CITIZEN SCIENCE:
THEORY AND PRACTICE

The Effect of the COVID-19 Pandemic and Associated Restrictions on Participation in Community and Citizen Science

SPECIAL COLLECTION:
DISASTER, INFRASTRUCTURE, AND PARTICIPATORY KNOWLEDGE

RESEARCH PAPER

]u[ubiquity press

SABRINA DRILL
CONNOR ROSENBLATT
CAREN COOPER
DARLENE CAVALIER
HEIDI BALLARD

*Author affiliations can be found in the back matter of this article

ABSTRACT

Citizen and community science can improve conservation efforts, help people connect with nature, and strengthen online social infrastructure during periods of disturbance. Volunteers for citizen and community science (CCS) projects engage in a variety of activities ranging from in-person group tasks to isolated online tasks. The diversity of available CCS engagement activity types was altered by the COVID-19 pandemic. Our goals were to document the impact of COVID-19 (1) on participation in different types of CCS projects and (2) across a varying landscape of pandemic-associated restrictions. We examined digital trace data from SciStarter.org to examine participation in CCS projects before and during COVID-19. We created a summative index of different COVID-19 restrictions to quantify how daily life in each US state was impacted. We found that during the pandemic, projects in which data collection occurred away from home had fewer joins than other types of projects. This contrasts with pre-pandemic, for which there was no difference in joins among the different project types. Although there was a decrease in joins among away from home projects that occurred during the pandemic, the difference between pre-pandemic and during the pandemic was not statistically significant. There was no difference in joins among the different project types between individuals in states with few COVID-19 restrictions compared with individuals in states with many COVID-19 restrictions. Interviews conducted with project leaders reinforced these findings and provided examples of how projects could be modified to continue generating data and connecting communities.

CORRESPONDING AUTHOR:

Sabrina Drill

University of California Agriculture and Natural Resources, US

sldrill@ucanr.edu

KEYWORDS:

citizen science; community science; COVID-19; pandemic; SciStarter

TO CITE THIS ARTICLE:

Drill, S, Rosenblatt, C, Cooper, C, Cavalier, D and Ballard, H. 2022. The Effect of the COVID-19 Pandemic and Associated Restrictions on Participation in Community and Citizen Science. *Citizen Science: Theory and Practice,* 7(1): 23, pp. 1–14. DOI: https://doi.org/10.5334/cstp.463

INTRODUCTION

Emergence of the COVID-19 global pandemic severely altered the lives of people worldwide (Bates et al. 2020). Governments responded by declaring and implementing restrictions on social life aimed at curbing the spread of the virus, including mandatory lockdowns, the closure of public spaces, and social distancing (Hale et al. 2021). The combination of COVID-19 and associated restrictions resulted in widespread mental health issues such as depression, anxiety, stress, boredom, and social isolation (Brooks et al. 2020; Qiu et al. 2020; Xiong et al. 2020).

COVID-19 control measures reduced access to real-world social infrastructure. Pandemic restrictions limited social activity and strained community cohesion (Brooks et al. 2020). It closed schools, brought travel to a stand-still (Wilder-Smith and Freedman 2020), and shifted activities to virtual environments, increasing the importance of the internet as social infrastructure (Schmidt and Power 2021). Enforced physical isolation catalyzed new approaches and infrastructure (such as the widespread adoption of Zoom among the general public) that could boost social connectedness.

Families and individuals sought out alternative ways to connect with the outside world. This included observing nature (Crimmins et al. 2021) as well as increasing engagement in online communities—both of which can be provided by participation in citizen and community science (CCS) (Schuttler et al. 2018). For example, CCS project introduction events, conceived as in-person events at public libraries, moved to Zoom and were open to anyone who registered. SciStarter, with support from the National Library of Medicine, coordinated close to 100 of these Zoom events for Citizen Science Month in April 2020 during the height of lockdowns.

There are many terms for public participation in research including citizen science (CS) and community science (Cooper et al. 2021; Grosholz et al. 2021). These terms carry different meanings and importance for different audiences. We use the term CCS to include a range of approaches. We acknowledge the importance of the term community science as emanating from social justice–oriented projects (Ballard et al. 2017) to address issues facing vulnerable communities. Citizen science, as the term has been used since the mid-1990s, focuses on institution- or researcher-led projects harnessing the data collection capacity of volunteers (Cooper et al. 2021), and/or projects created by educational institutions with a primary purpose of engaging communities in science. For this paper, we analyzed projects that fit the above definition of CS, though our findings may apply to CCS more broadly.

Participation in CCS has been shown to offer numerous mental and emotional benefits (Koss and Kingsley 2010) and increased sense of belonging to a community (Haywood, Parrish, and Dolliver 2016). Creating opportunities for people to be involved in primary data collection can empower them and improve the body of knowledge by engaging a variety of backgrounds and viewpoints (Halpern 2019). This empowerment improves science literacy, confidence, and trust (Merenlender et al. 2016). Nature-based projects can improve wellbeing through increasing participant connectedness to nature (Schuttler et al. 2018; Marselle et al. 2019).

Increased community engagement in the study and management of natural resources may also increase community resilience (Newman et al. 2016; de Sherbinin et al. 2021). Resilience has a variety of definitions and interpretations (Moser et al. 2019) that relate to the concept of adapting to change and continuing to exist under new conditions (Walker and Salt 2006). Strategies incorporate and integrate resilience among linked social–ecological–technological systems (SETS) (Iwaniec et al. 2021). By providing more complete data, especially from hard-to-access areas such as urban backyards (Li et al. 2019), CCS can improve conservation and restoration efforts (McKinley et al. 2017) that improve ecological resilience (Newman et al. 2016). CCS can support social resilience by increasing the knowledge and competency of community members who make decisions that affect SETS. Co-discovery, by scientists, managers, and citizens, of the processes that cultivate resilience is an important element of sustainability (Walker et al. 2002). Understanding how projects adapted to the unique situation brought about by COVID-19 provides insights as to how CCS can increase community resilience.

Interest and participation in CS boomed during the initial months of the pandemic. Contributions to popular platforms such as eBird, iNaturalist (Sánchez-Clavijo et al. 2021), and Zooniverse (Bowser et al. 2020) increased. On SciStarter (an online CS hub containing over 2,000 projects), there was a 480% increase in participation in April 2020 compared with April 2019 (Peterson 2020). The reasons behind this are myriad and interconnected, including desire for intellectual stimulation, need for social connection, and concern about the environment (Kornfeld 2020). The transition to online distance learning motivated parents to search for science education opportunities. Scientists turned to local volunteers to accomplish data collection that was no longer easily done by paid students and technicians because of social distancing requirements (Crimmins et al. 2021).

This trend of increased participation was not universal and varied with the type of project. Crimmins et al. (2021)

found that some large-scale biodiversity monitoring projects witnessed increased participation (iNaturalist, eBird), whereas participation in other such projects decreased (eButterly, Nature's Notebook). Basile et al. (2021) found no major change in the number of observations submitted to iNaturalist by birdwatchers in Italy and Spain. Large group projects were particularly impeded by social distancing mandates and witnessed a decrease in the number of new participants (Corlett et al. 2020). Kishimoto and Kobori (2021) found a 63% decrease in participants in the City Nature Challenge Tokyo in 2020 compared with 2019, though they saw an increase in identifications—an activity that can be done by individuals online.

The severity of lockdowns imposed by governments also resulted in differences in participation between different locations (Basile et al. 2021; Crimmins et al. 2021). Even for projects in which individuals continued to participate, the location changed, with more people participating in projects that could be done at or near home rather than traveling to distant places (Randler et al. 2020; Crimmins et al. 2021; Hochachka et al. 2021). Amongst these analyses, the question remains as to how participation in different types of CS projects was affected by COVID-19 restrictions.

To explore this question further, we had two objectives. Our first was to document the impact of the COVID-19 pandemic on participation in existing CS projects classified along a spectrum from in-home to public natural areas. Our second was to explore how participation in CS projects varied with geographically different government restrictions.

We hypothesized that differences in where projects occurred and how the data needed to be collected would determine whether there was an increase or a decrease in participation. Specifically, projects that could be conducted at home, whether online only or through making observations in or near home, would experience increased participation, while those that required a coordinated event or access to public spaces would see a decrease. We further hypothesized that there would be more participation in projects that could occur away from home in United States (US) states with fewer COVID-19 restrictions and more participation in at-home projects in states with many COVID-19 restrictions.

METHODS

We employed a mixed-methods approach. This consisted of examining digital trace data on CS participation from SciStarter.org before and during the pandemic, constructing a quantitative index to measure how restricted daily life in each US state was during COVID-19, and semi-structured conversations with project leaders to identify ways individual projects adapted to COVID-19 lifestyles.

PROJECT DATA

We examined the activity of SciStarter users. SciStarter is comprehensive hub for citizen science where potential volunteers can search for projects of interest and track their participation. The SciStarter database includes more than 2,000 projects and has close to 100,000 registered community members. We included projects that received at least one data contribution between March 19 and May 31, 2020. This time period began with the date the first statewide stay-at-home order was initiated in the US and ended when most states had loosened some of the initial COVID-19 restrictions and daily case numbers were relatively stable.

There were 93 unique CS projects that received at least one data contribution during this time period. We coded projects into mutually exclusive groups based on characteristics hypothesized to affect participation trends (Figure 1). The four groups of projects were: "online," for which the raw data had been previously collected and participants could observe, classify, and record data exclusively online (*n* = 27); "away from home" that required the participant to collect data in a public location, such as a park or coastline (*n* = 20); "at home indoor" that required the individual to collect data from inside their house (*n* = 13); and "at home outdoor," where participants were required to collect data outside in their yard or nearby neighborhood (*n* = 33).

Our data set was limited to projects in the US. SciStarter has been most actively used by projects in the US, and focusing on a single country allowed us to limit the COVID-19 policies we assessed. The results of our study directly apply to project design and participation in the US, although insights may be relevant to similar countries.

PARTICIPANT DATA

We obtained activity data from SciStarter on participants who made at least one contribution during this time period (*n* = 3,602). The activity data consisted of the number of project "joins" (i.e., how many new projects an individual joined) and the number of project "contributions" (i.e., how many data contributions an individual submitted to a project). We created a third variable for "engagement," which was a binary variable scored as a "1" if the individual made > 0 contributions to the project. This was created because effort required per contribution varies between projects, and this variable captured which projects participants were engaged in in some form. "Joins" thus represented new interest in projects, whereas

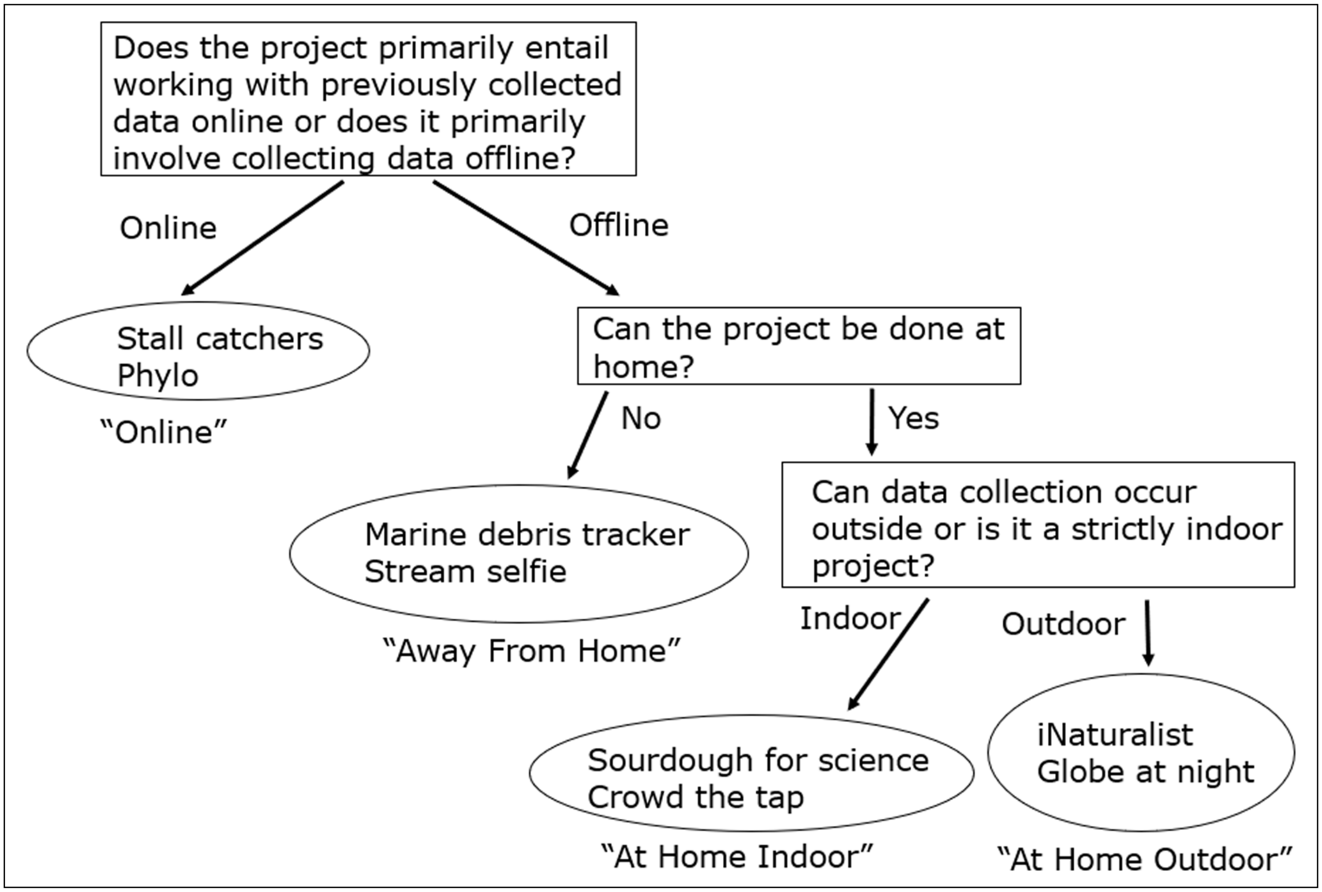

Figure 1 We classified citizen projects on SciStarter into four distinct groups according to this classification scheme. Rectangles indicate the primary questions used to classify projects at each level. Ovals indicate examples of projects in each classification group. Group names are provided in quotes below ovals.

"engagement" represented total activity for a project. We then combined the participant data with the project data to calculate the number of participants who joined and engaged with each project during our study period.

Additionally, we established a baseline by obtaining activity data from all participants who joined at least one project during January 1 through March 18, 2020. This represented trends in project joins prior to the start of pandemic, allowing comparison with data collected during the pandemic. A total of 1,955 participants joined 101 unique projects during this time period. We refer to joins from January 1 through March 18, 2020 as "pre-COVID-19" data, and joins from March 19 through May 31, 2020 as "COVID-19" data. We chose to use data on joins from earlier in 2020 rather than the same time period in an earlier year owing to the explosive growth of projects on SciStarter from 2019 to 2020. March 19 through May 31, 2019 saw only 323 project joins across 15 different projects. Thus, the data from January 1 through March 18, 2020 more closely resembles the COVID-19 data and serves as a better baseline.

COVID-19 RESTRICTION DATA

US states enacted varying restrictions on daily activities in response to COVID-19. To examine how this impacted CS participation, we categorized data on COVID-19 restrictions from the following sources: Kaiser Family Foundation (2021); National Academy for State Health and Policy (2021), and The Council of State Governments (2021). We used several restrictions as variables: whether there was a state-wide mandate requiring facial coverings; how many executive orders were issued; whether a stay-at-home order was enacted; the date a state first began to lift some initial restrictions on businesses openings; and whether a state had travel restrictions against out-of-state visitors. While we did not hypothesize these variables would necessarily explain variation in CS participation, they were used to gauge how restricted life in each state was.

We created an additive index for the total number of restrictions per state by coding our selected variables into binary categories. Mask mandate was coded as "1" if present statewide. Executive orders was coded as "1" if a state had issued more than 40, the mean number of executive orders issued over our study period. Stay-at-home order was coded as "1" if there was a state-wide stay-at-home order in effect. The date of first re-opening was coded as a "1" if states did not begin easing restrictions on businesses before May 8 (the mean re-opening date for states). Travel restrictions was coded as a "1" if travel restrictions for visitors were in place. This produced 6 possible groups a state could belong to (Table 1).

We further reclassified states into two classes based on the total number of restrictions. States with 5, 4, or 3 restrictions were grouped together as "highly restricted states" (n = 22 states), whereas states with 2, 1, or 0 restrictions were grouped together as "minimally restricted states" (n = 28 states). This allowed us to have two classes with similar numbers of members.

Because participants are not required to specify their location when registering with SciStarter, our sample was restricted to those who voluntarily supplied location in their SciStarter profile (n = 232). They represented 44 US states. We obtained location data for 129 individuals from highly restricted states and 103 individuals from minimally restricted states.

ANALYTIC METHODS

We used both project joins and project engagements as dependent variables to assess how the pandemic affected participation in different types of CS projects. Both dependent variables were log transformed to correct for a heavy right-skew in the distribution. We utilized R (R Core Development Team 2021) to perform Kruskal-Wallis tests to examine differences in mean number of joins and engagements among the four project groups. We examined differences between the groups using pairwise Wilcox tests with the Bonferroni correction to adjust for the number of comparisons. We used t-tests to explore differences in mean number of project joins among the different project types between the pre-COVID-19 and COVID-19 data. We used Kruskal-Wallis tests, chi-squared tests, and t-tests in R to explore how the number of joins and engagements among the four project groups differed between highly restricted states and minimally restricted states. We considered significant differences to be $P \leq 0.05$ for all analyses. We report means and standard deviations (sd) when appropriate.

ILLUSTRATIVE INTERVIEWS

To provide depth and context to our quantitative data, we selected five projects that exemplified the different CS project groups and conducted ~1-hour semi-structured interviews with project leads. We selected projects from the SciStarter database that had the highest (or one of the highest) number of joins in each project category. These included Phylo ("online," 144 joins), Stream Selfie ("away from home," 183 joins), and Crowd the Tap ("at home indoor," 132 joins). We also selected an extreme example of an "away from home" project not in the SciStarter database, Grunion Greeters, which requires observing fish behavior under very specific conditions. We selected ecoEXPLORE, a plant and wildlife observation project aimed at youth, as an example of "at home outdoor," although it could also be conducted away from home. One researcher conducted all interviews via Zoom in April and May 2021. For Crowd the Tap, a member of our author team serves as the project director and provided information here according to the interview script. Interview questions focused on whether project leaders saw changes in participation, and whether they modified aspects of the project (training, data collection methods, etc.) in response to COVID-19 restrictions. Analysis consisted of comparison between project leaders' perceptions of participation and our quantitative findings, and identifying similarities and differences in the ways projects were or were not modified.

NUMBER OF RESTRICTIONS	STATES
0	IA, SD, UT, WY
1	AL, IN, MS, MO, NE
2	AK, AR, CO, FL, GA, ID, LA, MN, MT, NV, NC, ND, OK, OR, SC, TN, TX, VT, WI
3	AZ, CA, HI, KS, KY, MI, NH, NM, OH, PA, WA, WV
4	DE, IL, ME, VA
5	CT, MD, MA, NJ, NY, RI

Table 1 Grouping of states according to the total number of COVID-19 related restrictions during March 19 through May 31, 2020. Possible restrictions included whether a state-wide mask mandate was required, the number of executive orders issued by the state, whether a stay-at-home order was enacted, the date a state first began to lift some of the initial restrictions on which businesses can be open, and whether a state had travel restrictions in place for visitors arriving from outside the state.

RESULTS

IMPACTS OF THE PANDEMIC ON PARTICIPATION IN EXISTING CITIZEN SCIENCE PROJECTS

SciStarter members joined a total of 68 unique projects over the study period (22 "online," 12 "away from home," 10 "at home indoor," and 24 "at home outdoor"). Kruskal-Wallis tests revealed a significant difference in the mean number of joins per project among the four different groups (X^2 = 8.418, p = 0.038; Figure 2). "Away from home" projects had the lowest mean number of joins (1.15, sd = 1.63), while "at home indoor" projects had the highest mean number of joins (2.54, sd = 1.45). No significantly different pairwise comparisons between these group means were found (Figure 2). However, the pairwise comparisons between "away from home" and "at home indoor" (p = 0.091) and between "away from home" and "at home outdoor" (p = 0.056) were significant at a $P \leq 0.10$ level.

Number of engagements was highly correlated with number of joins (r = 0.93). Kruskal-Wallis tests revealed there was also a significant difference in the mean number of engagements per project among the four different project groups (X^2 = 8.042, p = 0.045; Figure 3), with "away from home" projects having the lowest mean number of engagements (0.529, sd = 3.53) and "at home indoor"

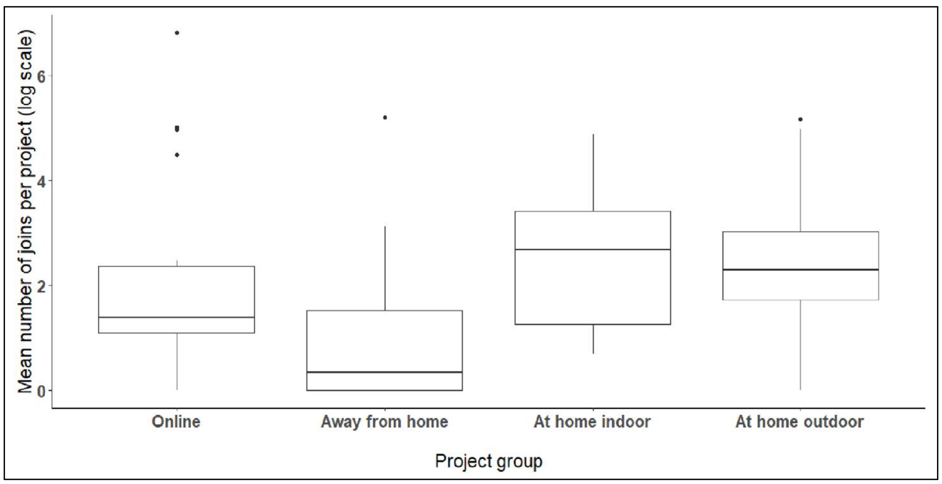

Figure 2 We found a significant difference in the mean number of joins (log scale) per project among the four project groups during the COVID-19 pandemic (X^2 = 8,418, p = 0.038) but no statistically significant pairwise differences. Boxes represent the interquartile range (25th percentile–75th percentile). Horizontal bar in each box represents the median. Vertical bars extend downward and upward from boxes to the minimum and maximum non-outlier values, respectively. Individual points represent outlier values.

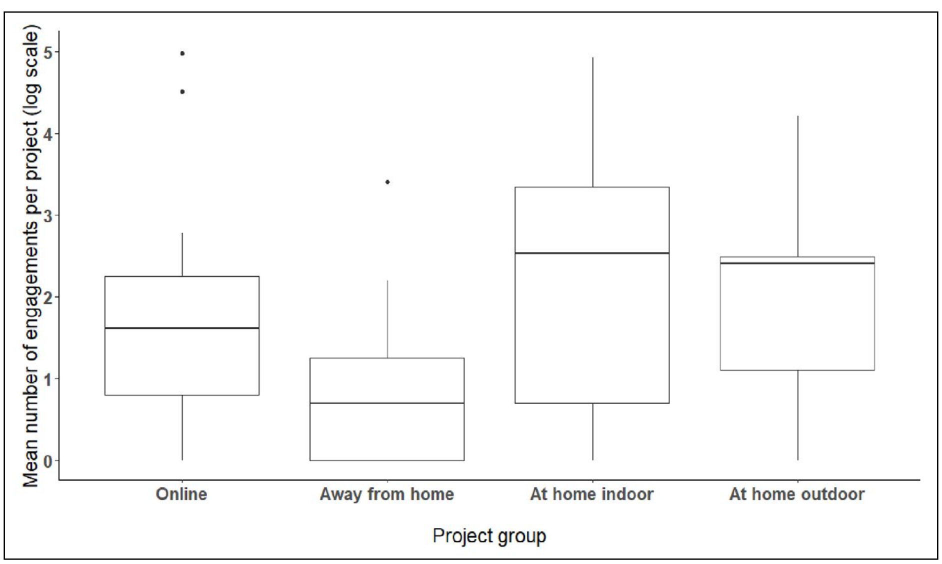

Figure 3 We found a significant difference in the mean number of engagements per project (log scale) among the four project groups during the COVID-19 pandemic (X^2 = 8.042, p = 0.045) but no statistically significant pairwise differences. Boxes represent the interquartile range (25th percentile–75th percentile). Horizontal bar in each box represents the median. Vertical bars extend downward and upward from boxes to the minimum and maximum non-outlier values, respectively. Individual points represent outlier values.

projects having the highest mean number of engagements (1.500, sd = 2.98). No pairwise comparisons were significantly different (Figure 3). The pairwise comparisons between "online" and "away from home" (p = 0.061) and between "away from home" and "at home indoor" (p = 0.080) were significant at a $P \leq 0.10$ level.

In contrast to the COVID-19 data, Kruskal-Wallis tests revealed no significant difference in the mean number of joins per project among the four different project groups in the pre-COVID-19 data (X^2 = 5.397, p = 0.145). T-tests revealed no significant differences in mean number of joins per project type between the pre-COVID-19 and COVID-19 data (Figure 4). While not statistically significant, there was a visually notable decrease in mean number of joins per project for "away from home" projects in the COVID-19 data compared with the pre-COVID-19 data (p = 0.201).

Chi-squared tests revealed no significant differences in the total number of engagements for different project groups between minimally restricted and highly restricted states (X^2 = 6.267, p = 0.201; Figure 5). T-tests revealed that there were no differences in total number of joins by project group between minimally and highly restricted states for "online" (p = 0.672), "away from home" (p = 0.168), "at home indoor" (p = 0.788), and "at home outdoor" (p = 0.207). The mean number of total engagements per state was slightly higher in highly restricted states (6.79,

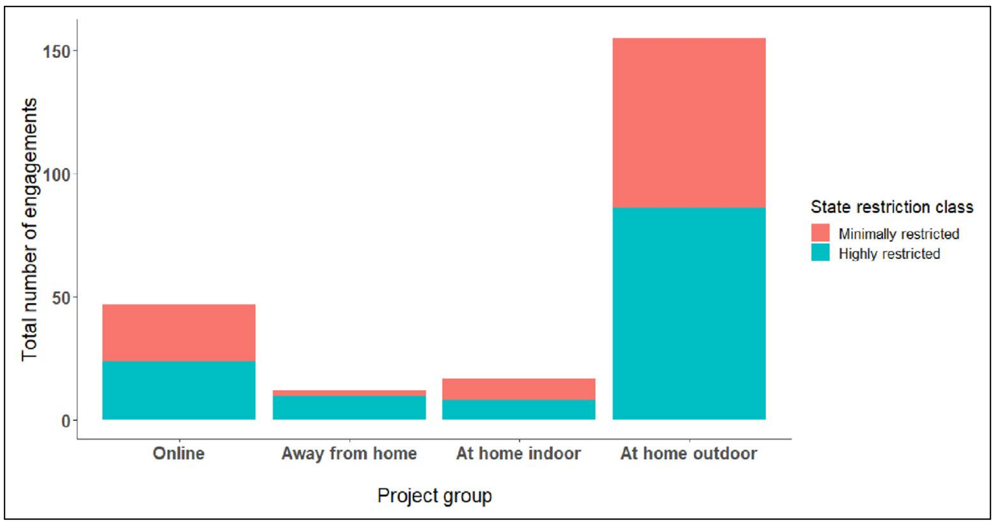

Figure 4 There were no significant differences in the mean number of joins (log scale) per project among the four project groups between the pre-COVID-19 and COVID-19 data. Boxes represent the interquartile range (25th percentile–75th percentile). Horizontal bar in each box represents the median. Vertical bars extend downward and upward from boxes to the minimum and maximum non-outlier values, respectively. Individual points represent outlier values.

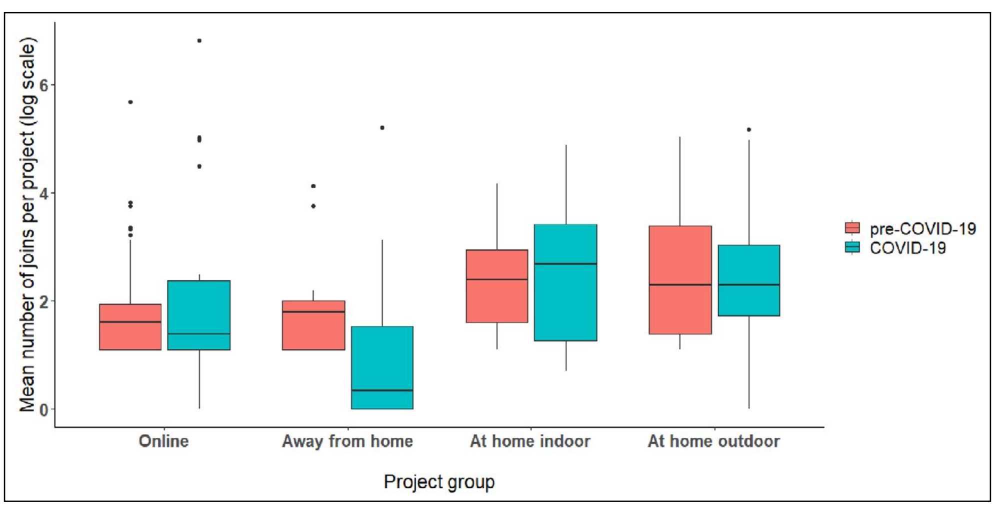

Figure 5 There were no significant differences in the total number of engagements for different project groups between participants from minimally and highly restricted states during the COVID-19 pandemic (X^2 = 6.267, p = 0.201).

sd = 6.65) than minimally restricted states (4.48, sd = 3.03), but Kruskal-Wallis tests revealed this difference was not statistically significant ($X^2 = 0.489$, $p = 0.484$).

HOW PROJECT LEADS ADAPTED PROJECTS IN RESPONSE TO COVID-19

Leads for examples of each project type shared their impressions of how the pandemic affected participation. They also described any modifications they made in response, and any opportunities it created.

Entirely online project: Phylo

Phylo is an example of a CS project that takes place entirely online. Participants align acquired DNA sequences to help determine the evolutionary history of various species. There is a low barrier to entry into the project; other than access to the internet, a device that can support the program, and enough bandwidth to use it, project participants can participate anywhere, with no training. The project lead did not see an increase in participation under COVID-19 restrictions, but noted that there is always seasonal fluctuation, with more engagement during winter months or when there is press coverage of the project. No modifications were made or needed for the project to be available to participants during COVID-19-related restrictions.

At home indoor project: Crowd the Tap

Crowd the Tap represents a "at home indoor" project that is "one-and-done," with a focus is on safe drinking water. Crowd the Tap participants answer questions about their pipes, water characteristics, and household characteristics to estimate risk of lead in their water. The project also collects water-chemistry data from those who request disposable chemistry strips. In the months before the pandemic, Crowd the Tap began preparing to work with two facilitator groups: librarians and teachers. The National Library of Medicine selected Crowd the Tap materials to be part of citizen science kits available in public libraries. The project director contracted with educational consultants for the creation of lesson plans for high school teachers. Initially, there was interest (e.g., inquiries) from librarians and teachers in the Crowd the Tap kits and lessons, but the PI suspected the pandemic negatively affected the ability of facilitator groups to follow through. More than 500 libraries ordered and received kits with Crowd the Tap materials and disposable chemistry strips. However, all libraries closed and reduced programming because of the pandemic. Only a few switched to online programs that featured Crowd the Tap, and only a few teachers requested disposable water chemistry strips for their students.

Away from home project with broad geographic inclusion: Stream Selfie

Stream Selfie, run by the Izaak Walton League of America (IWLA), is an example of a "away from home" project. Stream Selfie is a simple CS project designed to initiate public engagement in aquatic monitoring. The project can be done by an individual alone but does require collection of data at a stream location of their choice. The project leader saw an initial uptick in participation as COVID-19 restrictions were enacted, peaking through Citizen Science Month and Earth Day, with a subsequent drop to a level still higher than pre-pandemic. While the data collection procedure and interface did not change in response to COVID-19 restrictions, more detailed instructions were added to promote individuals joining through SciStarter. Recruitment messaging emphasized that the project was an outdoor activity amenable to social distancing. During the pandemic, the project leader put more effort on Stream Selfie compared with their other CS activities that required working in a group. Outreach also changed to encourage participants to investigate locations on their own property or at local parks rather than state and federal lands that were closed. Prior to the pandemic, most participants came from IWLA chapters, but since the pandemic and changes in project messaging, the project leader saw an increase in participants not associated with chapters. Participants noted how important it was to use the project to connect with nature during the pandemic.

Away from home project targeting specific locations: Grunion Greeters

Grunion Greeters, run by Pepperdine University and the Beach Ecology Coalition, represents an extreme example of a "away from home" project that requires access to specific sites at specific times in order to participate. California grunion, *Leuresthes tenuis,* are small marine fish who mate and deposit eggs on beaches from Tomales Bay, California to Ensenada, Baja California, Mexico from March to August during the highest high tides. These occur the night after the full and new moons, influenced by changes in the moon's gravitational pull on the Earth's oceans. Fish come up, or "run," on the beach to deposit eggs that develop buried in the sand until the next high high tide when larvae emerge. Determined by this astronomic event, grunion run on the same nights near the same times across their geographic range. Volunteers are a vital component of the monitoring program, which would be technologically challenging and prohibitively expensive without CS. Participants collect data about the fish and conditions that could disturb them, such as light levels and late-night beach recreation.

In spring of 2020, California closed public beaches in response to COVID-19, coinciding with grunion spawning and rendering CS monitoring at most areas illegal. This greatly reduced volunteer participation early in the spawning season. The California Department of Fish and Wildlife removed the public schedule from their website and the Grunion Greeter project was not promoted, though participants from previous years engaged with project leads via email. Some volunteers were able to access the beach legally, such as staff from beach management agencies, lifeguards, beachside residents, etc. In fact, far more members of the public were observed on beaches at night than during previous years, despite the closures, which were not well enforced. The 2020 dataset was therefore small.

In spring of 2021, the project re-focused recruitment efforts online, and provided online training rather than live workshops. The data collection season was in progress when the interview was conducted and at the time of writing, but the project leader estimated that participation in 2021 will more than double that of 2020.

"At home outdoor" project focused on youth: ecoEXPLORE

Unlike the projects described above, ecoEXPLORE, run by the North Carolina Arboretum, is specifically aimed at youth ages 5 to 13. It is an example of an "at home outdoor" project, although it could also occur "away from home." The project invites participants to observe flora and fauna, sometimes in response to specific badge-earning challenges to focus on a place (a hotspot) or taxon. The primary focus is engagement and education, but data are added to iNaturalist where they can be utilized for relevant research projects. Project leaders reported a rapid increase in participation and web traffic when the pandemic hit, which they attributed to school closures and the need for parents to oversee distance learning, though they also saw increased participation from adults who were not parents. Project leaders encouraged participation during the pandemic by shifting to web-based events and online training. This shift was possible because in-person educational activities at the Arboretum were cancelled, leaving staff more time to focus on ecoEXPLORE.

Prior to 2020, activities on ecoEXPLORE encouraged families to visit public parks, but the project was modified to encourage participants to observe nature within their local neighborhood. The move to encouraging independent local exploration also allowed the project to expand in geographic scope:

> "We had already launched two regional hubs across the state prior to COVID. These organizations were already facilitating ecoEXPLORE within their local communities. I would say that COVID did allow for greater virtual participation, and it helped us reach places in the state that we were struggling to reach."

DISCUSSION

We found significant differences in participation based on key characteristics of the CS projects. Projects that required data collection at specific sites away from home saw fewer joins and engagements by SciStarter members than projects that could occur at or near home. This matched the pattern found by Basile et al. (2021) of participants continuing to contribute data to projects but doing so from their neighborhoods rather than public locations. It was somewhat surprising that there were not more joins and engagements to "online" projects. This could be due to virtual meeting fatigue among people working from home who were searching for activities that took them away from a screen (Bennett et al. 2021).

An important limitation to the quantitative data is that we could not compare changes in joins and participation across years. Only 15 of the 68 projects in our sample were on SciStarter in 2019, impeding quantitative comparisons. We did compare joins in 2020 before and during COVID-19 to document a decrease in the number of joins for "away from home" projects. Our results still elucidate which types of projects received the most interest and engagement during the start of the COVID-19 pandemic.

The results of our quantitative analysis were well aligned with the experiences of project leads. Our exemplar of an "online project," Phylo, did not experience the increase in participation we expected, which paralleled our quantitative findings. This may be because it was not heavily promoted during the restricted period as project leads were more actively promoting newer projects. Crowd the Tap, our example of an "at home indoor" project, also did not see the increase in participation project leads had hoped for based on pre-COVID-19 promotion. This project was designed to be facilitated by teachers utilizing hands-on materials, and was not easily re-designed for home use. Many affiliated teachers were overwhelmed and opted not to add ambitious assignments like CS. The lack of increasing participation may also reflect a preference among CS contributors to spend time outdoors.

Projects that occurred outdoors received the most joins and engagement. Participation in Stream Selfie increased as expected based on our initial hypothesis. This ran counter to the quantitative data. Stream Selfie was classified as "away from home," as it required participants to search for a stream. However, further inspection of "away from home" projects revealed that Stream Selfie was an outlier with far more joins than other "away from home" projects. Stream Selfie differed from other projects in the "away from home" category. At the start of the pandemic, project managers encouraged more local exploration rather than visits to state or national lands. Project leads were able to capitalize on the additional interest due to their own increased availability. They further increased participation opportunities by marketing the project beyond IWL's usual community. The flexible approach adopted by Stream Selfie contributed to its success during the start of the pandemic and suggests strategies that other "away from home" projects could employ to avoid decreased participation.

As an example of an "at home outdoor" project, ecoEXPLORE exemplified our quantitative findings, as it saw a large increase in participation, including an increase in geographic scale. Project leads were able to capitalize on a new need for science- and nature-based activities parents could do with their children in lieu of in-class experiences. In the cases of ecoEXPLORE and Stream Selfie, the pandemic not only influenced participation but also the nature of the projects themselves.

In contrast to the above projects, for which location could be easily adapted, Grunion Greeters was an extreme example of a project impossible for a majority of people to contribute to from home. This project, driven less by a desire for public engagement and more by a need for efficient and reliable data collection, was negatively impacted by access restrictions. In this case, CS was an important data collection methodology contributing to conservation and was dramatically hindered by the pandemic.

Despite the widely different restriction levels states imposed throughout the pandemic, we found no evidence for differences in CS participation. States with a higher level of restriction had slightly more engagement, though that result was not significant and could have correlated with many factors. We should note our analyses were limited by the fact that we only had location data for 232 of the 3,602 participants in our sample. Accessing location data for more participants could have produced different results.

Our research faced another confounding factor. Since 2016, a date in April on or around Earth Day has also been recognized as Citizen Science Day, an event created to increase awareness, participation, and benefits from CS activity across the US. In 2020, with support from the National Library of Medicine, that event expanded to Citizen Science Month, planned long before COVID-19 appeared. In the 11 years since SciStarter.org emerged and the field of CS formalized, participation in these events has grown steadily. It is difficult to tease apart how much of the observed increases in participation were due to pandemic-associated factors versus successful outreach.

CONCLUSION

It is well documented that CCS can be used to understand and respond to global change. CCS can be used to monitor extreme events such as flooding (See 2019) and fire (Kirchhoff et al. 2021), to examine impacts to biodiversity (Cooper, Shirk, and Zuckerberg 2014; Theobald et al. 2015), and to understand shifts in ecology and phenology (Miller-Rushing, Gallinat, and Primack 2019). It can be a powerful tool to detect and monitor emerging pests and invasive species (Meyer, Drill, and Jadallah 2021) as well as infectious diseases (Smith et al. 2021). Engaging in these projects can build individual confidence, capacity for stewardship, and social capital for conservation (Merenlender et al. 2016). As more people rely on CCS for these important benefits, project leaders and the field as a whole need to be more agile and adaptable in the face of increasing uncertainty and disasters such as the COVID-19 pandemic. Project managers can adjust their approaches to sustain participation and to continue to provide these important community benefits. Our quantitative data demonstrates the shifts in participation that occurred, while the interviews suggest ways project managers adapted.

CCS can improve online communication infrastructure in a positive way that can increase community strength and resilience (Doyle et al. 2020). Community resilience to disaster is needed, particularly as climate-driven extreme weather and health events increase (Swain et al. 2020). CCS can also contribute to community resilience through the utilization of the internet as social infrastructure (Schmidt and Power 2021) to foster connectedness during periods of physical isolation.

The year 2020 reintroduced us to the fact that global pandemics have massive societal impacts. CCS can be an important tool for building community and a positive connection between nature and society that, in the case of this pandemic, took on increased resonance. A global disturbance such as COVID-19 is a rare occurrence. However, it is likely that the world will need to face global challenges such as combating emerging diseases, responding to resource limitations, and addressing impacts of more frequent and severe weather events in the coming years. CCS's ability to build connections may play an increasingly important role.

Intentionally building flexibility into CCS project design can create a more robust environment for participatory research. In order to ensure citizen science can be leveraged, we need to think about the characteristics of projects and how participation might be affected by major societal changes. Removing barriers, such as the need to attend in-person training, or the need for access to specific public spaces that may be difficult to reach, can increase inclusivity, broaden participation, and allow projects to continue to function under a range of disturbances. This goes hand-in-hand with efforts to expand broadband access. Though not all projects may be able to adopt this approach given their scientific objectives, for most projects, the benefits of building community and nature connectedness to improve socioemotional health can be realized. We hope our findings can inform the design, and re-design, of CCS projects that may guide project directors in increasing their capacity to respond to and continue through disturbances.

DATA ACCESSIBILITY STATEMENT

Data from the SciStarter database is available via info@scistarter.org, or the authors. Categorized data, R scripts, and interview notes are available via contacting the authors at either sldrill@ucanr.org or cjrosenblatt@ucdavis.edu. Data on COVID-19 restrictions from the following sources: Kaiser Family Foundation (2021); National Academy for State Health and Policy (2021), and The Council of State Governments (2021) are publicly available through their websites at the time of this writing.

ETHICS AND CONSENT

Our interview instrument was reviewed by the Institutional Review Board at UC Davis (1744610-1) and found to be exempt.

ACKNOWLEDGEMENTS

The authors would like to thank project leaders for sharing their perspectives with us. These include Karen Martin, Jérôme Waldispühl, Samantha Briggs, Jonathan Marchal, and Elizabeth Dobbs-Alexander. Renee Yang and Daniel Arbuckle extracted and provided participant data from the SciStarter database. Authors would like to acknowledge the support of the National Library of Medicine to SciStarter and Crowd the Tap.

COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

Sabrina Drill conceived of this project, conducted all interviews, and was the main author of this paper. Connor Rosenblatt prepared data, developed the analysis framework, analyzed the quantitative data, and was a primary co-author of this paper. Darlene Cavalier conceived of the SciStarter database, led collection of the quantitative data we analyzed here, and further developed the hypothesis and analysis. Caren Cooper further developed the hypothesis for this study, guided the analysis framework, and contributed to the summary of the Crowd the Tap project, which she leads. Heidi Ballard helped to develop the conceptual arguments of this paper and mentored author Rosenblatt.

AUTHOR AFFILIATIONS

Sabrina Drill orcid.org/0000-0001-8243-7422
University of California Agriculture and Natural Resources, US

Connor Rosenblatt orcid.org/0000-0003-1557-0535
University of California, Davis, US

Caren Cooper orcid.org/0000-0001-6263-8892
North Carolina State University, US

Darlene Cavalier orcid.org/0000-0002-6886-3289
Arizona State University, US

Heidi Ballard orcid.org/0000-0002-7841-8293
University of California, Davis, US

REFERENCES

Ballard, HL, Dixon, CGH and **Harris, EM.** 2017. Youth-focused citizen science: Examining the role of environmental science learning and agency for conservation. *Biological Conservation*, 208: 65–75. DOI: https://doi.org/10.1016/j.biocon.2016.05.024

Basile, M, Russo, LF, Russo, VG, Senese, A and **Bernardo, N.** 2021. Birds seen and not seen during the COVID-19 pandemic: The impact of lockdown measures on citizen science bird observations. *Biological Conservation*, 256: 109079. DOI: https://doi.org/10.1016/j.biocon.2021.109079

Bates, AE, Primack, RB, Moraga, P and **Duarte, CM.** 2020. COVID-19 pandemic and associated lockdown as a "Global Human Confinement Experiment" to investigate biodiversity conservation. *Biological Conservation*, 248: 108665. DOI: https://doi.org/10.1016/j.biocon.2020.108665

Bennett, AA, Campion, ED, Keeler, KR and **Keener, SK.** 2021. Videoconferencing fatigue? Exploring changes in fatigue after videoconference meetings during covid-19. *Journal* *of Applied Psychology*, 106: 330–344. DOI: https://doi.org/10.1037/apl0000906

Bowser, A, Parker, A and **Long, A.** 2020. Citizen Science and COVID-19: The Power of the (Distanced) Crowd. *Wilson Center Science and Technology Innovation Program*. https://www.wilsoncenter.org/blog-post/citizen-science-and-covid-19-power-distanced-crowd.

Brooks, SK, Webster, RK, Smith, LE, Woodland, L, Wessely, S, Greenberg, N and **Rubin, GJ.** 2020. The psychological impact of quarantine and how to reduce it: Rapid review of the evidence. *The Lancet*, 395: 912–920. DOI: https://doi.org/10.1016/S0140-6736(20)30460-8

Cooper, CB, Hawn, CL, Larson, LR, Parrish, JK, Bowser, G, Cavalier, D, Dunn, RR, Haklay, M, Gupta, KK, Jelks, NO, Johnson, VA, Katti, M, Leggett, Z, Wilson, OR and **Wilson, S.** 2021. Inclusion in citizen science: The conundrum of rebranding. *Science*, 372(6549): 1386–1388. DOI: https://doi.org/10.1126/science.abi6487

Cooper, CB, Shirk, J and **Zuckerberg, B.** 2014. The Invisible Prevalence of Citizen Science in Global Research: Migratory Birds and Climate Change. *PLOS ONE*, 9(9): e106508. DOI: https://doi.org/10.1371/journal.pone.0106508

Corlett, RT, Primack, RB, Devictor, V, Maas, B, Goswami, VR, Bates, AE, Koh, LP, Regan, TJ, Loyola, R, Pakeman, RJ, Cumming, GS, Pidgeon, A, Johns, D and **Roth, R.** 2020. Impacts of the coronavirus pandemic on biodiversity conservation. *Biological Conservation*, 246: 108571. DOI: https://doi.org/10.1016/j.biocon.2020.108571

Council of State Governments. 2021. *State Executive Orders – COVID-19 Resources for State Leaders*. https://web.csg.org/covid19/executive-orders/.

Crimmins, TM, Posthumus, E, Schaffer, S and **Prudic, KL.** 2021. COVID-19 impacts on participation in large scale biodiversity-themed community science projects in the United States. *Biological Conservation*, 256: 109017. DOI: https://doi.org/10.1016/j.biocon.2021.109017

de Sherbinin, A, Bowser, A, Chuang, TR, Cooper, C, Danielsen, F, Edmunds, R, Elias, P, Faustman, E, Hultquist, C, Mondardini, R, Popescu, I, Shonowo, A and **Sivakumar, K.** 2021. The Critical Importance of Citizen Science Data. *Frontiers in Climate*, 3: 20. DOI: https://doi.org/10.3389/fclim.2021.650760

Doyle, EEH, Lambie, E, Orchiston, C, Becker, JS, McLaren, L, Johnston, D and **Leonard, G.** 2020. Citizen science as a catalyst for community resilience building: A two-phase tsunami case study. *Australasian Journal of Disaster and Trauma Studies*, 24(1): 23–50.

Grosholz, E, Drill, S, McCann, L and **Bimrose, K.** 2021. Engaging the importance of community scientists in the management of an invasive marine pest. *California Agriculture*, 75(1): 40–45. DOI: https://doi.org/10.3733/ca.2021a0006

Hale, T, Angrist, N, Goldszmidt, R, Kira, B, Petherick, A, Phillips, T, Webster, S, Cameron-Blake, E, Hallas, L, Majumdar, S and **Tatlow, H.** 2021. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nature Human Behaviour*. DOI: https://doi.org/10.1038/s41562-021-01079-8

Halpern, M. 2019. Feminist standpoint theory and science communication. *Journal of Science Communication,* 18(4): C02. DOI: https://doi.org/10.22323/2.18040302

Haywood, BK, Parrish, JK and **Dolliver, J.** 2016. Place-based and data-rich citizen science as a precursor for conservation action. *Conservation Biology*, 30(3): 476–486. DOI: https://doi.org/10.1111/cobi.12702

Hochachka, WM, Alonso, H, Gutiérrez-Expósito, C, Miller, E and **Johnston, A.** 2021. Regional variation in the impacts of the COVID-19 pandemic on the quantity and quality of data collected by the project eBird. *Biological Conservation*, 254: 108974. DOI: https://doi.org/10.1016/j.biocon.2021.108974

Iwaniec, DM, Grimm, NB, McPhearson, T, Berbés-Blázquez, M, Cook, EM and **Muñoz-Erickson, TA.** 2021. A Framework for Resilient Urban Futures. In Hamstead, DM, et al. (eds.), *Resilient Urban Futures*, 1–9. New York: Springer. DOI: https://doi.org/10.1007/978-3-030-63131-4_1

Kaiser Family Foundation. 2021. *State COVID-19 Data and Policy Actions*. KFF. https://www.kff.org/coronavirus-covid-19/issue-brief/state-covid-19-data-and-policy-actions/.

Kirchhoff, C, Callaghan, CT, Keith, DA, Indiarto, D, Taseski, G, Ooi, MKJ, Le Breton, TD, Mesaglio, T, Kingsford, RT and **Cornwell, WK.** 2021. Rapidly mapping fire effects on biodiversity at a large-scale using citizen science. *Science of The Total Environment*, 755: 142348. DOI: https://doi.org/10.1016/j.scitotenv.2020.142348

Kishimoto, K and **Kobori, H.** 2021. COVID-19 pandemic drives changes in participation in citizen science project "City Nature Challenge" in Tokyo. *Biological Conservation*, 255: 109001. DOI: https://doi.org/10.1016/j.biocon.2021.109001

Kornfeld, M. 2020, June 23. As Scientists Struggle with Rollbacks, Stay At Home Orders and Funding Cuts, Citizens Fill the Gap. *Inside Climate News*. https://insideclimatenews.org/news/23062020/citizen-science-coronavirus/.

Koss, RS and **Kingsley, J.** 2010. Volunteer health and emotional wellbeing in marine protected areas. *Ocean and Coastal Management*, 53(8): 447–453. DOI: https://doi.org/10.1016/j.ocecoaman.2010.06.002

Li, E, Parker, SS, Pauly, GB, Randall, JM, Brown, BV and **Cohen, BS.** 2019. An urban biodiversity assessment framework that combines an urban habitat classification scheme and citizen science data. *Frontiers in Ecology and Evolution*, 7. DOI: https://doi.org/10.3389/fevo.2019.00277

Marselle, MR, Stadler, J, Korn, H, Irvine, K and **Bonn, A.** 2019. *Biodiversity and Health in the Face of Climate Change*.

New York: Springer. DOI: https://doi.org/10.1007/978-3-030-02318-8

McKinley, DC, Miller-Rushing, AJ, Ballard, HL, Bonney, R, Brown, H, Cook-Patton, SC, Evans, DM, French, RA, Parrish, JK, Phillips, TB, Ryan, SF, Shanley, LA, Shirk, JL, Stepenuck, KF, Weltzin, JF, Wiggins, A, Boyle, OD, Briggs, RD, Chapin, SF, Hewitt, DA, Preuss, PW and **Soukup, MA.** 2017. Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, 208: 15–28. DOI: https://doi.org/10.1016/j.biocon.2016.05.015

Merenlender, AM, Crall, AW, Drill, S, Prysby, M and **Ballard, H.** 2016. Evaluating environmental education, citizen science, and stewardship through naturalist programs. *Conservation Biology*, 30(6): 1255–1265. DOI: https://doi.org/10.1111/cobi.12737

Meyer, R, Drill, S and **Jadallah, C.** 2021. Special issue: Community and citizen science. *California Agriculture*, 75(1): 5–7. DOI: https://doi.org/10.3733/ca.2021a0003

Miller-Rushing, AJ, Gallinat, AS and **Primack, RB.** 2019. Creative citizen science illuminates complex ecological responses to climate change. *Proceedings of the National Academy of Sciences*, 116(3): 720–722. DOI: https://doi.org/10.1073/pnas.1820266116

Moser, S, Meerow, S, Arnott, J and **Jack-Scott, E.** 2019. The turbulent world of resilience: Interpretations and themes for transdisciplinary dialogue. *Climatic Change*, 153(1): 21–40. DOI: https://doi.org/10.1007/s10584-018-2358-0

National Academy for State Health and Policy. 2021. *States' COVID-19 Public Health Emergency Declarations, Mask Requirements and Travel Advisories*. https://www.nashp.org/governors-prioritize-health-for-all/.

Newman, G, Chandler, M, Clyde, M, McGreavy, B, Haklay, M, Ballard, H, Gray, S, Scarpino, R, Hauptfeld, R, Mellor, D and **Gallo, J.** 2017. Leveraging the power of place in citizen science for effective conservation decision making. *Biological Conservation*, 208: 55–64. DOI: https://doi.org/10.1016/j.biocon.2016.07.019

Peterson, C. 2020, September 8. Americans are observing nature during the pandemic, helping scientists with research. *National Geographic*. https://www.nationalgeographic.com/animals/2020/09/citizen-science-increasing-pandemic-insects/.

Qiu, J, Shen, B, Zhao, M, Wang, Z, Xie, B and **Xu, Y.** 2020. A nationwide survey of psychological distress among Chinese people in the COVID-19 epidemic: Implications and policy recommendations. *General Psychiatry*, 33: e100213. DOI: https://doi.org/10.1136/gpsych-2020-100213

R Core Development Team. 2021. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Randler, C, Tryjanowski, P, Jokimäki, J, Kaisanlahti-Jokimäki, ML and **Staller, N.** 2020. SARS-CoV2 (COVID-19) pandemic lockdown influences nature-based recreational activity: The case of birders. *International Journal of Environmental Research and Public Health*, 17: 7310. DOI: https://doi.org/10.3390/ijerph17197310

Sánchez-Clavijo, LM, Martínez-Callejas, SJ, Acevedo-Charry, O, Diaz-Pulido, A, Gómez-Valencia, B, Ocampo-Peñuela, N, Ocampo, D, Olaya-Rodríguez, MH, Rey-Velasco, JC, Soto-Vargas, C and **Ochoa-Quintero, JM.** 2021. Differential reporting of biodiversity in two citizen science platforms during COVID-19 lockdown in Colombia. *Biological Conservation*, 256: 109077. DOI: https://doi.org/10.1016/j.biocon.2021.109077

Schmidt, D and **Power, SA.** 2021. Offline World: The Internet as Social Infrastructure among the Unconnected in Quasi-Rural Illinois. *Integrative Psychological and Behavioral Science*, 55(2): 371–385. DOI: https://doi.org/10.1007/s12124-020-09574-9

Schuttler, SG, Sorensen, AE, Jordan, RC, Cooper, C and **Shwartz, A.** 2018. Bridging the nature gap: can citizen science reverse the extinction of experience? *Frontiers in Ecology and the Environment*, 16(7): 405–411. DOI: https://doi.org/10.1002/fee.1826

See, L. 2019. A Review of Citizen Science and Crowdsourcing in Applications of Pluvial Flooding. *Frontiers in Earth Science*, 7. DOI: https://doi.org/10.3389/feart.2019.00044

Smith, S, Sewalk, KC, Donaire, F, Goodwin, L, Zych, A, Crawley, AW, Brownstein, JS and **Baltrusaitis, K.** 2021. Maintaining user engagement in an infectious disease surveillance-related citizen science project. *Citizen Science: Theory and Practice*, 6(1): 7. DOI: https://doi.org/10.5334/cstp.302

Swain, DL, Singh, D, Touma, D and **Diffenbaugh, NS.** 2020. Attributing Extreme Events to Climate Change: A New Frontier in a Warming World. *One Earth*, 2(6): 522–527. DOI: https://doi.org/10.1016/j.oneear.2020.05.011

Theobald, EJ, Ettinger, AK, Burgess, HK, DeBey, LB, Schmidt, NR, Froehlich, HE, Wagner, C, HilleRisLambers, J, Tewksbury, J, Harsch, MA and **Parrish, JK.** 2015. Global change and local solutions: Tapping the unrealized potential of citizen science for biodiversity research. *Biological Conservation*, 181: 236–244. DOI: https://doi.org/10.1016/j.biocon.2014.10.021

Walker, B, Carpenter, S, Anderies, J, Abel, N, Cumming, G, Janssen, M, Lebel, L, Norberg, J, Peterson, G and **Pritchard, R.** 2002. Resilience management in social-ecological Systems: a working hypothesis for a participatory approach. *Conservation Ecology*, 6(1): 14. DOI: https://doi.org/10.5751/ES-00356-060114

Walker, B and **Salt, D.** 2006. *Resilience Thinking: Sustaining Ecosystems and People in a Changing World*. Washington, DC: Island Press.

Wilder-Smith, A and **Freedman, DO.** 2020. Isolation, quarantine, social distancing and community containment: Pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. *Journal of Travel Medicine*, 27(2): 1–4. DOI: https://doi.org/10.1093/jtm/taaa020

Xiong, J, Lipsitz, O, Nasri, F, Lui, LMW, Gill, H, Phan, L, Chen-Li, D, Iacobucci, M, Ho, R, Majeed, A and **McIntyre, RS.** 2020. Impact of COVID-19 pandemic on mental health in the general population: A systematic review. *Journal of Affective Disorders*, 277: 55–64. DOI: https://doi.org/10.1016/j.jad.2020.08.001

TO CITE THIS ARTICLE:
Drill, S, Rosenblatt, C, Cooper, C, Cavalier, D and Ballard, H. 2022. The Effect of the COVID-19 Pandemic and Associated Restrictions on Participation in Community and Citizen Science. *Citizen Science: Theory and Practice,* 7(1): 23, pp. 1–14. DOI: https://doi.org/10.5334/cstp.463

Submitted: 28 July 2021 Accepted: 21 December 2021 Published: 19 May 2022

COPYRIGHT:
© 2022 The Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC-BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. See http://creativecommons.org/licenses/by/4.0/.

Citizen Science: Theory and Practice is a peer-reviewed open access journal published by Ubiquity Press.