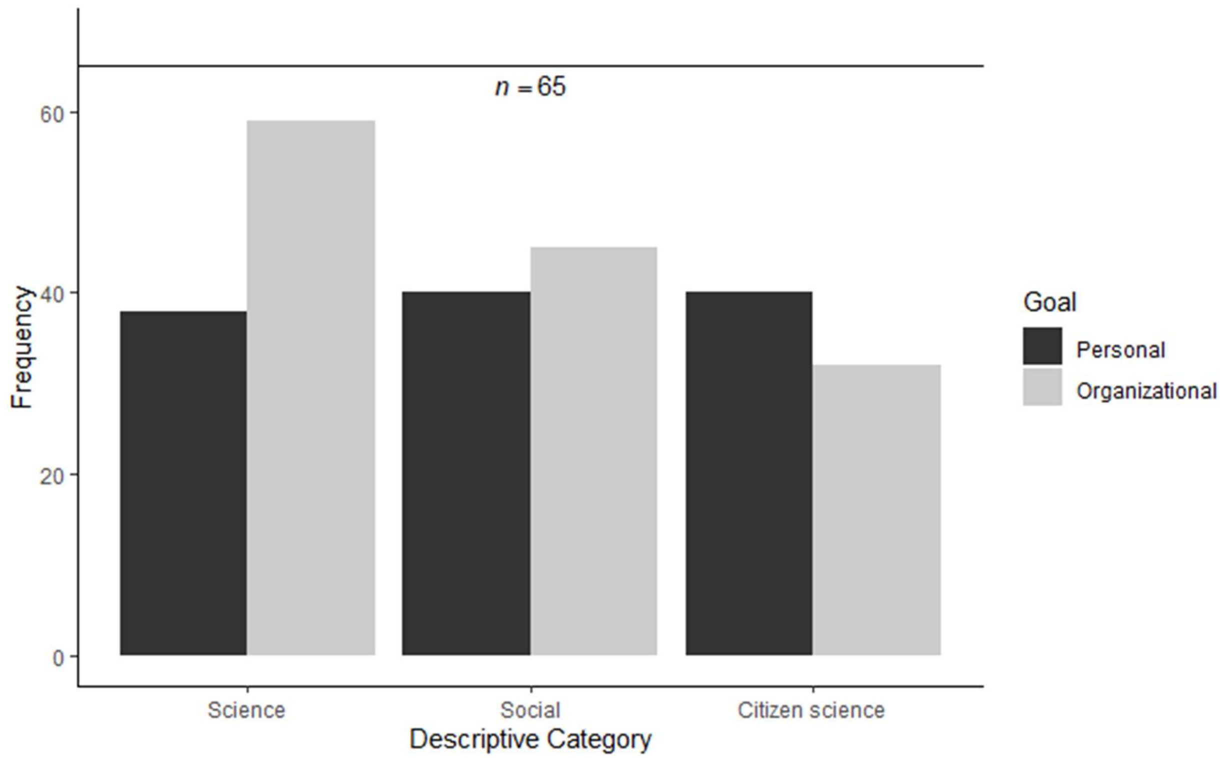

Figure 4.2: Frequency of personal and organizational goals within each theme.

Levels of misalignment were lower when we examined alignment of the three goal-related themes. Altogether, 43% of project leaders (n = 28) perceived misalignment between goals, 38% perceived partial alignment (n = 25), and 18% perceived complete alignment (n = 12). When participants perceived alignment of goals, it was most often related to scientific outcomes, while social or citizen science goals were more commonly perceived to be misaligned (Figure 4.4). A project leader for a local bumblebee project explained that organizational goals were related to "document[ing] declines of bumblebees," which aligned with her personal goals "to look at associations between presence of particular bumblebees and [...] what types of habitats support these bees." Her personal scientific goal, to answer research questions and conserve endangered species, aligned with her beliefs about her organization's scientific goals. Science goals were nearly unanimously reported by project leaders as personal goals and/or organizational goals.

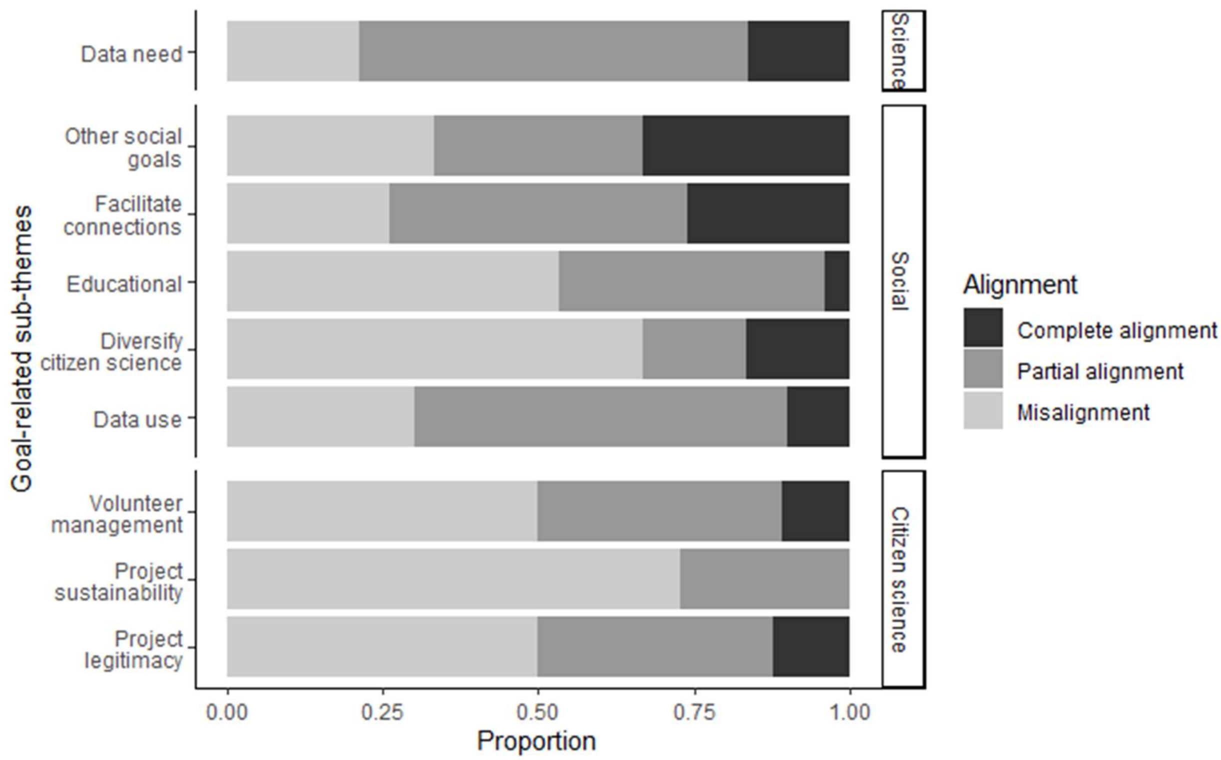

Figure 4.3: Proportion of individual goal alignment within each sub-theme. This graph shows the proportion of all project leaders who described each goal as a personal and/or organizational goal. Those who did not perceive a given goal were excluded from this analysis to account for the seemingly high levels of alignment amongst goals that were less commonly reported (Appendix F).

Participants perceived that their personal social and citizen science goals were misaligned with the organization's (Figure 4.4). One project leader working to control invasive species perceived that there was a "dual perspective" when it came to personal and organizational goals. While this person acknowledged that there were scientific goals, like answering research questions and managing invasive species, they explained that they were "...committed to doing everything I can so that a [volunteer] feels positive about the experience." In general, project leaders focused on citizen science goals (i.e., recruiting, training, managing), but they believed that the goals of the organization were focused on scientific outcomes. Fifteen project leaders did not report personal or organizational citizen science goals.

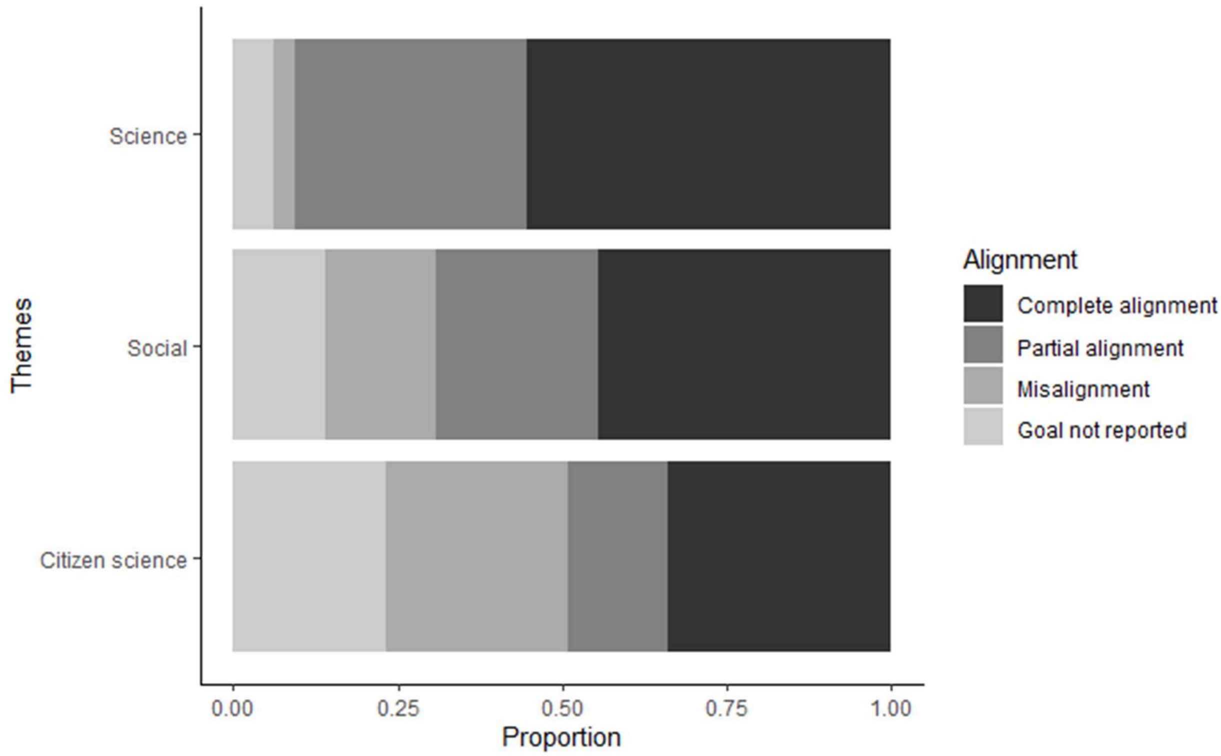

Figure 4.4: Proportion of goal alignment within each theme. In this graph, “Complete Alignment” represents project leaders who had the goal and perceived that their organization also had the goal, while “Goal not reported” represented project leaders who did not perceive that a given goal was their personal or organization’s goal. The people who were categorized as “Goal not reported” were in alignment with their organization.

Characteristics of projects by alignment level

Citizen science project leaders perceived several challenges. Challenges were perceived differently among those who were categorized as having complete alignment, partial alignment, and misalignment between personal and organizational goals.

Funding challenges

Seventy-one percent of the participants identified acquisition of funding to be a major challenge. Specifically, most participants described the challenge of maintaining financial resources for project sustainability. One project leader for a butterfly monitoring project pointed out, "...that there's a lot more willingness to fund new things. And I think one of the values of a lot of citizen science is monitoring, at least natural history. There's value in doing the same thing over and over and over." While citizen science is often used for long-term monitoring, funding agencies would rather support novel initiatives than pre-existing ones, creating challenges for projects studying long-term environmental phenomena. Second, participants indicated that resources are needed, in particular to hire more staff. The leader of a camera trap project described this challenge: "I wish we had the funding to put together a proper team. I wish we had a database manager, and I wish we had a social media manager, and I wish we had a dedicated computer scientist. I wish I could focus on education, or I could focus on research, but we don't have the manpower to do that. So it's a lot of running as fast as you can to stay on top of everything." This participant was overwhelmed with the amount of work expected of one individual to run a project.

Other less commonly mentioned funding challenges included hiring web managers, increasing current staff time, maintaining staff they had on the project, managing large scale projects, and starting new projects. Only project leaders with partially aligned or misaligned personal and organizational goals perceived challenges related to increasing current staff time on the project. One partially aligned project leader of a beach monitoring project shared with us that she had three jobs and only, "...10 hours per week on this project. And, truthfully, this job is at least part-time. So there's a lack of funding and a lack of time for me to be able to prioritize projects." She expressed her frustration trying to accomplish all her job expectations.

Project legitimacy challenges

Almost half (48%) of the participants felt that they needed to convince others of the credibility of their data. Regardless of goal alignment, project leaders perceived that they had to convince scientists outside of their organization of their project's data quality. Another butterfly monitoring project leader with aligned goals explained that "Even after we published our paper and it was peer-reviewed by [scientist] and [scientist], big names in the monarch world, [the academic community] would not accept our findings because we were not affiliated with a university." She described the challenges her organization experienced because they perceived that others questioned their legitimacy as credible scientists, even after the data had been published.

That said, those with misaligned and partially aligned goals perceived additional challenges with scientists inside of their organizations or within the project. A state employee who worked with several water monitoring programs explained: "We have a very big organization. It's heavy on the engineering side. So they don't have this inherent legacy of working with volunteers. They like to have certificates to hang on the wall. So it's a little foreign to them." He pointed out that engineers may have been hesitant to accept volunteer data because volunteer work is less common in their discipline. He elaborated and pointed out an irony that "We have folks that are in the office getting paid to do water quality management that haven't even operated a water quality meter, and they're questioning somebody else's data?"

Challenges related to balancing interests

Seventy-four percent of project leaders (n = 48) believed that balancing project goals was challenging. This sentiment was expressed more commonly by those whose personal goals were partially aligned or misaligned with perceived organizational goals. Those who had completely aligned goals were more likely to perceive challenges related to running the project, like balancing volunteer management with scientific outcomes or collaborating organization's interests. One project leader at a nature center discussed this tradeoff: "Project design gets in the way of [balancing goals]. You have to spend so much time managing stuff on the back end that there's no time really to focus on cultivating relationships with your volunteers, which is the most important part." He points out that setting up a project can get in the way of developing relationships with volunteers. That said, he also recognizes that, "You can have great relationships with your volunteers, but if you don't actually have any data to show for it then the project didn't have any utility." Thus, even if this participant develops these relationships, he acknowledges that there are still scientific outcomes that need to be accomplished for it to be worthwhile.

Those with partially aligned or misaligned goals reported challenges related to balancing volunteer management and scientific outcomes but also those related to managing their organization's interests. Specifically, they had trouble balancing their organization's interests with volunteer interests, their own personal goals, and other project outcomes. One volunteer coordinator's organization required all volunteers to get background checks for insurance purposes. However, the scientists in the organization did not want to lose volunteers, so they would tell their volunteers, "Don't do your background check. It's fine; you can still go out and monitor." Thus, they not only had misaligned goals, but direct barriers to accomplishing personal goals because organizational members did not communicate the same protocols to volunteers.

Discussion

Our study revealed that citizen science project leaders working in conservation and habitat management often perceive misalignment between their personal goals and their perceptions of their organizations' goals. Misaligned goals included those centering on citizen science goals (e.g., project sustainability, diversifying citizen science) or social goals (e.g., education). When there was goal misalignment, participants described additional challenges (i.e., acquiring funding to support themselves and balancing project interests with their organization's interests). These results are important for the field of citizen science because they expand how we think about intentional project design for meeting various outcomes. They also underscore vulnerabilities that organizations face when critical employees, like project leaders, feel stressed and are at risk of leaving (Adiguzel & Kucukoglu, 2019).

Role conflicts occur when people experience inconsistency in their perceptions of their positions and their organization's expectations for them, and can have several negative consequences like a limited capacity to carry out the duties of a position effectively (Rizzo et al., 1970). In our study, project leaders perceived different goals than those of their organizations, and thus their own expectations for their roles differed from that of their organization. Specifically, while there was often alignment for scientific goals, misalignment was common for citizen science goals (Figure 4.2), and project leaders perceived that their organization prioritized scientific goals over citizen science goals (Figure 4.3). It is unsurprising that scientific goals were commonly described as personal and/or organizational goals because top-down projects tend to focus on scientific goals (Heaney et al., 2007), and the majority of the project leaders in our study worked with top-down projects. Given that citizen science can contribute to the conservation of several taxa (Kelly et al., 2020; Kobori et al., 2016; Oberhauser & Prysby, 2008) and has benefited science in several other fields (Kullenberg & Kasperowski, 2016), it is interesting that organizational goals related to citizen science goals were least commonly mentioned in our study.

Furthermore, while we did not look at job performance specifically, we found that project leaders with misaligned goals less frequently reported challenges related to running the project like balancing volunteer management and scientific outcomes, and they more frequently perceived challenges related to managing their organization. Like the project leader who worked three jobs, they were more commonly part-time employees meaning that they were already dedicating less time toward accomplishing project goals. Those with misaligned goals also more frequently perceived challenges related to convincing colleagues in their organization of the data quality, even though several papers have demonstrated the quality of volunteer-collected data (Kosmala et al., 2016). When these challenges are compounded, job performance concerns seem likely and expected, underscoring role conflict that citizen science leaders may face. While some studies have found role conflict to negatively affect job performance (Fried et al., 1998), others suggest that the link is less conclusive (Tubre & Collins, 2000). Thus, future research should investigate whether citizen science project leaders experience role conflict and, given the emergent challenges our analysis uncovered, how that impacts the project success or organizational culture (Adiguzel & Kucukoglu, 2019). For example, several project leaders, regardless of alignment category, discussed challenges related to maintaining current staff, and these combined challenges may help explain the high turnover rate among citizen science employees.

To meet various project goals, citizen science researchers and practitioners are increasingly recognizing the need for intentional design. Specifically, they have described the need to design projects for scientific outcomes (Parrish et al., 2018), for learning outcomes (Phillips et al., 2018), or to balance multiple outcome goals (Shirk et al., 2012). Citizen science projects have called on their colleagues to focus on efforts to incorporate volunteer and community interests into projects (Pandya, 2012) yet have not considered how different stakeholders within organizations supporting citizen science projects consider various project outcomes. Our study focused on the distinction between the personal goals of those leading projects and their perceptions of their organization's goals for these projects.

Limitations

Although our study had a few limitations, we argue that the findings inform citizen science endeavors. Snowball sampling, while convenient, is often not representative of the community being studied because it is based on the limited networks of researchers and research participants (Parker et al., 2019). However, our objective was to provide a more in- depth understanding of how citizen science projects function, including the important role of project leaders in meeting multiple, sometimes competing, goals. As a result of this sampling bias, we have an over-representation of top-down, scientist-driven projects compared to bottom-up, community-driven ones. However, several papers have documented that the majority of citizen science projects tend to be top-down (Bela et al., 2016; Groulx et al., 2017; Lin Hunter et al., 2020), so our findings may, indeed, represent the experiences of many citizen science project leaders.

Implications

Citizen science can benefit conservation directly through management outcomes and indirectly through conservation research and social outcomes related to policy, education, livelihoods, and capacity building (Ballard et al., 2018). However, accomplishing these different outcomes will require conservation organizations to shift how they think about their goals. First, we encourage organizations to be explicit about goals and to consider not only the scientific goals they wish to accomplish, but also the social and citizen science goals. Intentional design requires considering all desired outcomes at the onset to ensure that project activities are effective at meeting goals. Second, we suggest that intentional design includes discussions between organizational leaders and project leaders about project leaders' roles in accomplishing stated goals. It is also essential to consider how these goals will be accomplished. Finally, we recommend that organizations explicitly articulate project goals when hiring project leaders and determine if newly hired personnel can address these goals. By doing so, organizations can help prevent goal misalignment up front and more efficiently work towards advancing social and scientific conservation goals and foster an organization culture where employees are satisfied and intend to remain (Adiguzel & Kucukoglu, 2019).

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CHAPTER 5

CONCLUSION

Summary of findings and implications

Through my dissertation, I sought to describe how citizen science project leaders describe and implement their projects. In doing so, my research addresses gaps in research on citizen science related to the understudied perspective of those who lead projects. The success of a citizen science program often rests on the citizen science leader, who communicates with both the volunteers and the organizational leaders and interacts with community members and professional scientists in other organizations. Understanding how citizen science leaders communicate about their projects with volunteers has important implications about the potential for citizen science to increase public scientific literacy, involvement in policy and management decisions, and recruiting fellow community members to join citizen science endeavors. Furthermore, how researchers and project leaders describe current projects affects how citizen science is perceived and how future researchers and project leaders may carry out projects.

The field of citizen science research is a relatively new academic discipline (Jordan et al., 2015). As such, citizen science practitioners and researchers are part of a developing community of practice. Communities of practice theory states that as members of a community interact with others in that community, they learn about the language and norms of the community (Lave & Wenger, 1991). In this manner, the citizen science community of practice is in the midst of clarifying and adopting language, structure, and practices that define the professional culture. Therefore, my research is timely and necessary, as citizen science programs have been increasing in popularity (Pocock et al., 2017). By documenting what, how, and why citizen science project leaders communicate their projects and goals, citizen science researchers can study the impact and outcomes on environmental management. This dissertation investigated communication from three angles: Chapter 2 investigated how volunteer tasks and project benefits are communicated by citizen science project leaders, Chapter 3 examined the citizen science community's perceptions of how project branding may imply commitment to inclusion, and Chapter 4 analyzed intra-organizational communication of project goals.

All three studies in this dissertation examined different aspects of citizen science communication. We found several misalignments of how citizen science is communicated and the intentions of the projects (Table 5.1). In Chapter 2, we found that project leaders described limited volunteer engagement in the scientific process, which can hinder opportunities to increase scientific literacy. Furthermore, described project benefits were often misaligned with known volunteer motives for participation, which can affect volunteer attrition. When project goals misalign with volunteer motives, there can be negative implications for volunteer retention. In Chapter 3 we found that, while project leaders perceived differences between the terms citizen science and community science, their decisions to rebrand implied that they were synonymous. Thus, there was a misalignment in which project leaders' behaviors did not match their perceptions. When citizen science projects change in name alone, there are negative implications for project inclusivity, as they fail to address deeper inclusivity issues related to whose goals are met and how people are compensated or credited for their contributions. Finally, Chapter 4 identified misalignments between project leaders' professional goals and their perceptions of their organization's goals. Project leaders who perceived goal misalignment were less able to focus on project tasks, and therefore, were potentially less effective at meeting project goals. As a result, those who perceived misalignment may have been less effective at carrying out successful citizen science projects. These misalignments prevent citizen science from accomplishing its full potential.

Table 5.1: Summary of the dissertation findings, implications, and recommendations

Chapter	Challenge addressed	Identified misalignment	Implications for citizen science	Recommendations for future projects
2	Democratic science	Volunteer tasks misaligned with commonly reported volunteer motives for participation.	Limited engagement in the scientific process hinders increases in volunteer scientific literacy. Volunteer retention will be low in projects that do not meet volunteer motives for participation. How we describe citizen science projects today affects how they are perceived and developed in the future.	Consider volunteer interests when designing projects and defining volunteer tasks. If science literacy is a volunteer goal, provide opportunities for volunteers to engage in other aspects of the scientific process besides data collection.
3	Diversity and inclusion, terminology	Perceptions of the terms citizen science and community science as distinct misaligned with rebranding behaviors that suggest the terms are synonymous.	Rebranding efforts co-opt previously existing definitions for community science as a grassroots effort. When projects change in name alone, they often fail to address deeper inclusivity issues.	The term citizen science should be used for projects initiated by scientists, while the term community science be reserved for bottom-up initiatives. Citizen science projects looking to address diversity and inclusivity issues should consider targeted recruitment, compensating volunteers, and translating project materials.
4	Democratic science	Project leaders'	Project leaders whose goals misaligned with	Organizations engaged in citizen science

		perceptions of their personal goals misaligned with perceptions of their organization's goals	their organizations were less able to focus on project goals, suggesting that they may less effectively accomplish project goals. When scientific goals go unmet, there can be implications for future funding. When social goals go unmet, there can be implications for volunteer retention.	should be explicit about the types of goals they want to accomplish at the start of the projects. Project leaders should be included in the goal defining stage of citizen science. Organizations hiring should be explicit about goals and ensure goal alignment when hiring project leaders.

While these misalignments may present the impression that organizations engaged in citizen science are disorganized and unfocused, I posit, instead, that they are in the midst of forming a professional culture. As the citizen science community of practice continues to develop, members of the community of practice will clarify how to communicate their goals, their tasks, and even what their organizations do.

I have provided recommendations for future projects wishing to address these challenges (Table 5.1) I recommend that more attention should be paid to volunteer motives when describing volunteer tasks and project benefits, especially at the start of the project when protocols are being designed. Otherwise, there is a risk of volunteers leaving projects if they have joined to increase their own understanding of scientific methods. However, if citizen science leaders believe that the branding of projects is important for recruiting diverse volunteers, they may want to clarify in names matter to volunteers. I recommend that the term, citizen science, should be used for top-down projects that are driven by scientists' interests, while community science should be reserved for projects that are driven by and for communities.

Furthermore, projects interested in addressing inclusivity issues should do so in meaningful ways, beyond simply changing their name. Finally, citizen science projects are successful because they rely on capable citizen science project leaders, but when those leaders feel burdened by expectations, there is a risk that they may leave. When organizations hire project leaders, they should ensure that prospective leaders' goals are aligned with those of the organization. In addition, I recommend that organizations explicitly identify all of the roles that they expect citizen science project leaders to have.

Future research directions

There are several avenues for future research that can stem from the studies in this dissertation. I am interested in investigating the two types of projects that are less commonly discussed in the research literature: contractual and collegial projects. The second chapter identified that the majority of projects are contributory (Lin Hunter et al., 2020), which others have also reported (Bela et al., 2016; Dickinson et al., 2010; Groulx et al., 2017; Pocock et al., 2017; Silvertown, 2009). Shirk and colleagues developed a five-part typology for categorizing citizen science projects based on volunteers' level of engagement (2012). While contributory projects were those in which volunteers collected and analyzed data for scientists, collaborative and co-created projects engaged volunteers in increasing aspects of the project respectively. Furthermore, contractual projects occur when communities hire scientists to answer questions for them, and collegial projects are when individuals engage in their own scientific investigations. However, the three most commonly discussed project types are contributory, collaborative, and co-created (Bonney et al., 2009). Contractual projects may not be common because, in these projects, researchers operate more as hired technicians on behalf of communities (Shirk et al., 2012). This switch in power dynamics in which communities drive research can be undesirable to researchers who entered academic science to define their own questions of interest (Heaney et al., 2007). Furthermore, scientists' interests and reward systems often differ from those of practitioners and community members, which can make collaborations more challenging (Roux et al., 2006).

However, I would be interested in investigating collegial citizen science more. I posit that these projects are less commonly discussed in academic research because scientists are often absent from these initiatives to publish on them. For example, at the Citizen Science Association conference last year, I had several conversations with a collegial citizen scientist who had systematically identified medical treatments for her son's eczema. While she said that she had shared the solution that she found with hundreds of other people, the academic community refused to accept her findings. I assume that there are other stories with varying degrees of success. These anecdotal stories spark my interest in conducting a case study analysis of different collegial projects to identify how their often ignored perspectives differ from citizen science projects that were designed in collaboration with professional scientists. The communities of practice would provide a useful lens for understanding their experiences with citizen science. The collegial citizen scientist with whom I spoke to had trouble entering the scientific community of practice. I am curious as to the role that the citizen science community of practice can play in offering in helping collegial citizen science increase their legitimacy in science. A clearer understanding of the dynamics that occur within citizen science communities of practice could inform whose ideas are valued, who remains engaged in citizen science projects, and how different cultural funds of knowledge are integrated into practices. We most explore the democratic potential of citizen science when it allows individuals and communities to address their own questions of interest.

All of my studies gravitated towards examining citizen science communication. It sparked my interest in further investigating citizen science discourse. Chapter 3 investigated differences in perceptions of the terms citizen science and community science. While citizen science researchers are increasingly criticizing efforts to rebrand as community science (Bonney, 2021; Cooper et al., 2021), issues related to terminology have not yet been resolved (Eitzel et al., 2017). The Citizen Science Association has described its next conference as a "C*Sci" conference (Citizen Science Association, 2021), and North Carolina State University describes citizen science as "Public Science" (NCSU, 2022). While these terms avoid co-option of previously existing terms like community science, it still remains to be seen how the citizen science community (volunteers, practitioners, and researchers) and the scientific community more broadly perceive these terms. There will be several opportunities to investigate perceptions of these terms and document how the field continues to evolve. Current discussions on terminology and discourse are occurring in academic circles. If the field of citizen science wants to be more democratic, future studies can be sure to include volunteers and communities in these discussions.

Citizen science researchers and practitioners who suggest strategies for making citizen science to be more inclusive often suggest that citizen science should operate at local scales with the goals of meeting local needs (Pandya, 2012). In other words, they advocate that citizen science becomes community science. However, this might limit the capacity of large scale citizen science to become more inclusive. One of the benefits of citizen science is its ability to work at large geographic and temporal scales (Dickinson et al., 2010; Lottig et al., 2014). While these scientific outcomes would be unattainable if citizen science simply became small-scale, local, community-oriented projects, large scale citizen science can learn from these more inclusive community science projects. I hope to investigate the effectiveness of interventions designed to promote inclusivity in large scale citizen science.

Finally, the fourth chapter investigated citizen science project leaders' perceptions of their experience managing goals. Specifically, we found that they had to balance scientific, social, and citizen science goals. To do so, they have to conduct tasks that are both scientific (e.g., designing experiments, developing sampling protocols, data analysis) and social (e.g., communication, volunteer management, evaluation). Thus, leading a citizen science project can be an interdisciplinary endeavor. I would like to investigate the type of professional identity that citizen science project leaders have. Specifically, I am interested in learning if they have a science identity, a social science identity, or some interdisciplinary citizen science identity. Alternatively, these individuals may have intersectional identities or identities in formation. At the moment, identity, and specifically science identity research in citizen science is limited (Hajibayova, 2020), and those that have investigated it have focused on the volunteers (Ballard et al., 2018; Landon et al., 2018; Lee, 2016; Tipaldo & Allamano, 2017; Wallace & Bodzin, 2017). Understanding project leaders has implications for the professional training that they receive as students and professional development that they can receive in their careers.

Research in the field of citizen science has long focused on the capacity of citizen science to contribute to science and volunteer motives and outcomes, often tied to learning. The research studies described in this dissertation expand the current scope of citizen science research by investigating the often understudied perspective of those who lead projects including investigations into how they communicate and their perceptions of their experiences. While these studies have opened the door into new avenues of research for the field including communication and studies on project leaders, there are several resulting opportunities for future work. I hope that these studies and suggestions for future work will be informative to citizen science practitioners seeking to better describe their projects and carry out their project goals.

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APPENDICES

Appendix A: Content analysis codebook

Who Is Doing The Task? is doing/trying to accomplish **Intended Task** to benefit
(Who?) (Type of task/outcome)

Who Is Benefiting? In order to do/accomplish this they perform a **Performed Task**.
(Beneficiary) (Low/Mid/High Order)

They are trying to understand **Study Subject**.
(Abiotic/Biotic/Both)

Who is doing the task?
Who is doing the task or trying to accomplish the outcome?

Who?	Notes
Volunteer	• If a sentence starts with a command verb and seems to be indicating that the volunteers do a task, it will be associated with them even though there is not an explicit subject in the sentence (i.e., **Take** a picture; **Upload** data; **Interpret** results). • However, be aware of command looking verbs in the Main description Goals section that are not actually commands (i.e., if you saw the "monitor pH" in the Goals section, this is not a task; it's a goal, so it's not clear that the volunteers are performing the task). This would be coded as unclear.
Project manager	• "We" is assumed to indicate the project manager unless previously specified otherwise.
Unclear	• If the text is vague and it is unclear who is supposed to do the task (i.e., above about command-looking verbs in the Main description or Goals sections)

Intended task
What type of task/outcome is being done/accomplished according to Bloom's Taxonomy? If there are more than one type of task/outcome associated with the participants, label this variable of as the higher order one.

Task or Outcome?	Notes
Low order	• Monitor, record, describe, document, characterize, add picture
Mid order tasks	• Assess, question, looking for, compare, analyze, investigate, validate, evaluate • These are measurable tasks. They are the tasks that will allow you to obtain the goals described below.
Mid order outcomes	• Understand, interested in, want to know, learn, discover • These are latent, or unmeasurable. These are goals related to understanding the environment.
High order tasks	• Decision making, inform, help, guide, assist, advance, affect, evaluate

	• Inform/making decisions here refers to informing/making decisions about policy and management
High order outcomes	• High Order Outcomes: informed, empowered • Citizens who are now informed/empowered to make decisions/enact change in their local environment
Education	• Increasing knowledge or awareness • No mention is made of trying to describe, understand, or change the environment. The focus is on education.
Opinion of the environment	• This is when citizen scientists are engaged by providing their opinion on the environment as the actual data point being studied.

Who is benefiting?

Who is benefiting from the task or outcome?

Who?	Notes
No one benefits	• If there is no discernable beneficiary from the text provided • No benefit is coded instead of citizen science project when the goal defined in the Goals section cannot be achieved by the task defined for volunteers AND when there is no other mention of how the project will benefit another entity.

Environment	• Anything that improves, recovers, or conservers the environment
	    o EX: “help clean our parks” – it is clear that the environment is benefiting because the parks are cleaner
	    o Counter example: “help us clean our parks” – the direct object is the project managers, and they are benefiting from the help. Therefore, this would be coded as project instead of the environment.
	• This is different from SES because in this the beneficiary of the task is the actual environment, whereas in SES the beneficiary is management, policy, etc. thereby making the volunteers impact on the environment indirect instead of direct.

Social ecological systems	• Improved management, policy, decision making, etc. • Note how this is different from the environment (see above)
Volunteers (technicians)	• Discuss that the volunteers will increase their knowledge or be made more aware. • If they describe bringing together a network and the task is low order, then it is coded as benefiting volunteer technicians
Volunteers (scientists)	• They are empowered with knowledge and skills to enact future change in their environment • If they describe bringing together a network and the task is mid or high order, then it is coded as benefiting volunteer scientists • Foster environmental stewardship will be coded as benefiting the volunteer scientist unless it is somehow explicit that it’s benefiting the community or environment.

Citizen Science Project	• This refers to any benefit that is *IN* organization (i.e., project manager's knowledge/understanding, collecting data for the project) o EX: "help us…" • If they mention that the goal is to collect data about some study subject, and they don't mention where the data will go it will be coded as benefiting the project. This is also the case for other verbs, like mapping, archiving etc. If the goal described in the Goals section is attainable through the task described, then it is coded as benefiting the project.
Community	• A benefit to the greater community that's not science related (i.e., food, economy, drinking water, public health, etc.)
Science knowledge	• This refers to any benefit that is *OUT* of the project (i.e., the data goes to researchers, agencies, etc., but NOT to managers-if it's describing management that's SES) • If they describe a research question and don't state that anyone else explicitly benefits, then it is coded as an *implicit* benefit to science knowledge

Performed task

What type of task is actually being done by the participants? When there are more than one type of tasks/outcomes associated with the participant, label this variable as the lower order task. This tries to account for all of the times when they suggest that citizen scientists can help/improve/etc. but all they are really doing is collecting/uploading a picture/etc.

Task or Outcome?	**Notes**
Low order	• A low order task (describing) is currently being described • It is found out that the way that a volunteer helps/improves/etc. is by doing something low order
Mid order tasks	• A mid order task (understanding) is being described and there's no indication that the volunteer is actually doing a low order task in order to understand
High order tasks	• A high order task (enacting change) is being done and there's no indication that the actual task for the volunteers to do is low order (i.e., enacting change in management, policy, or research) • This can include explicit mention of educating others (i.e., enacting change socially rather than environmentally)

Study Subject

Is the study subject abiotic, biotic, or both?

Study subject?	**Notes**
No study subject	• There is no discernable study subject
Abiotic	• Aquatic systems are assumed to be abiotic unless there is explicit mention of a biological factor (i.e., macroinvertebrates, fish, algae, etc.)

Biotic	• If they are interested in something biotic but have to measure it using an abiotic measure, label it as biotic (i.e., mosquito breeding containers are monitored, but it's not the abiotic container their interested in; it's the biotic mosquitos)
Both	•
Volunteers	• In some cases, the project managers were asking volunteers about their opinions of the environment. Therefore, in these cases, the volunteers themselves are the study subject.

Appendix B: Survey instrument

To what degree do you agree or disagree with each statement about citizen/community science? An outcome of citizen/community science is… (Strongly disagree 7 to Strongly agree 1) • Answering questions over long periods of time • Research that spans broad spatial scales • Answering questions that would be too expensive for paid staff • Answering previously unanswerable questions • Partnerships between scientists and the public • Informed management decisions • Effective ecosystem management • Useful data for managers • Collaboration between managers and public • Protection for endangered species • Effective conservation • Conservation of natural habitat • Data for conservation scientists • Collaborative conservation with communities • Scientific information that helps policymakers • Data for policymakers • Community relevant policy • Informed policy decision-making processes • Informed policy implementation • Inclusion of all people in science • Participation in science by diverse peoples • Exclusion of certain people based on citizenship status* • Inclusion of diverse voices in science • The collection of trustworthy data • Data that will be accepted by other researchers • Acceptance of volunteer-collected data as legitimate
To what degree do you agree or disagree with each statement about citizen/community science? Participation in citizen/community science can affect… (Strongly disagree 7 to Strongly agree 1) • Public scientific literacy

• Project specific content knowledge • Knowledge about scientific processes • Skills needed for scientific investigations • Awareness about a scientific issue • Science-informed behavior change • Engagement in civic action • Attitudes about science • Identities as a scientist • Environmental stewardship
In which parts of the scientific process do citizen/community science volunteers participate? Select all and then rank the selected options. • Asking research questions • Finding background information on the topic • Developing hypotheses • Designing methods for data collection or experiments • Collecting data or samples • Analyzing samples • Analyzing data • Interpreting data and drawing conclusions • Disseminating (sharing) findings of the project • Designing new studies based on previous findings
How likely are you to describe a project as each of the following? (Extremely likely 7 to Extremely unlikely 1) • Citizen science • Community science
Open ended questions • Why are you likely or unlikely to call a project "citizen science?" • Why are you likely or unlikely to call a project "community science?" • What name(s) do you call the project(s) of which you are a part AND why? If you are not part of a project, please write N/A.
Demographic data collected • Roll in a citizen or community science project • Discipline • Institution type • race/ethnicity • Gender • Level of education • Age

*Not included in the results, because it reduced the Cronbach's alpha

Appendix C: Codebook for qualitative survey questions

Code	Subcode	Definition
Reasoning for calling a project citizen science or community science		
Awareness/acceptance of term (by others)	Not well known/accepted	E.g., lack of agreed upon definition for the term
	Well known/accepted	use this if they just speak about it generally without saying who it's well known by or if the specify a stakeholder outside of the list below
	Well known/accepted by funding agencies	
	Well known/accepted by government agencies	E.g., the government requires you to call a project this
	Well known/accepted outside of citizen science community	
	Well known/accepted by the scientific community generally	
Driver of the project	Community driven	e.g., bottom up, activism, collegial To distinguish between volunteer tasks that are more than data collection and community driven: community driven requires them to say something on the lines of the community leads/drives/etc. the project and/or the community identifies or comes up with the project.
	Driven by both	e.g., collaboration or co-creation between the public and scientists; some indication that the project is being driven by both scientists and the public
	Scientist driven	e.g., top down, contributory
Familiarity with term (their own familiarity)	Familiar	the term is what I'm used to/familiar with
	Not familiar	I've never heard of this; I'm not very familiar with this term or what it means
Goals of the project	Scientific/data goals	E.g., publications, management, answering research questions; if they mention that the outcome is meant to benefit scientists or researchers

	Social/community goals	E.g., livelihoods, tourism; if they mention that the outcome is meant to benefit the community.
Inclusivity	Exclusive	E.g., the exclusionary nature of the word citizen, you have to be part of a community to be part of the project
	Inclusive	E.g., citizenship not required to participate; don't need to be part of a certain group/community to participate
Time (length of project)	Defined amount of time	The duration of the project is pre-set and lasts within a specified amount of time.
	Long period of time	The project lasts a long time or isn't time bound; there isn't a time commitment for participation
Types of participants	Community	participation in the project requires working with members of a community or group; OR requires people within close physical proximity
	Individual or smaller groups	participation in the project occurs on an individual or small group (e.g., family unit-sized groups) basis
	Non-scientist	E.g., not members of staff, amateurs, not professional Can be co-coded with community, individual, or wider public
	Wider public	Open to anyone; no requirement for close proximity or membership in a group/community to participate.
Volunteer tasks	Requires participation in entire project	If they mention that this name requires participation in the entire project (e.g., from conception of the project to communication of the findings)
	Requires participation in more than data collection	More than data collection but not necessarily the entire project
Names for projects		
Name change - only code once per survey	Currently going through a name change	e.g., they mention that they're currently looking for a new term to use
	Have already gone through a name change	e.g., they mention that they've already switched from one name to the other

Relationship between names - only code once per survey	Citizen science as part of community science	Citizen science is a specific subset of community science
	Community science as part of citizen science	Community science is a specific subset of citizen science
	Completely separate	Community science and citizen science are two different types of public participation/engagement in science
	Interchangeable	Citizen science and community science are interchangeable/synonymous

Appendix D: Interview protocol

1. Please describe the citizen project in which you're involved and your role in that project.
    a. How long have you been in your current role?
    b. How long have you worked in citizen science total?
2. Can you describe your experiences as a citizen science leader?
    a. Between you and your supervisors or organization.
    b. Between you and the volunteers.
    c. Between you and other community organizations who are not involved in the citizen science project.
3. How does your organization decide what citizen science projects to run?
4. What goals does your organization have for the citizen science projects?
5. What are your personal goals for the citizen science projects?
6. How do you prioritize the different goals of the project? How do you decide how to allocate your time towards a certain goal?
7. What challenges have you faced trying to accomplish the organization's project goals?
8. What strategies did you use or are you using to address them?
9. How has coronavirus affected your citizen science projects? How are you handling it?
10. How do you determine when you've met goals?
    a. What data do you use to determine if you've met your goal?
11. Is there anything else you'd like to share about your experience as a citizen science project leader?

Appendix E: Full thematic hierarchy for interview study

- Project leader role
    - Job tasks
        - A lot of roles
        - Collect data
        - Communication with policymakers
        - Communication with public
        - Communication with scientists
        - Communication with volunteers

        - Computer programmer
        - Connect people with nature
        - Connect people with policymakers
        - Connect people with science
        - Connect people with scientists
        - Create and distribute resources
        - Data analysis
        - Design and run experiments on volunteer collected data
        - Develop and maintain, partnerships, collaborations, and social networks
        - Develop volunteer culture
        - Develop volunteer protocols
        - Evaluate project
        - Make volunteer sampling schedule
        - Marketing
        - Obtain and manage funding
        - Recruit volunteers
        - Retain volunteers
        - Social media communication
        - Staff management
        - Train volunteers
        - Website manager
        - Write papers
    - Perceived training for role
        - Insufficient training for scientific role
        - Insufficient training for social role
        - Sufficient training for scientific role
        - Sufficient training for social role
- Priorities
    - Relationship between priorities
        - Social and scientific goals are viewed as intertwined
        - Social and scientific goals are viewed as separate
    - What is driving priorities
        - Community
        - Funding
        - Organizational goals
        - Partnerships
        - Personal goals
        - Volunteers
    - What is prioritized
        - No priorities
        - Only scientientific goals
        - Only social goals
        - Project is a low priority
        - Scientific over social
        - Social and scientific are equal
        - Social over scientific

        - Unclear priorities
  - Goals
    - Science goals
      - Data-related goals
        - Answer research questions
        - Collect data
        - Collect high quality data
        - Conserve and manage species or habitat
        - Improved data management
        - Meet grant deliverables
        - Publish papers
    - Social goals
      - Data use
        - Engage in decision-making
        - Data use by policymakers
        - Inform organizational advocacy behaviors
      - Diversity
        - Diversifying perceptions of who a scientist is
        - Diversifying volunteer base
      - Educational
        - Awareness
        - Communicate about science
        - Communicate about findings
        - Content knowledge
        - Develop volunteer science identity
        - Engage in advocacy behaviors
        - Engage in stewardship behaviors
        - Increase accessibility of science
        - Scientific reasoning
        - Scientific skills
      - Facilitate connections
        - Build partnerships, collaborations, and social networks
        - Connect people with nature
        - Connect people with science
        - Connect people with scientists
        - Connect scientists with local or indigenous knowledge
      - Other social goals
        - Empowerment
        - Environmental justice
        - Supporting livelihoods
        - Support local economy
    - Citizen science goals
      - Project legitimacy
        - Acceptance of data quality
      - Project sustainability
        - Expand the scope of the current project

            - Maintain the project as is
            - Project survival
        - Volunteer management
            - Build community with volunteers
            - Develop volunteer identity with the project/organization
            - Engagement
            - Incorporate volunteer or community interests into the project
            - Recruit volunteers
            - Retain volunteers

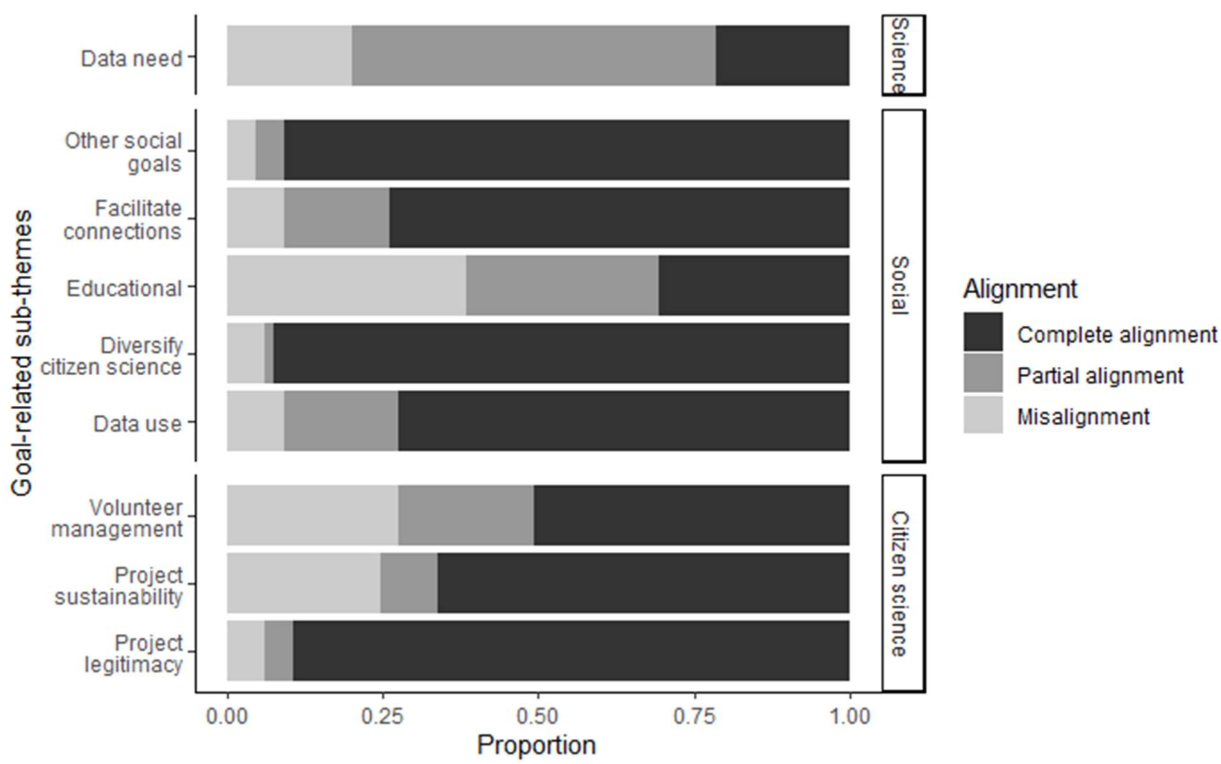
- Challenges
    - Individual capacity
        - Scientific knowledge and skills
            - Ability to develop web technology
            - Data management
        - Social knowledge and skills
            - Build trust with volunteers
            - Communicating with the public
            - Communicating with scientists
            - Diversifying citizen science
            - Increasing the accessibility of science
            - Promote behavior change
            - Recruit volunteers
            - Retain volunteers
            - Train volunteers
            - Volunteer adaptability
            - Volunteer management at a large scale
    - Organizational capacity
        - Funding
            - Resources to develop web technology
            - Resources to hire more staff
            - Resources to increase current staff time on the project
            - Resources to maintain current staff
            - Resources to maintain the project long term
            - Resources to manage large scale projects
            - Resources to start a project
        - Time
            - Need more hours in the day
            - Resources to maintain the project long term
            - Resources to start a project
            - Volunteer management is time consuming
    - Credibility
        - Trustworthiness
            - Scientists outside of the organization's perceptions of data quality
            - Scientists within the organization's perceptions of data quality
            - Scientists within the project's perceptions of data quality
            - Volunteer perceptions of data quality

                - Visibility
                    - Issue visibility
                    - Project visibility
        - Tensions
            - Managing goals
                - Bureaucratic interests vs project interests
                - Organizational goals vs collaborating organizations' goals
                - Organizational goals vs funding agency interests
                - Organizational vs personal goals
                - Personal goals vs funding agency interests
                - Volunteer interests vs organizational interests
                - Volunteer management vs scientific outcomes
            - Managing knowledge
                - Data quality vs data quantity
                - Local or indigenous knowledge systems vs scientific knowledge systems
                - Pace of research vs practitioner need
                - Open vs private data
- Solutions
    - Individual capacity
        - Scientific knowledge or skills
            - Data standardization across regions
            - Learning from others
            - Learning on the job
            - Pursued individual professional development
            - Receive support from supervisors
            - Strategic planning
            - Using a pre-existing database
        - Social knowledge and skills
            - Adapting to volunteer interests
            - Building community among volunteers
            - Build personal relationships with volunteers
            - Communicate findings with volunteers
            - Communicate other project outcomes with volunteers
            - Consider volunteer interests at the start of the project
            - Delegation of tasks across levels of management
            - Delegations of various roles in the projects
            - Volunteer appreciation
            - Learning from others
            - Learning on the job
            - Make data freely available and interpretable
            - Organization provided professional development
            - Pursued individual professional development
            - Receive support from supervisors
            - Recruit volunteers through partner organizations
    - Organizational capacity

        - Funding
            - Automate or streaming the project
            - Bring in temporary or part time paid staff
            - Bring in unpaid interns
            - Diversify funding sources
            - Diversify volunteer tasks
            - Donations
            - Have volunteers pay
            - Leverage volunteer time as a pre-existing source funds in grants
            - Partner and collaborate with other organizations
            - Temporarily suspend project
            - Write grants
        - Time
            - Automate or streaming the project
            - Bring in temporary or part time paid staff
            - Bring in unpaid interns
            - Diversify volunteer tasks
            - Partner and collaborate with other organizations
            - Setting personal and professional boundaries
    - Credibility
        - Trustworthiness
            - Communicate the data quality
            - Communicate the financial value of citizen science
            - Communicate the scientific value of citizen science
            - Increasing face time with volunteers
            - Increasing societal acceptance of volunteer data
            - Publish peer-reviewed articles
            - Receive support from supervisors
            - Receive support from other organizational staff who work with volunteers
            - Reputation of individuals and organizations associate with the project
            - Training volunteers in QA/QC protocols
        - Visibility
            - Marketing
            - Outreach and education
    - Tensions
        - Managing goals
            - Setting priorities
        - Managing knowledge
- Evaluation
    - Method of evaluation
        - Analytics
        - Anecdotal feedback
        - Checking things off a list
        - Data use
        - Logic models or strategic plants

- No evaluation method
- Recruitment and retention statistics
- Social science research
- Surveys
- Types of goals evaluated
  - Scientific
  - Social
- Want to improve evaluation of
  - Scientific goals
  - Social goals

Appendix F: Proportion of sub-theme alignment including those who did not report goals



Appendix F: Proportion of individual goal alignment within each sub-theme including those who did not report goals. There is a seemingly high proportion of personal and organizational goals in "Complete alignment" because several goals were less frequently reported by project leaders. When goals were absent from both personal and organizational goals, these would have been categorized as being aligned. See Figure 4.3 in Chapter 4 for the proportion of goal alignment excluding not reported goals.