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COVID-19 impacts on participation in large scale biodiversity-themed community science projects in the United States

Theresa M. Crimmins a,⁎, Erin Posthumus a,⁎, Sara Schaffer a,⁎, Kathleen L. Prudic a,⁎⁎

a School of Natural Resources and the Environment, University of Arizona, 1604 E. Lowell St., Tucson, AZ 85721, USA
b USA National Phenology Network, 1311 E. 4th St., Ste. 325, Tucson, AZ 85721, USA

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ABSTRACT

Shutdowns associated with the COVID-19 pandemic have had extensive impacts on professional and volunteer-based biodiversity and conservation efforts. We evaluated the impact of the widespread pandemic-related closures in the spring of 2020 on participation patterns and rates on a national and a state-by-state basis in the United States in four biodiversity-themed community science programs: eBird, eButterfly, iNaturalist, and Nature’s Notebook. We compared the number of participants, observations submitted, and proportion of observations collected in urban environments in spring 2020 to the expected values for these metrics based on activity in the previous five years (2015–2019), which in many cases exhibited underlying growth.

At the national scale, eButterfly and Nature’s Notebook exhibited declines in the number of participants and number of observations submitted during the spring of 2020 and iNaturalist and eBird showed growth in both measures. On a state-by-state basis, the patterns varied geographically and by program. The more popular programs – iNaturalist and eBird – exhibited increases in the Eastern U.S. in both the number of observations and participants and slight declines in the West. Further, there was a widespread increase in observations originating from urban areas, particularly in iNaturalist and eBird. Understanding the impacts of lockdowns on participation patterns in these programs is crucial for proper interpretation of the data. The data generated by these programs are highly valuable for documenting impacts of pandemic-related closures on wildlife and plants and may suggest patterns seen in other community science programs and in other countries.

1. Introduction

The COVID-19 pandemic has had extensive impact on all facets of human society (Bates et al., 2020; Diffenbaugh et al., 2020). To limit virus transmission, swift closures of public spaces including college campuses, K-12 schools, theaters, sports venues, and parks and recreation facilities swept through the United States in March 2020 and remained in place for variable durations across states through subsequent months. Consequently, tourism, recreation behaviors, and other forms of human activity patterns have been dramatically impacted (Bakar and Rosbi, 2020; Nicola et al., 2020). The dramatic shifts in human activities have had clear effects on wildlife and biodiversity; anecdotes suggest some wildlife may be moving into new areas or changing their behavior, while others may be at risk of increased exploitation or disturbance (Corlett et al., 2020; Rutz et al., 2020).

Community science – also referred to as citizen science, volunteer science, and public participation in scientific research – provides significant value to conservation efforts in both urban and non-urban areas (Cooper et al., 2007; Devictor et al., 2010; McKinley et al., 2017; Sullivan et al., 2017). Community science programs are characterized as scientific research conducted at least in part by amateur or volunteer scientists (Bonney et al., 2009; Dickinson et al., 2012). Designed to engage non-professionals in the act of science and data, these programs frequently yield data at spatial and temporal scales far beyond what professional scientists can achieve when working alone. Community science programs lead to increases in science literacy and an understanding of the process of “doing science”, a deepened sense of place, and a greater understanding and appreciation for the plants and animals they are observing (Dickinson et al., 2012; Evans et al., 2020). As such, community science programs were widely advertised during early weeks of the shutdown in the U.S. as stimulating and meaningful activities for children and adults alike during school and office closures (Bowman and

⁎ Correspondence to: T.M. Crimmins, School of Natural Resources and the Environment, University of Arizona, 1604 E. Lowell St., Tucson, AZ 85721, USA.
⁎⁎ Corresponding author.
E-mail addresses: theresa@usanpn.org (T.M. Crimmins), klprudic@arizona.edu (K.L. Prudic).

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2. Materials and methods

2.1. Community science programs

The data evaluated in this study represent four popular biodiversity-themed community science programs in the U.S. The programs vary in their aims, complexity in participating, and levels of standardization, though all contribute critical data and information for documenting and tracking status and trends in biodiversity (Kelling et al., 2019). Data from all four programs are frequently utilized by scientists, conservation organizations, and land management agencies to understand distributions and trends in species and to inform decisions (Cooper et al., 2007; Ellwood et al., 2017).

eButterfly engages participants in documenting checklists of butterflies across North America (Pradick et al., 2017). Participants submit their observations for a new or existing location on a web browser; all locations are stored to encourage repeated observations from established locations. Similar to eBird, participants choose from one of four types of sampling protocols and are presented with a checklist of butterfly species known to occur in the state or province; participants are invited to report presence or absence for all species on the list. Participants are encouraged to submit photos of their observations so that species identification can be verified by other participants in the community. Over 1000 species of butterflies and moths have been contributed to eButterfly to-date (eButterfly, 2020).

Naturalist engages participants across the globe to photo document plants, animals, fungi, and algae (Seltzer, 2019). Photos are uploaded through a web browser or mobile application to an online community where other participants verify the species identification (Nugent, 2018; Unger et al., 2020). Species identification is also facilitated by a machine learning algorithm which evaluates the submitted photo and makes suggestions on species identification to the participant (Van Horn et al., 2018). Since the program’s launch, over 300,000 species have been documented worldwide through iNaturalist (Loarie, 2020). Projects and events can also be created within the platform, such as bioblitz and City Nature Challenge events in which participants survey the biodiversity of a specific area during a defined time period. Dozens of such events took place across the U.S. in spring 2020, despite pandemic lockdowns.

Nature’s Notebook, coordinated by the USA National Phenology Network (USA-NPN), engages individuals and groups of participants observing collectively in documenting plant and animal phenology across the U.S. (Denny et al., 2014). Participants first register one or more locations (sites) at which they make repeated observations, then register individual plants and/or a checklist of animal species to observe at each site. Participants collect observations of the status of seasonal growth and development (conditions such as presence of leaves, open flowers, or ripe fruits in plants and presence of individuals, mating, courtship calling, or egg laying in animals) via a web browser or mobile application. Participants are encouraged to make observations 2–3 times per week during the season when plants and animals are active and indicate the presence or absence of each phenological stage at each visit (Rosemartin et al., 2014). Protocols are currently available for participants to track the phenology of over 1000 species of plants and nearly 400 species of insects, fish, amphibians, reptiles, birds, and mammals (USA National Phenology Network, 2020a).

eBird engages a global network of participants who submit observations of birds to a central data repository via a web browser or the eBird mobile application (Sullivan et al., 2014). Participants report bird species identity, occurrence, and relative abundance at either predefined birthing hotspots or observer-specified locations; locations can be saved and returned to for repeat observations. Participants choose from one of four types of sampling protocols and are presented with a checklist of bird species most likely to be observed at their selected location; participants are invited to report presence or absence and number of individuals for all species on the list. Some participants report only occasionally; others complete daily checklists (Sullivan et al., 2014).
As of 2019, eBird boasted 10,721 bird species in the program’s taxonomy (Team eBird, 2019).

Citizen science programs generally have shown growth in recognition and participation over the past decade (McKinley et al., 2017). Three of the four programs examined – iNaturalist, Nature’s Notebook, and eBird – similarly experienced either steady or exponential growth in participation in recent years (Fig. 1a, b).

2.2. Data preparation

We downloaded the prepackaged eBird “basic sampling event dataset” from the eBird website on August 15, 2020 (eBird Basic Dataset, 2020). This dataset includes all validated observations and unique participants from checklists entered into eBird as well as covariates entered into the checklists regarding location and effort, but not species (Sullivan et al., 2014).

We accessed iNaturalist “research grade” observations through the Global Biodiversity Information Facility filtering by state, month, year, and unique participant (GBIF, 2020). Research grade observations are observations with a date, latitude/longitude coordinates, and a consistent species identification made by at least two reviewers (Ueda, 2020), which is analogous to the internal vetting processes of eBird and eButterfly. We accessed eButterfly data through the eButterfly database. All records for observations within the United States were retained.

For Nature’s Notebook, we downloaded all “status and intensity” records collected 2015–2020 from the USA-NPN National Phenology Database using the rnpn package (USA National Phenology Network, 2020b). Status and intensity records reflect each time an observer recorded data on an individual plant or an animal at location over the course of the season (Rosemartin et al., 2018). We excluded data contributed by the National Ecological Observatory Network (NEON) and records contributed at locations outside of the U.S. We treated each instance of observing a single organism on a single date as an “observation,” consistent with the definition of an observation in the other community science programs in this study.

For each program-specific dataset, we excluded all records collected in months other than March, April, May, and June and we removed all observations falling outside of the United States. Next, we intersected observation locations with a shapefile representing the boundaries of urban areas (U.S. Census Bureau, 2017) and assigned a binary value of urban/non-urban to each observation based on its latitude/longitude reported location. Finally, we tallied the number of observations and the number of unique participants for each program in each year, and then again by state in each year. Similarly, for each program, we calculated the percentage of observations within each year that fell within urban areas as well as the percentage of observations within urban areas in each state in each year.

2.3. Statistical analyses

To determine the impact of the shutdowns on participation in community science programs, we examined the number of individuals...
contributing observations and the number of observations submitted. Because several of the variables under examination exhibit growth over the past five years (Fig. 1, Table A.1), we performed a likelihood ratio test to select between linear and polynomial models for each program. Residuals were normally distributed as determined by a visual inspection of a QQ plot. We tested homogeneity of variance by plotting fitted values versus residuals. The final models selected appear in Table A.2.

We then constructed a model between 2015 and 2019 and used this model to create an expected 2020 value with a 95% prediction interval for 2020 (Knowles and Frederick, 2016). We then compared the predicted 2020 value to the observed 2020 value, calculated the percent difference between the two, and then assessed whether the observed fell outside of the predicted 95% interval as our measure of significance (Knowles and Frederick, 2016). We evaluated both the number of unique participants contributing to the program and the number of observations submitted in each of the programs (eButterfly, iNaturalist, Nature’s Notebook, and eBird) for the entire U.S. as well as for each state in the U.S. For the state-by-state analyses, iNaturalist and eBird data were log transformed, and Nature’s Notebook and eButterfly data were square root-transformed. We also used this approach to evaluate whether a larger proportion of records originated from within urban areas in the spring of 2020.

For all three metrics (number of observations, number of unique participants, percent urban observations), we evaluated the effect of stay at home orders on the percent change between the observed and expected 2020 values in each of the programs (eButterfly, iNaturalist, Nature’s Notebook, and eBird) for the entire U.S. as well as for each state. Number of stay at home days by state were acquired from the National Academy for State Health Policy (2020).

All analyses were performed in Rv3.5.3 with RStudio v1.2.5001 as the integrated development environment. Both data and R code are archived in Zenodo (DOI: https://doi.org/10.5281/zenodo.4430966).

3. Results

Spring (March-Jun) participation rates vary dramatically across the four programs evaluated in this study (Fig. 1, Table A.1). iNaturalist and eBird engage tens to hundreds of thousands of participants each spring — far more than Nature’s Notebook, which engages thousands, and eButterfly, which engages hundreds of individuals each spring. Accordingly, the quantities of incoming observations also vary among the programs: eButterfly participants report thousands of observations each spring, where eBird participants report millions of observations. Participants in iNaturalist and Nature’s Notebook contribute hundreds of thousands of observations each spring. Nature’s Notebook boasts the highest rate of observations originating from urban areas; eButterfly’s observations are submitted primarily from non-urban areas.

In 2020, two of the four programs, eButterfly and Nature’s Notebook, experienced fewer participants than expected, and Nature’s Notebook saw significantly fewer observations than expected (Fig. 2, Table A.1). In 2020, two of the four programs, eButterfly and Nature’s Notebook, experienced fewer participants than expected, and Nature’s Notebook saw significantly fewer observations than expected (Fig. 2, Table A.1).
contrast, both iNaturalist and eBird show sustained activity or increases in these variables across the nation, though gains over what was predicted were non-significant (Fig. 2a, b). All programs but eButterfly experienced more observations originating in urban areas in 2020 than expected, and this proportion was significantly greater than expected for iNaturalist and eBird (Fig. 2c).

The number of participants and amount of data coming into each program is markedly greater in certain states (Table A.4). California is among the top five states in all four programs in terms of participants and observations contributed 2015–2019, and Texas and New York are in the top five states for both metrics in three of the four programs during the pre-COVID springs. The extent to which the number of participants and amount of incoming data from these states was impacted in spring of 2020 was not consistent among programs. For example, the levels of participation in California and Texas declined noticeably across programs in 2020, though the measures changed little for New York.

### 3.1. Contributing participants

State-by-state analyses revealed widespread decreases in participation across all four programs, though spatial patterns in changes varied by program. eButterfly exhibited significant drops in participation in Alaska, Hawai’i, and through the Great Plains states and also showed sharp increases in participation in other states, though the increase over expected levels of participation were only significant in Utah (Fig. 3a, Table A.4). iNaturalist demonstrated decreases in participation in 2020 over expected numbers nearly nationwide, with significant decreases in many western states as well as decreases in states that contribute the largest proportions of observations and participants (Fig. 3b, Table A.4). Changes in participation in Nature’s Notebook were spatially patchy (Fig. 3c). California, a top-contributing state in Nature’s Notebook pre-COVID, saw a significant decline in participation in 2020, though other top-observing states, including Massachusetts and New York, remained steady in 2020 (Table A.4). Similar to iNaturalist, eBird showed a significant decrease in participation over what was expected based on previous years in many western states as well as significant decreases in Eastern Seaboard states (Fig. 3d).

### 3.2. Observation activity

Overall patterns of change in observations in 2020 paralleled the patterns seen in participants. For all states combined, Nature’s Notebook participants contributed significantly fewer observations in 2020 (98,256 observations) compared to what was expected (95% prediction interval: 105,980–170,849; Table A.3). eButterfly, iNaturalist, and eBird each exhibited a non-significant increase in the number of participants over what was expected based on 2015–2019 patterns (Table A.3).

Spatial patterns of change in observations submitted to the eButterfly program (Fig. 3a, Table A.4) paralleled changes observed in participants (Fig. 3a). Changes in observations contributed to iNaturalist and eBird both exhibited a fairly clear east-west gradient, where western states generally showed decreases in observations and states east of the

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**Fig. 3.** Percent difference in the observed number of participants in March–June 2020 from the expected number of participants in March–June 2020 based on participation patterns in March–June 2015–2019 in four biodiversity community science programs: a) eButterfly, b) iNaturalist, c) Nature’s Notebook, and d) eBird. Blue tones indicate fewer participants than expected in 2020; red tones indicate more participants than expected in 2020; hatching indicates a significant difference between predicted and observed number of participants in 2020 (p < 0.05). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
hundredth meridian tended to show increases in observations (Fig. 4b, d). Finally, most states exhibited a decrease in the number of observations reported to *Nature’s Notebook* in 2020 (Fig. 4c).

### 3.3. Shift in geography of observations

When all states were combined, the percent of observations submitted from within urban areas significantly increased in 2020 over what was expected for both iNaturalist and eBird (Fig. 2c). In 2020, 45% of iNaturalist and 46% of eBird observations originated in urban areas (iNaturalist 95% prediction interval: 41–44%; eBird 95% prediction interval: 37–42%; Table A.3). The percentage of observations submitted from within urban areas decreased non-significantly in both eButterfly and *Nature’s Notebook* over what was expected based on 2015–2019 patterns (Table A.3).

State-specific results varied appreciably by program in the shift of observations submitted from urban and non-urban areas. Across much of the western U.S. and the Ohio Valley, the proportion of observations submitted from within urban areas dropped sharply in 2020 in the eButterfly program, though none of these decreases were significant (Fig. 5a, Table A.4). In contrast, iNaturalist and eBird both exhibited increases in the proportion of observations reported from within urban areas in 2020 across the majority of states, and the shifts toward more urban observations were significant for many states in the eBird program (Fig. 5b, d). Patterns apparent in *Nature’s Notebook* were mixed, with large increases in the proportion of observations reported from within urban areas increasing in states in the Southeast, Northeast, and West, and decreasing in many Great Plains states (Fig. 5c).

### 3.4. Influence of length of lockdown on participants, observations, and percent urban observations

There was a suggestive but inconclusive positive relationship between the number of days states were in lockdown and the number of participants contributing data to eButterfly by state (\( p = 0.103, \text{adj} \ r^2 = 0.03 \); Table A.5), such that the longer a state was in lockdown, the greater the number of participants contributing in 2020. There were similarly significantly positive relationships between the number of days in lockdown and the percentage of observations submitted from urban areas to both eButterfly (\( p = 0.032, \text{adj} \ r^2 = 0.07 \)) and *Nature’s Notebook* (\( p = 0.066, \text{adj} \ r^2 = 0.05 \)), such that states experiencing longer periods of lockdown were associated with a higher proportion of observations submitted from urban areas. The number of days in lockdown did not show a relationship with the number of participants in iNaturalist, *Nature’s Notebook*, or eBird; in the proportion of observations submitted from within urban areas to iNaturalist or eBird; or with the number of observations contributed to any of the programs (Table A.5).

![Fig. 4. Percent difference in observed observations submitted in March–June 2020 from the expected number of observations in March–June 2020 based on participation patterns in March–June 2015–2019 in four biodiversity community science programs: a) eButterfly, b) iNaturalist, c) *Nature’s Notebook*, and d) eBird. Blue tones indicate fewer observations than expected in 2020, red tones indicate more observations than expected in 2020; hatching indicates a significant difference between predicted and observed number of observations submitted in 2020 (\( p < 0.05 \)). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)](image-url)
4. Discussion

This study evaluated impacts of COVID-related stay-at-home orders and widespread closures on the participation and activity level in four biodiversity-themed community science programs in the United States. The four studies evaluated here vary by orders of magnitude in terms of the numbers of participants and observations submitted (Fig. 1). Further, within programs, data contributions vary by geography, with certain states accounting for a large proportion of the participation. This is important because even small changes in participation in states that account for a large proportion of participation can translate to substantial impacts to overall participation numbers for a program.

Overall, the results of this evaluation revealed variable patterns in activity among the programs and across geography - inconsistent with our expectations that all programs would show uniform drops in participation as a consequence of the pandemic. The two programs exhibiting the greatest participation, iNaturalist and eBird, showed similarities in their patterns of change.

4.1. Changes in participant activity varied by program and geography

We had predicted that both the number of participants and the amount of observations submitted across the U.S. in spring 2020 would be fewer than what would have been expected had COVID not occurred. Though we see a clear overall decrease in participants and observations submitted to Nature’s Notebook, these patterns did not hold for the other three programs. Further, patterns of change varied dramatically among states and programs.

The patterns exhibited in participants and incoming observations across the U.S. in iNaturalist and eBird follow an interesting pattern oriented along a longitudinal gradient. The largest decreases in both metrics were observed in western states and increases were generally observed in eastern states, and a more in-depth assessment should be undertaken to fully evaluate the reasons for this pattern. One explanation for the increases documented in iNaturalist, especially in the Northeast, may be that iNaturalist continued to encourage participation in local and regional BioBlitz events and other community biodiversity projects throughout spring 2020 (City Nature Challenge, 2020). The City Nature Challenge, an event that takes place in cities worldwide and utilizes the iNaturalist platform, occurred late in April in 2020 (City Nature Challenge, 2020). In 2020, 244 cities participated in the City Nature Challenge, a substantial increase over 2019, when 159 cities participated (Young, 2020). Many of the U.S. in the City Nature Challenge 2020 were concentrated in the eastern portion of the country. In addition, iNaturalist featured instructions on how to participate in the program safely during the pandemic on their homepage from April to June of 2020 (Iwane, 2020); this may also account for increased participation in the program. eBird similarly experienced intense...
activity in May because of an annual springtime event. Global Big Day, occurring annually in the spring, engages birders worldwide in documenting and celebrating birds. Global Big Day took place on May 9, 2020 and broke records for participation, yielding a larger than 30% increase in participants over 2019 (Team eBird, 2020). Finally, social justice movements such as #BlackBirdersWeek and #BlackInNature took place in the spring 2020 (Mock, 2020) may also account for the upticks observed in these two programs.

The patterns we see in eButterfly participation for 2020 across states and for the U.S. as a whole is complicated by two factors outside of COVID. First, the program released a new version of the web platform with associated messaging to the community in mid-May; the need to adjust to a new interface may have slowed users’ contributions to some extent. Second, reports of butterflies are typically low in spring (March–June) in the U.S. due to their phenology. Patterns in eButterfly participation may be driven by the comparatively low sample sizes in this program.

Nature’s Notebook exhibited highly variable patterns of increases and decreases in participants and incoming observations in 2020. The dramatic increases in participation seen in several states, including Indiana, Oklahoma, Louisiana, and Colorado are likely due to the establishment of several new groups of individuals tracking phenology in these states. A unique aspect of Nature’s Notebook is that monitoring can be undertaken by individuals as well as by community or regionally-organized groups referred to as Local Phenology Programs (LPPs). Organizations such as nature centers, arboretas, land conservancies, and National Wildlife Refuges use Nature’s Notebook to meet a diversity of outcomes, including asking and answering scientific questions about the impact of environmental change, informing natural resource management and decision-making, and educating and engaging the public. Several new LPPs were established in early 2020 in the states depicting the largest increases in participants; one of these states was the focus of a data collection campaign in late 2019 and early 2020. Newly established LPPs are also the likely reason for the increase in observations seen in several states in 2020, including Indiana and New Jersey. The large increase in participants in Texas is likely the result of the launch of a new campaign focused on tracking juniper pollen in this state in late 2019. The clear decrease in participation and incoming observations observed in California, Tennessee, New York, and other states are likely attributable to closures of public spaces such as parks, nature centers, natural areas, and schools where many active Nature’s Notebook LPP sites exist.

The mixed patterns we see in participation and incoming data in these four programs in the spring of 2020 are partially in conflict with the reports of record-breaking participation in other community science projects (Bowser et al., 2020; Kubis, 2020; Dinneen, 2020). One reason for such differences may be the way in which volunteers participate: in many of the programs boasting large increases, volunteers participate completely online using a computer or other device. In contrast, the programs evaluated in this study focus on outdoor phenomena, and participants typically step outside to identify or evaluate individual organisms. Many parts of the country were still experiencing inclement environmental change, informing natural resource management and including asking and answering scientific questions about the impact of wildfire danger (Nathan et al., 2019); a sudden drop in incoming observations on these indicator species could negatively impact managers assessing wildfire danger in public lands. Similarly, the California Department of Fish and Wildlife leveraged iNaturalist and eBird observations to develop a connectivity plan and identify key land acquisitions to grow and maintain corridors (Jennings et al., 2019). The results of this study demonstrate that pandemic-related shutdowns can have serious consequences on the availability of volunteer-contributed data necessary to support these sorts of management and planning activities. This is especially true for states where community science is more widely adopted and data contribution is high, such as California, which experienced a drop in incoming data in spring 2020 over what was expected based on previous years in all four programs evaluated.

4.2. Shift toward urban observation locations in more popular programs

We had predicted that participants would log a larger proportion of observations from urban locations in 2020 as a result of the stay-at-home orders issued across the country over the spring period. eBird and iNaturalist exhibited the clearest and most widespread shifts toward increased urban-based observations contributed in 2020. iNaturalist exhibited a clear increase in all three measures, suggesting enthusiastic involvement in this program in urban areas, likely resulting at least in part from major growth in City Nature Challenge events. eBird also showed growth the number of incoming observations, though not in the number of participants, suggesting increased participation, especially in urban areas, by approximately the same number of participants as in spring 2019. A shift toward urban participation during COVID lockdown has been reported for iNaturalist in Europe as well BIOCON-20-00460, this issue.

Findings for eButterfly and Nature’s Notebook were more mixed. We observed a significant increase in the percent urban observations in New York. We suspect many participants who live in urban areas such as New York City and travel to more butterfly biodiversity spring locations such as the southwest and California switched their behavior to local environments, but more in-depth analysis is needed. Many other states show drops in the proportion of observations submitted from within urban areas in eButterfly; the states showing shifts away from urban areas are also those exhibiting decreases in overall participation (Figs. 3a and 5a).

Patterns of shifts in Nature’s Notebook show large increases in urban participation in many states, which is likely the result of the USA-NPN’s concerted efforts to encourage participants to register new sites and continue monitoring close to home if the facilities where they previously been collecting observations were closed. Recognizing the potential for significant drops in Nature’s Notebook activity due to such closures, USA-NPN staff sent email newsletters and social media messages throughout spring 2020 encouraging participants to establish new sites in their yards or nearby, accessible locations to offset the loss of incoming data from sites no longer accessible. The positive relationship between the proportion of observations originating from urban areas and the length of lockdown in both eButterfly and Nature’s Notebook suggests that participants responded and reoriented their activities to locations closer to their homes. Incidentally, visitation to urban, peri-urban, and other natural areas dramatically increased during stay-at-home lockdowns (Fish et al., 2020; Goodier and Rayman, 2020), consistent with the large-scale shift toward urban observations in the community science programs evaluated in this study. The increases in urban observations might reflect either increased usage of urban greenspaces or a shift to greater observation activity closer to urban dwellings, or both.

4.3. Conservation implications

Several federal and state agencies and other conservation organizations rely on data from programs such as those evaluated in this study to inform management decision making. For example, data contributed to Nature’s Notebook have been used to develop phenological indicators of wildfire danger (Nathan et al., 2019); a sudden drop in incoming observations on these indicator species could negatively impact managers assessing wildfire danger in public lands. Similarly, the California Department of Fish and Wildlife leveraged iNaturalist and eBird observations to develop a connectivity plan and identify key land acquisitions to grow and maintain corridors (Jennings et al., 2019). The results of this study demonstrate that pandemic-related shutdowns can have serious consequences on the availability of volunteer-contributed data necessary to support these sorts of management and planning activities. This is especially true for states where community science is more widely adopted and data contribution is high, such as California, which experienced a drop in incoming data in spring 2020 over what was expected based on previous years in all four programs evaluated.
A long-recognized benefit of community science programs is that they contribute valuable insights that are otherwise not possible to achieve. That community science programs fill in gaps in knowledge and understanding is particularly true during pandemic-related closures, when many other forms of monitoring have been shuttered (Pennisi, 2020). One way in which observations contributed through community science programs might prove especially useful is in documenting the changes in wildlife, such as increases in species richness, higher breeding success, and reduced road-killing that have occurred as a result of reduced traffic and other changes associated with pandemic-related closures (Manenti et al., 2020). The results of this study indicate that participation in these volunteer programs have been affected as well; even so, the incoming data stand to provide one of the best approaches for documenting wildlife responses to COVID-related shutdowns. The findings specific to the four programs evaluated here may point to what might be expected regarding patterns in participation and consequent impacts on resultant data in other community science programs and in other countries.

The results of this study also underscore the value of greenspaces and urban and peri-urban parks. The importance of urban greenspaces to support biodiversity as well as mental health during lockdown and closures has rapidly been documented (Kleinschroth and Kowarik, 2020; Slater et al., 2020). We see clear evidence that people appreciate these spaces as opportunities to document wildlife, plants, progression of phenological events like leaf-out and flowering over the course of the season. The closure of many parks and public facilities where participants in Nature’s Notebook in particular had regularly observed prior to the COVID shutdowns resulted in a clear drop in incoming data in the spring of 2020. Second, it seems highly likely that the greater proportion of observations originating from urban locales during shutdowns is being collected at greenspaces that have remained open, including city parks or open lots. An increased understanding of the importance of greenspaces for the biodiversity they support as well as in maintaining mental health will help city planners manage them as ecosystems (Plummer et al., 2020).

The findings of this analysis offer insights for staff managing biodiversity-themed community science programs. Program staff may use the changes documented here to encourage adaptations to participation patterns and rates in four national-scale biodiversity-themed community science programs: eBird, eButterfly, iNaturalist, and Nature’s Notebook. We had predicted a decline in the number of participants and observations contributed to the four programs as a result of COVID-related lockdowns, but found that patterns were not as clear or stark as we had feared. Overall, Nature’s Notebook exhibited the largest declines in participants and observations compared to what was expected for spring 2020, and iNaturalist showed large increases over what was expected in both metrics. Further, as predicted, both iNaturalist and eBird experienced significant increases in the proportion of records coming from urban areas. Patterns varied by state and by program. Finally, we anticipated changes in participation to be driven by the length of lockdown; these patterns were weak.

Our findings suggest that participation in the community science programs evaluated had adapted as a result of lifestyle changes imposed by pandemic-related closures. Participants have generally continued their activity, albeit in different locations than previously. Though the numbers of participants generally decreased in some programs compared to what was expected for 2020, the amount of incoming data appears to be impacted to a lesser degree, offering a sense of hope for the future of these programs and the incoming data. That participants in these programs are persevering is encouraging, as the rich and geographically extensive volunteer-contributed reports of plants and animals originating from these programs have the potential to provide important insight into wildlife responses to pandemic-related closures and yield data to offset losses due to the shuttering of formal plant and animal monitoring efforts.

Declaration of competing interest

The authors declare no conflicts of interest.

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Data statement

The data and code used in this analysis are available at https://zenodo.org/record/4430966#.X_uQmlNKiV4.
Appendix A

Table A.1
Total number of participants, observations submitted, and percentage of observations originating from urban areas contributed to eButterfly, iNaturalist, Nature’s Notebook, and eBird in the U.S., March–June 2015–2020.

| Program      | Year | Participants | Observations | %Urban observations |
|--------------|------|--------------|--------------|---------------------|
| eButterfly   | 2015 | 318          | 10,373       | 28%                 |
|              | 2016 | 299          | 8066         | 22%                 |
|              | 2017 | 281          | 10,391       | 23%                 |
|              | 2018 | 223          | 6361         | 20%                 |
|              | 2019 | 204          | 5722         | 23%                 |
|              | 2020 | 184          | 5547         | 19%                 |
| iNaturalist  | 2015 | 9963         | 185,519      | 36%                 |
|              | 2016 | 17,745       | 351,788      | 37%                 |
|              | 2017 | 21,242       | 589,864      | 38%                 |
|              | 2018 | 32,876       | 902,758      | 40%                 |
|              | 2019 | 75,578       | 1,441,358    | 41%                 |
|              | 2020 | 110,023      | 1,945,420    | 45%                 |
| Nature’s Notebook | 2015 | 141           | 107,850      | 30%                 |
|              | 2016 | 1582         | 106,068      | 44%                 |
|              | 2017 | 1922         | 123,691      | 46%                 |
|              | 2018 | 2188         | 132,627      | 44%                 |
|              | 2019 | 1937         | 126,387      | 47%                 |
|              | 2020 | 1744         | 98,256       | 51%                 |
| eBird        | 2015 | 66,846       | 126,515      | 38%                 |
|              | 2016 | 79,622       | 1,464,060    | 37%                 |
|              | 2017 | 91,016       | 1,744,873    | 38%                 |
|              | 2018 | 107,925      | 2,144,422    | 39%                 |
|              | 2019 | 130,385      | 2,486,899    | 39%                 |
|              | 2020 | 128,225      | 2,948,944    | 46%                 |

Table A.2
Model selection.

| Program      | Program y | Model selected |
|--------------|-----------|----------------|
| eButterfly   | Observations | Linear         |
|              | Participants | Linear         |
| iNaturalist  | Observations | Polynomial     |
|              | Participants | Polynomial     |
| Nature’s Notebook | Observations | Linear     |
|              | Participants | Linear         |
| %Urban       | Linear       | Polynomial     |
| eBird        | Observations | Linear         |
|              | Participants | Linear         |
| %Urban       | Polynomial   |               |

Table A.3
Predicted 2020 counts, observed 2020 counts, 95% predicted 2020 interval, and percent change between predicted and observed participants, contributed observations, and percent of observations originating from within urban areas, March–June 2020, for four community science programs. *Denotes 2020 actual value falls outside of 95% prediction interval.

| Program         | Observed 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent change (observed vs. predicted 2020 participants) |
|-----------------|-----------------------------|----------------------------|-------------------------|---------------------------------------------------------|
| Nature’s Notebook | 1744                        | 2328                       | 1460–3195               | -25                                                    |
| eButterfly      | 184                         | 174                        | 116–231                 | 6                                                      |
| iNaturalist     | 110,023                     | 75,389                     | 12,331–138,448          | 46                                                    |
| eBird           | 128,225                     | 141,773                    | 123,001–160,545         | -10                                                   |

| Program         | Observed 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent change (observed vs. predicted 2020 observations) |
|-----------------|-----------------------------|-----------------------------|-------------------------|---------------------------------------------------------|
| Nature’s Notebook | 98,256                      | 138,415                     | 105,980–170,849         | -29*                                                   |
| eButterfly      | 5547                        | 4880                        | 0–11,898                | 13                                                     |
| iNaturalist     | 1,945,420                   | 1,613,212                   | 1014,473–2,211,951      | 21                                                     |
| eBird           | 2,948,944                   | 2,758,238                   | 2,439,344–3,077,132     | 7                                                      |

| Program         | Observed 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent change (observed vs. predicted 2020 %urban observations) |
|-----------------|-----------------------------------|------------------------------------|-------------------------|---------------------------------------------------------|
| Nature’s Notebook | 51%                              | 56%                                | 30–75%                  | -3%                                                     |

(continued on next page)
### Table A.3 (continued)

| Program          | Observed 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent change (observed vs. predicted 2020 %urban observations) |
|------------------|-----------------------------------|------------------------------------|-------------------------|---------------------------------------------------------------|
| Nature's Notebook|                                   |                                    |                         |                                                               |
| eButterfly       | 19%                                | 20%                                | 8.32% – 32%             | –5%                                                           |
| iNaturalist      | 45%                                | 43%                                | 41.44% – 44%            | 6%*                                                          |
| eBird            | 46%                                | 40%                                | 37.42% – 42%            | 16%*                                                          |

### Table A.4

Predicted 2020 counts, observed 2020 counts, 95% predicted 2020 interval, and percent change between predicted and observed participants, contributed observations, and percent of observations originating from within urban areas by state, March–June 2020, for four community science programs. * Denotes 2020 actual value falls outside of 95% prediction interval. Tables are sorted by number of observations, participants, or %urban observations reported in 2020.

#### Table A.4.a. eButterfly predicted and observed counts of observations.

| State               | 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent difference |
|---------------------|-------------------|-----------------------------|-------------------------|--------------------|
| South Carolina      | 1108              | 748                         | 336–1305                | 48                 |
| Virginia            | 646               | 303                         | 71–643                  | 113*               |
| Vermont             | 637               | 567                         | 230–1062                | 12                 |
| Arizona             | 396               | 317                         | 77–682                  | 25                 |
| Massachusetts       | 294               | 223                         | 42–553                  | 32                 |
| Texas               | 254               | 579                         | 240–1045                | –56                |
| North Carolina      | 246               | 230                         | 50–596                  | 7                  |
| California          | 242               | 624                         | 267–1158                | –61*               |
| Arkansas            | 219               | 85                          | 0–311                   | 158                |
| Idaho               | 196               | 2                           | 0–89                    | 11278*             |
| New Jersey          | 191               | 64                          | 0–270                   | 200                |
| Florida             | 183               | 295                         | 69–689                  | –38                |
| Michigan            | 140               | 227                         | 35–513                  | –38                |
| Georgia             | 112               | 84                          | 0–329                   | 34                 |
| Rhode Island        | 83                | 46                          | 0–228                   | 79                 |
| Maryland            | 73                | 308                         | 79–684                  | –76*               |
| Pennsylvania        | 72                | 12                          | 0–142                   | 504                |
| Maine               | 70                | 76                          | 0–319                   | –8                 |
| Indiana             | 67                | 22                          | 0–161                   | 201                |
| New Mexico          | 58                | 72                          | 0–290                   | –19                |
| Washington          | 51                | 9                           | 0–123                   | 443                |
| Utah                | 34                | 1                           | 0–56                    | 6445               |
| Oregon              | 33                | 23                          | 0–176                   | 41                 |
| Wisconsin           | 30                | 19                          | 0–168                   | 60                 |
| Iowa                | 23                | 63                          | 0–288                   | –63                |
| Colorado            | 21                | 11                          | 0–137                   | 83                 |
| Minnesota           | 18                | 1                           | 0–90                    | 1135               |
| Connecticut         | 12                | 47                          | 0–241                   | –74                |
| New York            | 12                | 74                          | 0–298                   | –84                |
| New Hampshire       | 11                | 30                          | 0–196                   | –63                |
| Ohio                | 8                 | 189                         | 31–471                  | –96*               |
| Delaware            | 2                 | 0                           | 0–61                    | 2413               |
| Illinois            | 2                 | 0                           | 0–70                    | 7111               |
| Nevada              | 2                 | 6                           | 0–131                   | –67                |
| Wyoming             | 1                 | 0                           | 0–83                    | 223                |
| Alabama             | 0                 | 7                           | 0–125                   | –100               |
| Alaska              | 0                 | 5                           | 0–128                   | –100               |
| District of Columbia| 0                 | 0                           | 0–67                    | –100               |
| Hawaii              | 0                 | 0                           | 0–89                    | –100               |
| Kansas              | 0                 | 1                           | 0–83                    | –100               |
| Kentucky            | 0                 | 0                           | 0–65                    | –100               |
| Louisiana           | 0                 | 1                           | 0–88                    | –100               |
| Mississippi         | 0                 | 2                           | 0–46                    | –100               |
| Missouri            | 0                 | 18                          | 0–178                   | –100               |
| Montana             | 0                 | 1                           | 0–89                    | –100               |
| Nebraska            | 0                 | 1                           | 0–55                    | –100               |
| North Dakota        | 0                 | 4                           | 0–43                    | –100               |
| Oklahoma            | 0                 | 0                           | 0–89                    | –100               |
| South Dakota        | 0                 | 3                           | 0–49                    | –100               |
| Tennessee           | 0                 | 2                           | 0–106                   | –100               |
| West Virginia       | 0                 | 8                           | 0–131                   | –100               |

#### Table A.4.b. eButterfly predicted and observed counts of participants.

| State               | 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent difference |
|---------------------|-------------------|-----------------------------|-------------------------|--------------------|
| Vermont             | 20                | 18                          | 9–30                    | 14                 |
| Virginia            | 19                | 14                          | 5–25                    | 40                 |

(continued on next page)
Table A.4.b. eButterfly predicted and observed counts of participants.

| State            | 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent difference |
|------------------|-------------------|-----------------------------|-------------------------|--------------------|
| Arizona          | 12                | 8                           | 2.18                    | 56                 |
| Massachusetts    | 12                | 5                           | 1.13                    | 143                |
| California       | 11                | 17                          | 7.29                    | –35                |
| South Carolina   | 10                | 8                           | 2.18                    | 23                 |
| Michigan         | 9                 | 9                           | 3.19                    | 0                  |
| North Carolina   | 9                 | 12                          | 4.23                    | –22                |
| Washington       | 7                 | 3                           | 0.10                    | 130                |
| Florida          | 5                 | 13                          | 5.25                    | –62*               |
| Maine            | 5                 | 4                           | 0.11                    | 35                 |
| Maryland         | 5                 | 6                           | 1.15                    | –16                |
| New Jersey       | 5                 | 4                           | 0.10                    | 39                 |
| New Mexico       | 5                 | 2                           | 0.8                     | 108                |
| Ohio             | 5                 | 5                           | 1.13                    | –1                 |
| Connecticut      | 4                 | 2                           | 0.8                     | 80                 |
| Pennsylvania     | 4                 | 4                           | 1.11                    | –8                 |
| Texas            | 4                 | 11                          | 4.22                    | –64                |
| Georgia          | 3                 | 6                           | 1.14                    | –46                |
| Iowa             | 3                 | 1                           | 0.6                     | 114                |
| New Hampshire    | 3                 | 4                           | 0.11                    | –19                |
| Rhode Island     | 3                 | 1                           | 0.6                     | 213                |
| Utah             | 3                 | 0                           | 1.3                     | 237*               |
| Arkansas         | 2                 | 1                           | 0.7                     | 52                 |
| Colorado         | 2                 | 2                           | 0.8                     | –12                |
| Minnesota        | 2                 | 1                           | 0.5                     | 203                |
| New York         | 2                 | 6                           | 1.15                    | –67                |
| Oregon           | 2                 | 3                           | 0.10                    | 40                 |
| Wisconsin        | 2                 | 2                           | 0.7                     | 32                 |
| Delaware         | 1                 | 0                           | 1.4                     | 175                |
| Idaho            | 1                 | 1                           | 0.6                     | 1                  |
| Illinois         | 1                 | 0                           | 0.4                     | 109                |
| Indiana          | 1                 | 2                           | 0.8                     | –55                |
| Nevada           | 1                 | 1                           | 0.5                     | –6                 |
| Wyoming          | 1                 | 0                           | 1.3                     | 925                |
| Alabama          | 0                 | 1                           | 0.6                     | –100*              |
| Alaska           | 0                 | 3                           | 0.9                     | –100*              |
| District of Columbia | 0         | 0                           | 0.4                     | –100*              |
| Hawaii           | 0                 | 0                           | 1.2                     | –100*              |
| Kansas           | 0                 | 0                           | 1.3                     | –100*              |
| Kentucky         | 0                 | 0                           | 1.3                     | –100*              |
| Louisiana        | 0                 | 1                           | 0.5                     | –100*              |
| Mississippi      | 0                 | 0                           | 1.2                     | –100*              |
| Missouri         | 0                 | 0                           | 0.7                     | –100*              |
| Montana          | 0                 | 0                           | 0.4                     | –100*              |
| Nebraska         | 0                 | 0                           | 1.2                     | –100*              |
| North Dakota     | 0                 | 0                           | 2.1                     | –100*              |
| Oklahoma         | 0                 | 0                           | 0.4                     | –100*              |
| South Dakota     | 0                 | 0                           | 1.2                     | –100*              |
| Tennessee        | 0                 | 1                           | 0.6                     | –100*              |
| West Virginia    | 0                 | 1                           | 0.5                     | –100*              |

Table A.4.c. eButterfly predicted and observed percent of observations originating from urban areas. Prediction intervals >100% are reported to indicate the size of the interval, even though >100% is not possible.

| State            | 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent difference 2020 |
|------------------|---------------------------|------------------------------------|-------------------------|------------------------|
| New York         | 67                        | 13                                 | –36.63                  | 394*                   |
| Ohio             | 63                        | 32                                 | –20.80                  | 95                     |
| Georgia          | 62                        | 24                                 | –24.75                  | 156                    |
| New Hampshire    | 55                        | 7                                  | –42.58                  | 640                    |
| Arizona          | 45                        | 38                                 | –23.77                  | 17                     |
| Maryland         | 45                        | 26                                 | –7.88                   | 71                     |
| Massachusetts    | 45                        | 27                                 | –20.78                  | 68                     |
| Indiana          | 43                        | 32                                 | –19.85                  | 37                     |
| Florida          | 37                        | 27                                 | –20.78                  | 38                     |
| Wisconsin        | 37                        | 29                                 | –21.78                  | 28                     |
| New Jersey       | 36                        | 25                                 | –21.78                  | 43                     |
| Virginia         | 33                        | 16                                 | –35.65                  | 108                    |
| Washington       | 18                        | 17                                 | –33.65                  | 3                      |
| California       | 17                        | 16                                 | –33.66                  | 9                      |
| Pennsylvania     | 14                        | 12                                 | –39.61                  | 19                     |
| Maine            | 13                        | 9                                  | –40.59                  | 36                     |
| Utah             | 12                        | 5                                  | –47.53                  | 144                    |
| Rhode Island     | 11                        | 31                                 | –15.83                  | –66                    |
| Texas            | 10                        | 23                                 | –26.74                  | –10                    |
| Iowa             | 9                         | 44                                 | –19.81                  | –80                    |
Table A.4. (continued)

Table A.4.c. eButterfly predicted and observed percent of observations originating from urban areas. Prediction intervals >100% are reported to indicate the size of the interval, even though >100% is not possible.

| State                  | 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent difference 2020 |
|------------------------|--------------------------|------------------------------------|-------------------------|-------------------------|
| New Mexico             | 9                        | 16                                 | 5–90                    | −47                     |
| Oregon                 | 9                        | 30                                 | −34–68                  | −70                     |
| Connecticut            | 8                        | 19                                 | −32–68                  | −55                     |
| Vermont                | 7                        | 15                                 | −34–65                  | −54                     |
| Minnesota              | 6                        | 6                                  | −24–76                  | −73                     |
| North Carolina         | 6                        | 27                                 | −44–54                  | −79                     |
| South Carolina         | 5                        | 9                                  | −40–59                  | −44                     |
| Michigan               | 4                        | 14                                 | −34–64                  | −69                     |
| Arkansas               | 2                        | 4                                  | −45–53                  | −51                     |
| Alabama                | 0                        | 6                                  | −42–56                  | −100                    |
| Alaska                 | 0                        | 19                                 | −29–68                  | −100                    |
| Colorado               | 0                        | 8                                  | −40–59                  | −100                    |
| Delaware               | 0                        | 23                                 | −23–73                  | −100                    |
| District of Columbia   | 0                        | 57                                 | 7–104                   | −100*                   |
| Hawaii                 | 0                        | 20                                 | −27–72                  | −100                    |
| Idaho                  | 0                        | 16                                 | −32–67                  | −100                    |
| Illinois               | 0                        | 28                                 | −21–80                  | −100                    |
| Kansas                 | 0                        | 6                                  | −44–59                  | −100                    |
| Kentucky               | 0                        | 17                                 | −31–64                  | −100                    |
| Louisiana              | 0                        | 35                                 | −14–82                  | −100                    |
| Mississippi            | 0                        | 17                                 | −29–61                  | −100                    |
| Missouri               | 0                        | 2                                  | −50–51                  | −100                    |
| Montana                | 0                        | 4                                  | −48–57                  | −100                    |
| Nebraska               | 0                        | 4                                  | −46–51                  | −100                    |
| Nevada                 | 0                        | 9                                  | −38–56                  | −100                    |
| North Dakota           | 0                        | 4                                  | −48–55                  | −100                    |
| Oklahoma               | 0                        | 11                                 | −40–64                  | −100                    |
| South Dakota           | 0                        | 4                                  | −47–51                  | −100                    |
| Tennessee              | 0                        | 4                                  | −43–54                  | −100                    |
| West Virginia          | 0                        | 3                                  | −44–57                  | −100                    |
| Wyoming                | 0                        | 3                                  | −43–54                  | −100                    |

Table A.4.d. iNaturalist predicted and observed counts of observations.

| State                  | 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent difference |
|------------------------|-------------------|-----------------------------|-------------------------|--------------------|
| California             | 421,217           | 646,163                     | 298,846–1,371,409       | −35                |
| Texas                  | 324,382           | 417,169                     | 191,859–847,278         | −22                |
| Florida                | 102,353           | 89,616                      | 38,673–196,973          | 14                 |
| New York               | 69,034            | 55,263                      | 24,233–125,965          | 25                 |
| Virginia               | 64,914            | 48,953                      | 21,810–111,707          | 33                 |
| Massachusetts          | 62,134            | 34,308                      | 15,718–79,581           | 81                 |
| North Carolina         | 57,913            | 54,998                      | 23,821–128,904          | 5                  |
| Ohio                   | 56,446            | 63,488                      | 28,495–148,840          | −11                |
| Pennsylvania           | 53,803            | 39,138                      | 18,068–90,312           | 37                 |
| New Jersey             | 51,865            | 45,634                      | 20,711–102,604          | 14                 |
| Maryland               | 48,320            | 44,035                      | 19,535–99,190           | 10                 |
| Illinois               | 46,632            | 51,279                      | 22,674–121,561          | 9                  |
| Washington             | 34,030            | 39,698                      | 18,419–91,715           | −14                |
| Oregon                 | 33,731            | 37,700                      | 16,826–83,479           | −11                |
| Arizona                | 32,992            | 60,004                      | 26,386–135,104          | −45                |
| Vermont                | 31,067            | 62,015                      | 27,096–140,588          | −50                |
| Minnesota              | 30,584            | 25,307                      | 19,970–57,865           | 21                 |
| Wisconsin              | 27,845            | 26,248                      | 12,412–59,896           | 6                  |
| Tennessee              | 27,436            | 24,027                      | 10,716–54,993           | 14                 |
| Georgia                | 25,908            | 15,146                      | 6783–34,783             | 71                 |
| Alabama                | 25,809            | 27,035                      | 12,479–57,656           | −5                 |
| Michigan               | 25,430            | 27,326                      | 11,988–63,880           | −7                 |
| Colorado               | 23,825            | 25,432                      | 11,158–58,757           | −6                 |
| Louisiana              | 21,120            | 16,983                      | 7511–40,129             | 24                 |
| New Mexico             | 20,597            | 15,388                      | 6991–33,828             | 34                 |
| Arkansas               | 18,287            | 15,936                      | 7017–34,138             | 15                 |
| Oklahoma               | 17,626            | 17,294                      | 7542–38,104             | 2                  |
| Indiana                | 14,546            | 7444                        | 3376–17,452             | 95                 |
| Missouri               | 13,430            | 11,929                      | 5068–26,152             | 13                 |
| South Carolina         | 13,363            | 16,100                      | 6898–35,862             | −17                |
| Connecticut            | 13,021            | 12,398                      | 5551–25,433             | 5                  |
| Utah                   | 12,369            | 12,579                      | 5704–29,990             | −2                 |
| New Hampshire          | 11,881            | 7538                        | 3498–16,869             | 58                 |
| Mississippi            | 11,638            | 7725                        | 3365–18,211             | 51                 |
| Nevada                 | 11,224            | 16,394                      | 7787–40,065             | −32                |
| Kentucky               | 10,675            | 6795                        | 3021–15,530             | 57                 |
| Idaho                  | 8260              | 9084                        | 4082–20,943             | −12                |
| Nebraska               | 8220              | 3214                        | 1359–7286              | 156*               |

(continued on next page)
| State          | 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent difference |
|---------------|-------------------|-----------------------------|-------------------------|--------------------|
| Maine         | 7877              | 11,197                      | 4725-26,598             | −30                |
| Kansas        | 7470              | 8675                        | 3833-18,720             | −14                |
| Alaska        | 7418              | 16,885                      | 6830-36,057             | −56                |
| West Virginia | 5925              | 5862                        | 2613-13,397             | 1                  |
| Hawaii        | 5594              | 17,054                      | 7854-38,337             | −67*               |
| Iowa          | 4845              | 4106                        | 1760-9393               | 18                 |
| Rhode Island  | 4416              | 1667                        | 701-3778                | 165*               |
| Montana       | 4204              | 4268                        | 1824-9663               | −1                 |
| District of Columbia | 3897 | 7608 | 3223-17,827 | −49 |
| Delaware      | 3573              | 4704                        | 2654-10,395             | −24                |
| South Dakota  | 2879              | 2690                        | 1207-6258               | 7                  |
| Wyoming       | 2573              | 3980                        | 1830-8782               | −35                |
| North Dakota  | 812               | 1338                        | 592-2835                | −39                |

| State          | 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent difference |
|---------------|-------------------|-----------------------------|-------------------------|--------------------|
| California    | 17,307            | 30,102                      | 17,997-51,653           | −43*               |
| Texas         | 11,120            | 16,064                      | 9115-27,829             | −31                |
| Florida       | 7534              | 8086                        | 4815-14,115             | −7                 |
| New York      | 4437              | 4953                        | 2772-8669               | −10                |
| North Carolina| 4371              | 4547                        | 2657-7939               | −12                |
| Pennsylvania  | 3882              | 3467                        | 2037-5890               | −12                |
| Virginia      | 3755              | 4587                        | 2715-8345               | −18                |
| Massachusetts | 3653              | 3846                        | 2239-6782               | −5                 |
| Ohio          | 3195              | 4254                        | 2525-7687               | −25                |
| Maryland      | 2865              | 3020                        | 1665-5466               | −5                 |
| Washington    | 2864              | 3528                        | 2126-6215               | −19                |
| Georgia       | 2628              | 2128                        | 1280-3624               | 24                 |
| Illinois      | 2375              | 2815                        | 1656-4924               | −16                |
| New Jersey    | 2173              | 2136                        | 1226-3626               | 2                  |
| Oregon        | 2166              | 3486                        | 2030-6194               | −38                |
| Minnesota     | 2110              | 2197                        | 1306-3891               | −4                 |
| Tennessee     | 2102              | 2216                        | 1332-3886               | −5                 |
| Arizona       | 2087              | 3898                        | 2178-6472               | −46*               |
| Colorado      | 1984              | 3243                        | 1853-5443               | −39                |
| Michigan      | 1971              | 2044                        | 1228-3664               | −1                 |
| Wisconsin     | 1670              | 1904                        | 1079-3178               | −32                |
| Missouri      | 1612              | 1393                        | 843-2416                | 16                 |
| Connecticut   | 1456              | 1265                        | 730-2201                | 15                 |
| Alabama       | 1407              | 1667                        | 947-2963                | −16                |
| Vermont       | 1372              | 2366                        | 1389-4116               | −42*               |
| Utah          | 1342              | 1826                        | 1099-3300               | −27                |
| Indiana       | 1335              | 1201                        | 701-2060                | 11                 |
| South Carolina| 1300              | 1615                        | 917-2826                | −19                |
| Louisiana     | 1149              | 1431                        | 836-2488                | −20                |
| New Hampshire | 1054              | 1013                        | 594-1726                | 4                  |
| Oklahoma      | 1030              | 1138                        | 666-1980                | −10                |
| New Mexico    | 963               | 1527                        | 874-2658                | −37                |
| Arkansas      | 929               | 1082                        | 641-1941                | −14                |
| Kentucky      | 884               | 1113                        | 634-1874                | −21                |
| Maine         | 818               | 1131                        | 664-1999                | −28                |
| Nebraska      | 788               | 594                         | 336-1014                | −33                |
| Hawaii        | 592               | 1727                        | 1022-2941               | −66*               |
| Nevada        | 580               | 1355                        | 820-2313                | −57*               |
| Idaho         | 579               | 1017                        | 579-1796                | −43                |
| Iowa          | 555               | 645                         | 385-1112                | −14                |
| Kansas        | 524               | 649                         | 390-1240                | −19                |
| Mississippi   | 519               | 756                         | 420-1291                | −31                |
| West Virginia | 495               | 690                         | 401-1206                | −28                |
| District of Columbia | 467 | 1079 | 619-1868 | −57* |
| Montana       | 448               | 845                         | 465-1428                | −47*               |
| Rhode Island  | 399               | 320                         | 180-547                 | −24                |
| Delaware      | 344               | 493                         | 285-862                 | −30                |
| Wyoming       | 304               | 752                         | 421-1318                | −60*               |
| Alaska        | 242               | 1084                        | 617-1870                | −78*               |
| South Dakota  | 213               | 363                         | 215-621                 | −41*               |
| North Dakota  | 74                | 196                         | 112-343                 | −62*               |

Table A.4.d. iNaturalist predicted and observed percent of observations originating from urban areas. Prediction intervals >100% are reported to indicate the size of the interval, even though 100% is not possible.
Table A.4. (continued)

Table A.4.f. iNaturalist predicted and observed percent of observations originating from urban areas. Prediction intervals >100% are reported to indicate the size of the interval, even though >100% is not possible.

| State                  | 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent difference |
|------------------------|---------------------------|-----------------------------------|--------------------------|--------------------|
| District of Columbia   | 100                       | 102                               | 88-117                   | -2                 |
| New Jersey             | 64                        | 63                                | 47-78                    | 2                  |
| New York               | 62                        | 57                                | 43-72                    | 8                  |
| Illinois               | 58                        | 58                                | 42-73                    | 0                  |
| Massachusetts          | 57                        | 73                                | 57-87                    | -21                |
| Virginia               | 57                        | 55                                | 40-70                    | 4                  |
| Georgia                | 55                        | 41                                | 41-70                    | 33                 |
| Maryland               | 55                        | 56                                | 25-56                    | -2                 |
| Pennsylvania           | 55                        | 41                                | 28-56                    | 32                 |
| Connecticut            | 54                        | 60                                | 34-65                    | -10                |
| Rhode Island           | 54                        | 49                                | 45-75                    | 9                  |
| Texas                  | 51                        | 48                                | 34-63                    | 5                  |
| Florida                | 48                        | 44                                | 29-58                    | 9                  |
| Louisiana              | 46                        | 44                                | 24-53                    | 4                  |
| Missouri               | 46                        | 39                                | 29-60                    | 20                 |
| Washington             | 46                        | 40                                | 25-55                    | 15                 |
| Indiana                | 45                        | 54                                | 38-69                    | -16                |
| North Carolina         | 45                        | 52                                | 24-53                    | -14                |
| South Carolina         | 45                        | 39                                | 35-65                    | 16                 |
| Minnesota              | 44                        | 40                                | 25-55                    | 11                 |
| Tennessee              | 44                        | 31                                | 17-46                    | 44                 |
| California             | 43                        | 42                                | 27-57                    | 4                  |
| Nebraska               | 42                        | 40                                | 26-56                    | 5                  |
| Michigan               | 41                        | 26                                | 11-41                    | 57*                |
| Ohio                   | 41                        | 40                                | 26-55                    | 2                  |
| Kansas                 | 39                        | 27                                | 12-42                    | 43                 |
| Utah                   | 38                        | 25                                | 10-39                    | 53                 |
| Oklahoma               | 37                        | 37                                | 21-52                    | -1                 |
| Colorado               | 35                        | 32                                | 11-41                    | 12                 |
| Delaware               | 35                        | 26                                | 17-47                    | 38                 |
| Hawaii                 | 34                        | 34                                | 18-49                    | 1                  |
| Oregon                 | 34                        | 31                                | 17-48                    | 9                  |
| Wisconsin              | 34                        | 24                                | 10-39                    | 40                 |
| Iowa                   | 33                        | 34                                | 19-49                    | -4                 |
| Alabama                | 30                        | 45                                | 30-59                    | -33                |
| Arizona                | 26                        | 27                                | 8-37                     | -2                 |
| Arkansas               | 26                        | 23                                | 12-42                    | 13                 |
| Nevada                 | 26                        | 26                                | 9-41                     | 0                  |
| Maine                  | 23                        | 19                                | 4-34                     | 23                 |
| Mississippi            | 23                        | 29                                | 14-44                    | -21                |
| New Mexico             | 22                        | 20                                | 7-36                     | 10                 |
| Kentucky               | 21                        | 20                                | 4-35                     | 7                  |
| West Virginia          | 21                        | 31                                | 17-47                    | -32                |
| Alaska                 | 20                        | 20                                | 5-36                     | -2                 |
| Idaho                  | 18                        | 23                                | 1-32                     | 23                 |
| North Dakota           | 18                        | 16                                | 8-39                     | 10                 |
| Montana                | 17                        | 19                                | 5-34                     | -12                |
| New Hampshire          | 16                        | 19                                | 3-33                     | -17                |
| South Dakota           | 15                        | 13                                | 6-34                     | 13                 |
| Vermont                | 15                        | 20                                | -1-28                    | 26                 |
| Wyoming                | 10                        | 8                                 | -7-22                    | 27                 |

Table A.4.g. Nature’s Notebook predicted and observed counts of observations.

| State                  | 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent difference |
|------------------------|-------------------|-----------------------------|--------------------------|--------------------|
| Massachusetts          | 12,238            | 8075                        | 4687-12,627              | 52                 |
| New York               | 9712              | 15,005                      | 9730-20,572              | -35*               |
| Minnesota              | 9385              | 13,879                      | 8997-19,570              | -32                |
| Arizona                | 7720              | 6290                        | 3218-10,248              | 23                 |
| Michigan               | 7137              | 6783                        | 3616-11,565              | 5                  |
| Tennessee              | 6072              | 11,694                      | 7169-17,093              | -48*               |
| California             | 5699              | 15,462                      | 10,506-21,799            | -63*               |
| Maine                  | 4565              | 4633                        | 2157-8290                | -1                 |
| Indiana                | 3515              | 802                         | 37-2522                  | 338*               |
| North Carolina         | 3463              | 4214                        | 1895-7625                | -18                |
| New Hampshire          | 2722              | 4223                        | 1747-7424                | -36                |
| Colorado               | 2209              | 4520                        | 1864-7998                | -51                |
| Ohio                   | 2161              | 1454                        | 260-3463                 | 49                 |
| Oregon                 | 1842              | 1980                        | 449-4466                 | -7                 |
| Illinois               | 1800              | 2580                        | 808-5483                 | -30                |
| Pennsylvania           | 1726              | 2401                        | 689-4940                 | -28                |
| New Jersey             | 1665              | 144                         | 0-1146                   | 1053*              |
| Louisiana              | 1477              | 492                         | 0-1951                   | 200                |
### Table A.4 (continued)

**Table A.4.g. Nature’s Notebook predicted and observed counts of observations.**

| State                | 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent difference |
|----------------------|-------------------|-----------------------------|--------------------------|--------------------|
| Maryland             | 1452              | 1348                        | 200-3448                 | 8                  |
| New Mexico           | 1085              | 1865                        | 413-4157                 | -42                |
| Texas                | 1030              | 2311                        | 536-4942                 | -55                |
| Washington           | 856               | 1559                        | 304-3729                 | -45                |
| Wisconsin            | 834               | 915                         | 67-2789                  | -9                 |
| Georgia              | 795               | 368                         | 0-1859                   | 116                |
| Virginia             | 790               | 2424                        | 723-5119                 | -67                |
| Florida              | 709               | 1906                        | 493-4379                 | -63                |
| Mississippi          | 707               | 392                         | 0-1786                   | 80                 |
| Iowa                 | 599               | 256                         | 0-1453                   | 134                |
| Utah                 | 483               | 386                         | 0-1746                   | 25                 |
| Kentucky             | 436               | 678                         | 16-2286                  | -36                |
| West Virginia        | 381               | 740                         | 40-2548                  | -48                |
| Arkansas             | 372               | 230                         | 0-1397                   | 62                 |
| Kansas               | 356               | 708                         | 17-2319                  | -50                |
| South Dakota         | 343               | 901                         | 57-2884                  | -62                |
| Vermont              | 325               | 155                         | 0-1248                   | 109                |
| Wyoming              | 320               | 358                         | 0-1727                   | -11                |
| Alabama              | 277               | 503                         | 0-2061                   | -45                |
| Alaska               | 222               | 226                         | 0-1503                   | -2                 |
| Missouri             | 205               | 794                         | 27-2689                  | -74                |
| District of Columbia | 138               | 246                         | 0-1478                   | -44                |
| Delaware             | 130               | 50                          | 0-814                    | 158                |
| South Carolina       | 99                | 970                         | 71-2746                  | -90                |
| Oklahoma             | 65                | 105                         | 0-1085                   | -38                |
| Connecticut          | 54                | 403                         | 0-1843                   | -87                |
| Montana              | 47                | 584                         | 1-2090                   | -92                |
| Rhode Island         | 20                | 66                          | 0-982                    | -70                |
| Idaho                | 13                | 355                         | 0-1666                   | -96                |
| Nebraska             | 4                 | 95                          | 0-1148                   | -96                |
| Nevada               | 1                 | 154                         | 0-1218                   | -96                |
| Hawaii               | 0                 | 56                          | 0-1009                   | -100               |
| North Dakota         | 0                 | 543                         | 7-1953                   | -100*               |

### Table A.4.h. Nature’s Notebook predicted and observed counts of participants.

| State                | 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent difference |
|----------------------|-------------------|-----------------------------|--------------------------|--------------------|
| New York             | 231               | 190                         | 114-303                  | 22                 |
| Texas                | 179               | 30                          | 6-77                     | 491*               |
| Massachusetts        | 130               | 132                         | 62-220                   | -1                 |
| California           | 88                | 250                         | 160-364                  | -65*               |
| Arizona              | 81                | 104                         | 48-186                   | -22                |
| North Carolina       | 76                | 73                          | 25-138                   | 4                  |
| Minnesota            | 66                | 97                          | 39-174                   | -32                |
| Colorado             | 65                | 118                         | 56-207                   | -45                |
| Michigan             | 64                | 50                          | 13-105                   | 28                 |
| Pennsylvania         | 63                | 53                          | 15-113                   | 19                 |
| Illinois             | 62                | 53                          | 17-116                   | 16                 |
| Maine                | 61                | 79                          | 32-148                   | -22                |
| Oregon               | 45                | 61                          | 20-121                   | -27                |
| Tennessee            | 35                | 60                          | 21-125                   | -41                |
| Washington           | 34                | 31                          | 5-76                     | 11                 |
| Indiana              | 33                | 18                          | 1-56                     | 85                 |
| Maryland             | 31                | 51                          | 15-106                   | -39                |
| New Hampshire        | 31                | 30                          | 4-74                     | 4                  |
| Wisconsin            | 31                | 30                          | 5-73                     | 4                  |
| New Mexico           | 30                | 35                          | 8-88                     | -15                |
| Ohio                 | 30                | 25                          | 2-70                     | 22                 |
| Virginia             | 30                | 49                          | 14-106                   | -39                |
| Oklahoma             | 27                | 6                           | 0-34                     | 362                |
| Louisiana            | 24                | 11                          | 0-43                     | 110                |
| Wyoming              | 19                | 11                          | 0-45                     | 66                 |
| Kentucky             | 18                | 112                         | 53-193                   | -84*               |
| South Dakota         | 15                | 17                          | 0-57                     | -10                |
| Utah                 | 15                | 15                          | 0-52                     | -2                 |
| District of Columbia | 13                | 16                          | 0-51                     | -18                |
| New Jersey           | 12                | 13                          | 0-47                     | -6                 |
| Kansas               | 11                | 21                          | 2-59                     | 47                 |
| Mississippi          | 11                | 8                           | 0-38                     | 30                 |
| Florida              | 10                | 31                          | 5-82                     | -68                |
| Missouri             | 10                | 21                          | 1-63                     | -52                |
| West Virginia        | 9                 | 24                          | 3-68                     | -62                |
| Vermont              | 8                 | 10                          | 0-42                     | -17                |
| Connecticut          | 7                 | 10                          | 0-44                     | -31                |

(continued on next page)
### Table A.4.h. Nature’s Notebook predicted and observed counts of participants.

| State          | 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent difference |
|----------------|-------------------|-----------------------------|--------------------------|-------------------|
| Georgia        | 7                 | 15                          | 0.51                     | –54               |
| Iowa           | 6                 | 12                          | 0.45                     | –51               |
| Montana        | 5                 | 9                           | 0.39                     | –41               |
| Arkansas       | 4                 | 8                           | 0.36                     | –49               |
| Alaska         | 3                 | 7                           | 0.34                     | –59               |
| Idaho          | 3                 | 23                          | 2.73                     | –87               |
| Nebraska       | 3                 | 6                           | 0.35                     | –52               |
| Delaware       | 2                 | 3                           | 0.26                     | –22               |
| Rhode Island   | 2                 | 4                           | 0.27                     | –45               |
| South Carolina | 2                 | 7                           | 0.34                     | –69               |
| Alabama        | 1                 | 9                           | 0.39                     | –89               |
| Nevada         | 1                 | 6                           | 0.34                     | –85               |
| Hawaii         | 0                 | 6                           | 0.32                     | –100              |
| North Dakota   | 0                 | 16                          | 0.55                     | –100*             |

### Table A.4.i. Nature’s Notebook predicted and observed percent of observations originating from urban areas. Prediction intervals >100% are reported to indicate the size of the interval, even though >100% is not possible.

| State                       | 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent difference |
|-----------------------------|---------------------------|------------------------------------|--------------------------|-------------------|
| District of Columbia        | 100                       | 86                                 | 29-141                   | 17                |
| Nevada                      | 100                       | 74                                 | 19-129                   | 35                |
| South Carolina              | 100                       | 69                                 | 15-127                   | 44                |
| Rhode Island               | 100                       | 50                                 | –7-105                   | 95                |
| Idaho                      | 100                       | 44                                 | –10-98                   | 127*              |
| Delaware                   | 100                       | 17                                 | –34-71                   | 483*              |
| Kentucky                   | 100                       | 80                                 | 24-134                   | 25                |
| Georgia                    | 99                        | 29                                 | –26-85                   | 240*              |
| Florida                    | 99                        | 58                                 | 5-113                    | 70                |
| Oklahoma                   | 95                        | 47                                 | –8-104                   | 103               |
| Michigan                   | 95                        | 66                                 | 13-128                   | 44                |
| Arkansas                   | 92                        | 61                                 | 9-116                    | 50                |
| Maryland                   | 91                        | 34                                 | –18-87                   | 168*              |
| Indiana                    | 84                        | 51                                 | –3-107                   | 64                |
| Illinois                   | 79                        | 66                                 | 10-124                   | 20                |
| Oregon                     | 78                        | 27                                 | –27-83                   | 190               |
| West Virginia              | 72                        | 33                                 | –21-90                   | 117               |
| Washington                 | 71                        | 55                                 | 2-110                    | 30                |
| Massachusetts              | 71                        | 47                                 | –4-99                    | 50                |
| Connecticut                | 70                        | 28                                 | –23-84                   | 152               |
| Virginia                   | 67                        | 57                                 | 2-110                    | 18                |
| Iowa                       | 59                        | 51                                 | –4-102                   | 15                |
| Texas                      | 59                        | 81                                 | 29-132                   | –27               |
| Mississippi                | 58                        | 17                                 | –40-73                   | 234               |
| North Carolina             | 56                        | 22                                 | –30-74                   | 157               |
| Wyoming                    | 51                        | 56                                 | 4-111                    | –9                |
| Pennsylvania               | 50                        | 25                                 | –28-83                   | 104               |
| Ohio                       | 50                        | 63                                 | 2-119                    | –20               |
| Nebraska                   | 50                        | 20                                 | –38-72                   | 148               |
| Minnesota                  | 45                        | 31                                 | –27-89                   | 45                |
| Arizona                    | 43                        | 43                                 | –10-96                   | 0                 |
| New Mexico                 | 43                        | 36                                 | –20-92                   | 20                |
| Wisconsin                  | 42                        | 62                                 | 6-116                    | –33               |
| Maine                      | 39                        | 32                                 | –23-85                   | 22                |
| Louisiana                  | 36                        | 5                                  | –55-61                   | 638               |
| New York                   | 34                        | 46                                 | –5-101                   | –25               |
| California                 | 32                        | 21                                 | –39-81                   | 54                |
| Colorado                   | 28                        | 49                                 | –7-100                   | –43               |
| Utah                       | 26                        | 56                                 | –1-110                   | –54               |
| Missouri                   | 21                        | 31                                 | –25-81                   | –32               |
| New Hampshire              | 17                        | 1                                  | –53-58                   | 1508              |
| Tennessee                  | 12                        | 4                                  | –53-58                   | 213               |
| Vermont                    | 10                        | 27                                 | –26-84                   | –63               |
| Alaska                     | 8                         | 24                                 | –35-76                   | –68               |
| South Dakota               | 7                         | 59                                 | 6-112                    | –89               |
| New Jersey                 | 5                         | 71                                 | 19-127                   | –93*              |
| Kansas                     | 2                         | 12                                 | –40-67                   | –84               |
| Alabama                    | 0                         | 36                                 | –19-92                   | –100              |
| Hawaii                     | 0                         | 19                                 | –32-77                   | –100              |
| Montana                    | 0                         | 11                                 | –44-68                   | –100              |
| North Dakota               | 0                         | 35                                 | –21-88                   | –100              |

### Table A.4.j. eBird predicted and observed counts of observations.

(continued on next page)
| State          | 2020 observations | Predicted 2020 observations | 95% prediction interval | Percent difference |
|---------------|-------------------|-----------------------------|-------------------------|--------------------|
| New York      | 9385              | 12,104                      | 9355-15,317             | 22                 |
| New York      | 8039              | 7965                        | 6227-10,180             | 1                  |
| Texas         | 6012              | 8267                        | 6580-10,418             | 27*                |
| Florida       | 5879              | 8233                        | 6657-10,253             | 29*                |
| Pennsylvania  | 5872              | 5871                        | 4602-7,406              | 0                  |
| Ohio          | 4559              | 5817                        | 4558-7,320              | 22*                |
| Virginia      | 4456              | 4796                        | 3734-6,148              | 7                  |
| Massachusetts | 4391              | 4703                        | 3687-5,968              | 7                  |
| Rhode Island  | 4576              | 4754                        | 3763-6,079              | 8                  |
| Michigan      | 4369              | 5039                        | 4019-6,369              | 13                 |
| Illinois      | 4004              | 4326                        | 3389-5,533              | 7                  |
| North Carolina| 3935              | 4101                        | 3232-5,258              | 4                  |
| Wisconsin     | 3842              | 4539                        | 3561-5,677              | 15                 |
| Colorado      | 3777              | 4439                        | 3497-5,632              | 15                 |
| Maryland      | 3470              | 3641                        | 2854-4,689              | 5                  |
| Arizona       | 3204              | 5087                        | 3969-6,421              | 37*                |
| New Jersey    | 3188              | 4126                        | 3267-5,162              | 23*                |
Table A.4 (continued)

### Table A.4.k. eBird predicted and observed counts of participants.

| State            | Observed 2020 participants | Predicted 2020 participants | 95% prediction interval | Percent difference 2020 observations (observed – predicted / predicted * 100) |
|------------------|-----------------------------|----------------------------|-------------------------|------------------------------------------------------------------------|
| Oregon           | 3097                        | 3637                       | 2858–4619               | –15                                                                   |
| Minnesota        | 2793                        | 3141                       | 2510–3937               | –11                                                                  |
| Georgia          | 2705                        | 3157                       | 2447–4036               | –14                                                                  |
| Indiana          | 2551                        | 2598                       | 2058–3293               | –2                                                                   |
| Tennessee        | 2085                        | 2378                       | 1880–3041               | –12                                                                  |
| Connecticut      | 2015                        | 2139                       | 1695–2674               | –6                                                                   |
| Missouri         | 2007                        | 2153                       | 1718–2744               | –7                                                                   |
| South Carolina   | 1999                        | 2542                       | 1996–3174               | –21                                                                  |
| Maine            | 1878                        | 2814                       | 2237–3525               | –33*                                                                  |
| Utah             | 1654                        | 2281                       | 1798–2875               | –27*                                                                  |
| New Mexico       | 1511                        | 2276                       | 1786–2896               | –34*                                                                  |
| New Hampshire    | 1416                        | 1830                       | 1449–2301               | –23*                                                                  |
| Vermont          | 1374                        | 1779                       | 1387–2258               | –23*                                                                  |
| Montana          | 1344                        | 1644                       | 1289–2098               | –18                                                                  |
| Idaho            | 1314                        | 1397                       | 1090–1765               | –6                                                                   |
| Kentucky         | 1139                        | 1361                       | 1055–1733               | –16                                                                  |
| Iowa             | 1130                        | 1259                       | 987–1600                | –10                                                                  |
| Kansas           | 1123                        | 1463                       | 1156–1880               | –23*                                                                  |
| Alabama          | 1114                        | 1402                       | 1090–1761               | –21                                                                  |
| Louisiana        | 1033                        | 1537                       | 1222–1953               | –33*                                                                  |
| Oklahoma         | 934                         | 1300                       | 1019–1639               | –28*                                                                  |
| Delaware         | 924                         | 1513                       | 1196–1915               | –39*                                                                  |
| West Virginia    | 920                         | 1204                       | 925–1541                | –24*                                                                  |
| Wyoming          | 903                         | 1348                       | 1065–1706               | –33*                                                                  |
| Nebraska         | 895                         | 1060                       | 841–1339                | –16                                                                  |
| Arkansas         | 857                         | 1041                       | 819–1315                | –18                                                                  |
| Rhode Island     | 740                         | 712                        | 560–904                 | 4                                                                    |
| Nevada           | 735                         | 1356                       | 1078–1711               | –46*                                                                  |
| Alaska           | 725                         | 1694                       | 1328–2162               | –57*                                                                  |
| District of Columbia | 651                        | 951                        | 741–1213                | –32*                                                                  |
| Mississippi      | 634                         | 842                        | 661–1075                | –25*                                                                  |
| South Dakota     | 510                         | 655                        | 521–823                 | –22*                                                                  |
| North Dakota     | 413                         | 597                        | 460–761                 | –31*                                                                  |
| Hawaii           | 344                         | 847                        | 669–1073                | –59*                                                                  |

### Table A.4.l. eBird predicted and observed percent of observations originating from urban areas. Prediction intervals > 100% are reported to indicate the size of the interval, even though > 100% is not possible.

| State            | Observed 2020 %urban observations | Predicted 2020 %urban observations | 95% prediction interval | Percent difference 2020 observations (observed – predicted / predicted * 100) |
|------------------|-----------------------------------|------------------------------------|-------------------------|------------------------------------------------------------------------|
| District of Columbia | 100                             | 103                                | 97–110                  | –3                                                                    |
| Illinois         | 63                                | 63                                 | 57–68                   | 1                                                                     |
| New Jersey        | 61                                | 56                                 | 50–62                   | 8                                                                     |
| Florida           | 60                                | 55                                 | 49–61                   | 8                                                                     |
| Massachusetts     | 60                                | 60                                 | 54–65                   | 0                                                                     |
| Connecticut      | 59                                | 64                                 | 58–70                   | –8                                                                    |
| Georgia           | 58                                | 52                                 | 46–58                   | 11*                                                                   |
| California       | 57                                | 48                                 | 43–54                   | 18*                                                                   |
| Rhode Island     | 54                                | 49                                 | 43–54                   | 11                                                                   |
| Washington       | 53                                | 40                                 | 35–46                   | 33*                                                                   |
| Louisiana        | 51                                | 37                                 | 31–42                   | 40*                                                                   |
| Maryland         | 50                                | 49                                 | 43–55                   | 3                                                                     |
| Kentucky         | 49                                | 43                                 | 38–49                   | 13*                                                                   |
| North Carolina   | 49                                | 46                                 | 40–52                   | 6                                                                     |
| Texas            | 49                                | 39                                 | 34–45                   | 24*                                                                   |
| Virginia         | 49                                | 46                                 | 40–52                   | 5                                                                     |
| Ohio             | 47                                | 38                                 | 32–44                   | 25*                                                                   |
| Colorado         | 46                                | 36                                 | 30–42                   | 26*                                                                   |
| Tennessee        | 46                                | 41                                 | 35–47                   | 11                                                                   |
| Minnesota        | 45                                | 46                                 | 40–52                   | –3                                                                   |
| South Carolina   | 45                                | 41                                 | 35–47                   | –9                                                                   |
| Alabama          | 44                                | 35                                 | 29–41                   | 27*                                                                   |
| Pennsylvania     | 44                                | 45                                 | 39–50                   | –3                                                                   |
| Indiana          | 43                                | 37                                 | 32–43                   | 17*                                                                   |
| New York         | 43                                | 46                                 | 40–52                   | –8                                                                   |
| Oregon           | 42                                | 36                                 | 30–41                   | 18*                                                                   |
| Hawaii           | 41                                | 35                                 | 29–41                   | 17*                                                                   |
| Mississippi      | 41                                | 41                                 | 36–47                   | 0                                                                     |
| Missouri         | 41                                | 40                                 | 34–47                   | 3                                                                     |
| Nevada           | 40                                | 38                                 | 32–44                   | 5                                                                     |
| New Mexico       | 40                                | 35                                 | 30–41                   | 14                                                                   |
| Michigan         | 37                                | 36                                 | 31–42                   | 1                                                                     |
| Wisconsin        | 37                                | 31                                 | 25–36                   | 20*                                                                   |
Table A.4 (continued)

| State          | Observed 2020 Urban observations | Predicted 2020 Urban observations | Percent difference 2020 observations (observed – predicted) / predicted * 100 |
|----------------|----------------------------------|-----------------------------------|--------------------------------------------------------------------------------|
| Oklahoma       | 35                               | 40                                | 34–46                                                                            | –13                                                                             |
| Utah           | 35                               | 31                                | 25–37                                                                            | 15                                                                              |
| Delaware       | 34                               | 34                                | 28–39                                                                            | 1                                                                               |
| Kansas         | 33                               | 28                                | 22–34                                                                            | 18                                                                              |
| New Hampshire  | 33                               | 34                                | 29–40                                                                            | –4                                                                              |
| Arizona        | 32                               | 29                                | 24–35                                                                            | 10                                                                              |
| Arkansas       | 32                               | 34                                | 28–40                                                                            | –6                                                                              |
| Alaska         | 30                               | 23                                | 18–29                                                                            | 29*                                                                             |
| Nebraska       | 29                               | 26                                | 20–31                                                                            | 15                                                                              |
| Idaho          | 26                               | 25                                | 19–31                                                                            | 5                                                                               |
| Iowa           | 26                               | 34                                | 28–39                                                                            | –21*                                                                            |
| Maine          | 24                               | 25                                | 20–31                                                                            | –7                                                                              |
| West Virginia  | 22                               | 25                                | 19–31                                                                            | –13                                                                             |
| Montana        | 21                               | 18                                | 12–24                                                                            | 14                                                                              |
| North Dakota   | 19                               | 20                                | 15–26                                                                            | –5                                                                              |
| Wyoming        | 19                               | 20                                | 14–26                                                                            | –8                                                                              |
| Vermont        | 18                               | 17                                | 11–23                                                                            | 8                                                                               |
| South Dakota   | 13                               | 16                                | 10–22                                                                            | –16                                                                             |

Table A.5

Correlation between the length of stay-at-home orders (days) and counts of 2020 participants 2020 observations, and 2020 percent of observations originating from within urban areas, March–June 2020, for four community science programs.

| Program            | y (2020 observations) | x (Length stay at home (days)) | Adj r squared | F1,49 statistic | p value | Estimate | Standard error |
|--------------------|-----------------------|--------------------------------|---------------|-----------------|---------|----------|---------------|
| Nature's Notebook  | 2020 observations     | Length stay at home (days)     | –0.01973      | 0.0327          | 0.8571  |          |               |
| eButterfly         | 2020 observations     | Length stay at home (days)     | –0.01963      | 0.03732         | 0.8476  |          |               |
| iNaturalist        | 2020 observations     | Length stay at home (days)     | –0.01954      | 0.04176         | 0.8389  |          |               |
| eBird              | 2020 observations     | Length stay at home (days)     | –0.02041      | 0.0000615       | 0.9934  |          |               |
| Nature's Notebook  | 2020 participants     | Length stay at home (days)     | 0.01969       | 0.03467         | 0.8531  |          |               |
| eButterfly         | 2020 participants     | Length stay at home (days)     | 0.03397       | 2.758           | 0.1031  | –3.305   | 1.99          |
| iNaturalist        | 2020 participants     | Length stay at home (days)     | –0.01711      | 0.159           | 0.6918  |          |               |
| eBird              | 2020 participants     | Length stay at home (days)     | –0.0007943    | 0.9603          | 0.3219  |          |               |
| Nature's Notebook  | 2020 %urban observations | Length stay at home (days) | 0.04846   | 3.547           | 0.06561 | 2.788   | 1.48          |
| eButterfly         | 2020 %urban observations | Length stay at home (days) | 0.07229   | 4.896           | 0.03161 | 1.5966  | 0.7216        |
| iNaturalist        | 2020 %urban observations | Length stay at home (days) | –0.01922   | 0.05694         | 0.8124  |          |               |
| eBird              | 2020 %urban observations | Length stay at home (days) | –0.008157  | 0.5955          | 0.444   |          |               |

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