Biological Conservation 255 (2021) 109001

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

COVID-19 pandemic drives changes in participation in citizen science project “City Nature Challenge” in Tokyo

Keidai Kishimoto [a,*], Hiromi Kobori [b]

[a] Graduate School of Media and Governance, Keio University, 5322 Endo, Fujisawa City, Kanagawa Prefecture 252-0882, Japan.
[b] Faculty of Environmental Studies, Tokyo City University, 3-3-1 Ushikubo-Nishi, Tsuzuki-ku, Yokohama City, Kanagawa Prefecture 224-8551, Japan.

ARTICLE INFO

Keywords:
Coronavirus
iNaturalist
Behavior
Enthusiastic
Geographical bias

ABSTRACT

The COVID-19 pandemic has changed the way large citizen science events can be carried out—reducing gatherings of large groups and shifting toward individual, small-group, and online participation. This paper aims to describe changes in participant engagement in the City Nature Challenge (CNC) in Tokyo. The CNC is a four-day international event held in April to document biodiversity in cities using an online citizen science platform, iNaturalist. To assess the impact of COVID-19, we compared the number of participants, observations, species, and identification rates in 2019 (pre-pandemic) and 2020 (during the pandemic). We also used cluster analysis to elucidate participation patterns, and we assessed changes in the geographical distribution of observation sites. The results showed: (1) the number of participants and observations decreased by 63% and 68%, respectively; however, the number of species was almost the same in the two years, and the identification rate increased 154% in 2020 relative to 2019. (2) The most enthusiastic participants contributed in similar amounts in 2019 and 2020, but participation by less enthusiastic volunteers drastically declined. (3) The spatial distribution of observation sites changed from cluster-like to scattered. Understanding participant engagement during the pandemic could help to improve data quality, reduce geographical bias in observations, maintain records, and recruit more users in future years. Online citizen science could provide opportunities for many citizens to get outside and participate in conservation science during and after the pandemic.

1. Introduction

Since the World Health Organization declared the COVID-19 outbreak a global pandemic in March 2020, public health around the world has been in crisis. Governments and public health organizations have mandated or recommended physical distancing in public and even at home (World Health Organization, 2020), and activities of individuals have been legally or voluntarily restricted, depending on policies and level of infections in each country. Accordingly, communications among people have drastically changed from in-person to online, outdoor to indoor especially in cities, and group to individual. These changes have greatly influenced citizen science participation (Crimmins et al., this issue).

Citizen science is characterized by non-specialist individuals participating in some part of the scientific research process, such as designing research questions and study processes, collecting data, and interpreting results (Bonney et al., 2009). Citizen science contributes to advances in scientific research, education, and problem-solving (Kobori et al., 2016), and enables scientists to collect data at large scales and to sustain long-term monitoring. It allows individuals to collect and understand scientific knowledge and helps policymakers solve regional issues. Citizen science is useful in a variety of fields, especially in biology (Follett and Strezov, 2015). Bioblitzes are a specific and widely used type of citizen science event—field events in which scientists, naturalists, and non-expert participants work together to identify and record many species within a designated time and region (Robinson et al., 2013; Roger and Klistorner, 2016). Bioblitzes are especially effective at documenting biodiversity in urban areas because volunteers can document biodiversity in many small green areas, such as gardens and vegetated roadsides, and private lands, which can support abundant biodiversity (Rudd et al., 2002). Individuals often have easier access to private lands in their neighborhoods than do professional scientists, so urban bioblitzes can facilitate extensive data collection that would not be possible otherwise (Spear et al., 2017). These characteristics have helped make citizen science data an important source of information for establishing protected areas and implementing conservation programs

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* Corresponding author.
E-mail addresses: keidai@keio.jp (K. Kishimoto), kobori@tcu.ac.jp (H. Kobori).

https://doi.org/10.1016/j.biocon.2021.109001
Received 18 September 2020; Received in revised form 20 January 2021; Accepted 25 January 2021

(McKinley et al., 2015; Pellissier et al., 2020).

COVID-19 could have severely affected implementation of citizen science due to limits on public gatherings, including bioblitzes. Reductions in bioblitzes and similar data typically gathered by large groups of citizen scientists, could in turn reduce biodiversity data collection and affect conservation activities that rely on the data. Additionally, the stagnation of transportation and economic activities due to COVID-19 has significantly changed urban environments and regional ecosystems. For example, the reduction of transportation has reduced daily CO_2 emissions by as much as 17% (Le Quéré et al., 2020), and reduced NO_2 emissions in major cities (Muhammad et al., 2020). In the United Kingdom, demand for green spaces has increased because of their importance for leisure, relaxation, and exercise after lockdown levels eased (Day, 2020). Citizen science, such as bioblitzes, can help researchers understand how biodiversity and ecosystems have been affected by these changes in urban environments and the ways humans use them (Bates et al., 2020; Terry et al., this issue).

The emergence of online citizen science, supported by the internet and smartphones, has made it possible for participants to contribute to citizen science projects without face-to-face events. Smartphone apps and their behind-the-scenes cyberinfrastructure can streamline data collection, manage data, control quality, and facilitate communication (Newman et al., 2012). Platforms for online citizen science such as iNaturalist, eBird, and iSpot, which are already used by many people, can be especially useful during COVID-19 (Crimmins et al., this issue).

Although it is technically possible for people to continue to participate in these citizen science programs, it is less clear how the COVID-19 pandemic might affect their motivation to participate. In our study, we focus on how the pandemic is affecting the level at which volunteers participate in citizen science. Researchers have previously studied citizen science participants' engagement, psychological motivation, and behavior patterns based on behavior logs (Aristeidou et al., 2017). These studies have found that major motives for participation include contributions to science and conservation, social factors, and recreation (Larson et al., 2020). At least one study reported that social factors motivating participants are absent for online citizen science programs (Maund et al., 2020). Moreover, few studies have examined participation in citizen science in Asia, including Japan, even during non-pandemic times (Sakurai et al., 2015).

In Japan, the government declared a state of emergency on April 7 until the end of May in Tokyo. During this period, the social life of individuals significantly changed. Businesses such as cultural and sports facilities, events, and schools were suspended; many restaurants and shops were closed or shortened their business hours; and many companies changed to primarily telework, even though there were no traffic or logistics suspensions, compulsory suspension of business, or restrictions on going out. As many people began to spend more time outside near their homes, concentrations of people in nearby parks and supermarkets became a social problem (e.g. The Yomiuri Shimbun, 2020; NHK, 2020; Ito and Nonaka, 2020).

Due to the emergency declaration to stay at home and the move of citizen science online, we predicted that the number of participants in citizen science would decrease. However, some enthusiasts might continue to observe plants and animals for stress relief. Further, we predicted that the time spent observing living things would be less than before and the place of observation would have shifted to the vicinity of home rather than farther away. In this study, therefore, we focused on how levels and patterns of participation in citizen science changed before and during the COVID-19 pandemic, using an urban bioblitz activity, the City Nature Challenge (CNC) Tokyo, as a case study. The CNC is a four-day citizen science event in which participants use the online platform, iNaturalist, to document biodiversity in cities around the world (Leong and Trautwein, 2019; https://citynaturechallenge.org/). This paper gives information on how the citizen science data obtained during the pandemic can be utilized for conservation related activities, and insight into how to continue citizen science during or after the pandemic.

2. Methodology & data

2.1. Research framework

Our research followed a three-step procedure: (1) comparing the number of participants, number of observations, the number of species, and the identification rate for the CNC Tokyo in 2019 (CNC2019-Tokyo) and 2020 (CNC2020-Tokyo); (2) using cluster analysis of participants' observation logs to examine changes in observers' behavioral patterns between 2019 and 2020; and (3) analyzing the geographical distribution of observation sites in 2019 and 2020. No major social or natural disruptions occurred during the CNC2019-Tokyo, whereas during the CNC2020-Tokyo people were required to refrain from unnecessary travel and social gatherings due to the COVID-19 pandemic.

2.2. Data source of citizen science project

We obtained data through iNaturalist (https://www.inaturalist.org/), an online citizen science platform. iNaturalist is a free online tool that collects images and metadata describing biodiversity observations (Heberling and Isaac, 2018). After downloading the smartphone application, participants can record photos and audio for any organisms they see or hear; they can post Global Navigation Satellite System (GNSS) location information, propose species identification, and record additional notes. For species identifications, participants can use suggestions made by the artificial intelligence of iNaturalist, and then a community of 1.5 million iNaturalist registrants, including citizens, naturalists, and researchers around the world can confirm or correct the identification. Data are classified into three grades. "Research Grade" observations include a date, are georeferenced, include photos or sounds, are not of captive of cultivated species, and are confirmed by two-thirds of species identifiers during the species identification steps. In contrast, "Casual" data lack basic metadata. "Needs ID" data do not satisfy the standards of "Research Grade." Many biodiversity databases, such as the Global Biodiversity Information Facility (GBIF), include iNaturalist "Research Grade" data, but not "Casual" or "Needs ID" data.

The City Nature Challenge is held annually in late April, and attracted 32,000 participants from 159 cities around the world in 2019 and 41,000 people from 244 cities in 2020 (City Nature Challenge, 2019, 2020). We have organized CNC activities in Tokyo since 2018.

This study used data from CNC2019-Tokyo and CNC2020-Tokyo. The island areas of Tokyo were not included in 2019 or 2020. The CNC2019-Tokyo occurred from April 26 to 29. The event was convenient for many people to participate because three days out of the four-day event were holidays. Only two days were holidays during CNC2020-Tokyo, which was held April 24 to 27. The weather, on the other hand, was better for participating in 2020 than 2019 according to the Japan Meteorological Agency. Tokyo had less rain during the event in 2020 compared to 2019. The CNC was advertised by website and posters at various organizations and universities. Other factors that attracted people to CNC2019-Tokyo included a lecture and a simultaneous biodiversity observation event held in Futako-Tamagawa, Setagaya City within Tokyo.

The authors downloaded the CNC2019-Tokyo and CNC2020-Tokyo observation records from iNaturalist on July 28, 2020 including participants' ID, observation type, date and time, and geographical coordinates.

2.3. Data analysis

2.3.1. Comparison of observation

First, we compared the number of users, observations, species, and the identification rates obtained from the observation records. The numbers of users and observations were calculated from all the posted observation records. To calculate the number of species and the identification rates, we used only "Research Grade" observations and excluded "Casual" data and "Needs ID" data. We calculated identification rate as the proportion of "Research Grade" relative to all observation records for the CNC Tokyo in each year.

2.3.2. *Clustering analysis*

We conducted a cluster analysis of participants' behaviors. The following indices were calculated from the observer's ID to enable us to characterize the behavior of each participant while engaged in observation. We based these indicators on similar indicators developed in previous studies of participant behavior (Aristeidou et al., 2017; Boakes et al., 2016). Definitions of the three indicators used in this study are described below.

Activity Ratio indicates how many days an observer posted at least one observation record during the four days of CNC. If at least one observation was posted, the observer was considered active. People with a value closer to 1 participated on more days.

Daily Devoted Time was defined simply as a duration, the difference between starting and ending time when an observer collected observation records on each day.

Daily Observations was defined as the average number of observations per one active day; the number of total observations divided by the number of active days.

Other indicators used in previous studies—such as relative activity duration, variation in periodicity, and lurking ratio—were not used in this study because the CNC was held only for four days and login records necessary to calculate these indicators were not accessible.

We calculated the three indicators—activity ratio, daily devoted time, and daily observations—for 2019 and 2020. We identified 11 observers who participated in both 2019 and 2020, but we calculated indicators for the two years separately to track changes between the years. The total number of participants in 2019 and 2020 combined was 216, which we regarded as the population for cluster analysis. The value of each index of the population was normalized to a value between 0 and 1.

$$Y = \frac{X - x_{min}}{x_{max} - x_{min}}$$

Here we set any value of the variable to X, maximum value to x_{max}, minimum value to x_{min}, and normalized value to Y. We normalized activity ratio, daily devoted time, and daily observations in the same way.

We then conducted a hierarchical cluster analysis using the 'scipy.cluster.hierarchy' library in a Python3 environment. Euclidean was used for metric and ward was used for method. We used the results to group participants into four categories. Based on their characteristics we named the groups: enthusiastic, off-and-on, temporary, and intense. These groupings derive from those used in previous cluster analyses examining citizen science participant motivations and behaviors. For example, Ponciano and Brasileiro (2014) classified participant behaviors as: hardworking, spasmodic, persistent, lasting, and moderate. Boakes et al. (2016) classified behaviors as: dabbler, steady, and enthusiast. Aristeidou et al. (2017) classified users' behavior as: loyal, hardworking, persistent, lurker, and visitor.

2.3.3. *Geographical analysis*

We used ArcGIS Pro 2.5 to visualize geographical changes in observation sites between 2019 and 2020. We used average nearest neighbor analysis to quantitatively evaluate the tendency of variance/cluster in the distribution pattern. We inputted data from CNC2019-Tokyo and CNC2020-Tokyo, used the area of Tokyo as the analysis range, and performed calculations based on Euclidean distance.

3. Results

3.1. *Comparison of observations*

We compared the number of participants, observations, species, and the identification rates among the observation records in CNC2019-Tokyo and CNC2020-Tokyo.

The number of participants and observations declined by more than 60% between 2019 and 2020 (Table 1). In contrast, the number of observed species did not change as substantially (Table 1). Broken down by taxonomic groups, participants observed more plants (281 species in 2019, 277 in 2020) than insects (37 species in 2019, 19 in 2020) or birds (32 species in 2019, 17 in 2020) in both years. Moreover, the identification rate increased between 2019 and 2020 (Table 1), meaning fewer observations lacked a confirmed identification. In 2020, the number of "Research Grade" identifications was 816 (72.1%).

3.2. *Changes in behavior*

The behavioral pattern was divided into four clusters: enthusiastic, off-and-on, temporary, and intense. Fig. 1 and Table 2 show the comparison between the average normalized score of each cluster and changes between the two years. The activity ratio was the largest in the enthusiastic cluster. The intense and enthusiastic clusters had the largest daily devoted time and daily observation. The number of participants in the off-and-on and temporary clusters drastically declined between 2019 and 2020. However, the temporary cluster had more participants than other clusters in both years. The features of these clusters are described in detail below.

Enthusiastic: This cluster of participants most consistently participated in the project. There were 11 people in this cluster in 2019 and 8 people in 2020. They participated for 3 or 4 days out of the 4-day project. The average time spent on the project per day was 2 h and 44 min. The number of observations per day was relatively high at 25.2.

Off-and-on: This cluster participated moderately. The number of people in this cluster was 57 in 2019 and 10 in 2020. They participated in the project for 2 days on average. The average time spent on the project per day was 1 h and 28 min, and the number of observations per day was 12.5, which was about half of the observations of the enthusiastic cluster.

Temporary: This cluster participated for only one day and had a very small number of observations and observation hours. The number of people who belonged to this cluster was 64 in 2019 and 34 in 2020. The average project engagement time per day was 15 min. The number of observations per day was 4.2.

Intense: This cluster consisted of participants who had a small number of participation days but observed very hard on the day of participation. The number of people who belonged to this cluster was 26 in 2019 but just 6 in 2020. They participated in the project for one day on average. The average time spent on the project per day was 3 h and 35 min. The number of observations per day was 27.2.

Table 1
The number of participants, observations, species, "Research Grade" data, and their changes between 2019 and 2020. "Research Grade"/Observations indicates the number of "Research Grade" data relative to the total number of observations (including "Casual" and "Needs ID").

	2019	2020	Percent change
Participants	158	58	63.3%↓
Observations	3576	1131	68.4%↓
Species	366	321	12.3%↓
"Research Grade"	1677	816	51.3%↓
"Need ID"	1899	230	87.9%↓
"Casual"	0	85	–
Observations/participants	22.6	19.5	13.8%↓
"Research Grade"/observations	0.469	0.721	53.7%↑

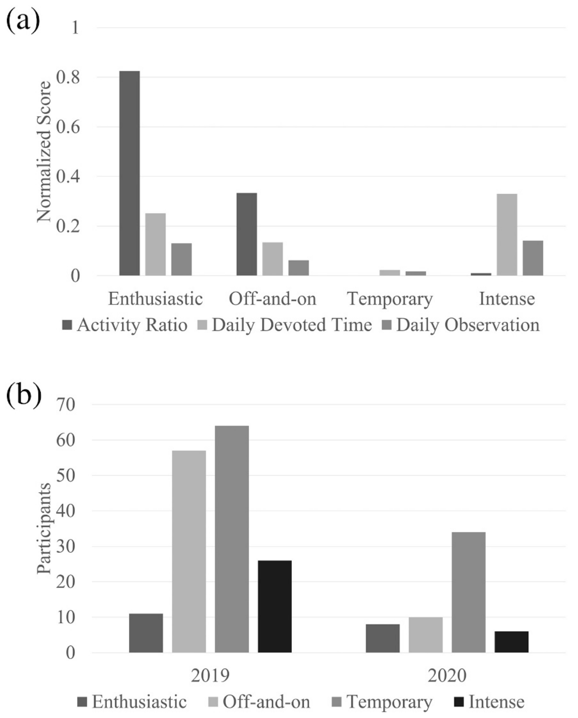


Fig. 1. Behavior patterns derived by cluster analysis. (a) Average index values of activity ratio, daily devoted time, and daily observation for four engagement profiles. (b) Number of participants in four engagement profiles in 2019 and 2020.

Table 2
Normalized scores and population in each engagement cluster.

	Score			Population	
	Activity ratio	Daily observation	Daily devoted time	2019	2020
Enthusiastic	0.82 (86.8%)	0.25 (25.2/day)	0.13 (2:44:02/day)	11	8
Off-and-on	0.33 (50.0%)	0.13 (12.5/day)	0.06 (1:27:46/day)	57	10
Temporary	0 (25.0%)	0.02 (4.2/day)	0.02 (0:15:02/day)	64	34
Intense	0.01 (25.8%)	0.33 (27.2/day)	0.14 (3:34:58/day)	26	6

We also traced the changes in the behavioral patterns of the 11 people who participated in both years (Table 3). Two participants made many observations in both 2019 and 2020 and were enthusiastic both years. They participated in the morning and evening, or the day and evening, and observed intensively on some days. Three participants were grouped as off-and-on or intense in 2019 but became enthusiastic in 2020; two of the three participated for more days and recorded more observations each day in 2020, while the other of the three shifted from intense participation on one day in 2019 to participating for more days but making fewer observations per day in 2020. Two participants grouped as off-and-on in 2019 and became intense in 2020. One participant was grouped as temporary in 2019 but as off-and-on in 2020, although their number of observations did not change significantly. Two participants grouped as off-and-on in 2019 made fewer observations in 2020 and were grouped as temporary. One participant was grouped as temporary in both 2019 and 2020.

Although there was a small number of enthusiastic observers, the number did not change drastically between 2019 and 2020. Two participants contributed greatly to recording observations both years, and some off-and-on and intense participants became enthusiastic. Furthermore, three participants did not participate in 2019 but participated enthusiastically in 2020. On the other hand, the number of intense participants and the number of off-and-on participants declined substantially from 2019 to 2020. Some participants fell into these categories in both years. The number of temporary participants who tried the CNC dropped by half between 2019 and 2020. Some participants who were off-and-on in 2019 became temporary in 2020, and some remained as temporary participants both years.

3.3. *Geographical change*

Average nearest neighbor analysis yielded a *p*-value sufficiently smaller than 0.01 and the *Z*-score was sufficiently smaller than -2.58 to exclude the null hypothesis that the distribution of observations was random. As a result, the shortest distance index was 0.14 for CNC2019-Tokyo and 0.31 for CNC2020-Tokyo. These values (indices less than 1) indicate that the geographic distribution of observations was clustered. The larger value for CNC2019-Tokyo reflects that clustering was stronger in 2019 (Fig. 2).

Observation records of CNC2019-Tokyo were concentrated in core places such as Point 1 (Fig. 2) where a park was developed along the riverbed and the targeted bioblitz event was held. This point is only 15 km from the center of Tokyo and is a popular area with many green spaces and rivers. Point 2 is a large-scale park and temple in central Tokyo, including the Meiji Jingu Shrine, Shinjuku Gyoen National Garden, Yoyogi Park, and Shinjuku Central Park. Point 3 and Point 4 are riverbeds and satoyama areas—i.e., a traditional landscape with mosaic-like land use (Ichikawa et al., 2006; Takeuchi et al., 2003)—that remain within the city limits. The surrounding area is a biodiversity hot spot, although the satoyama landscape is being lost with urbanization. Point 5 is located in a mountainous coniferous forest area that was designated as a national park.

The observation records of CNC2020-Tokyo were dispersed more than in 2019. There were some areas that were still core, such as Point 1; however, observations were widely scattered in the city. Participants seemed to record observations made in small green areas near homes.

4. Discussion

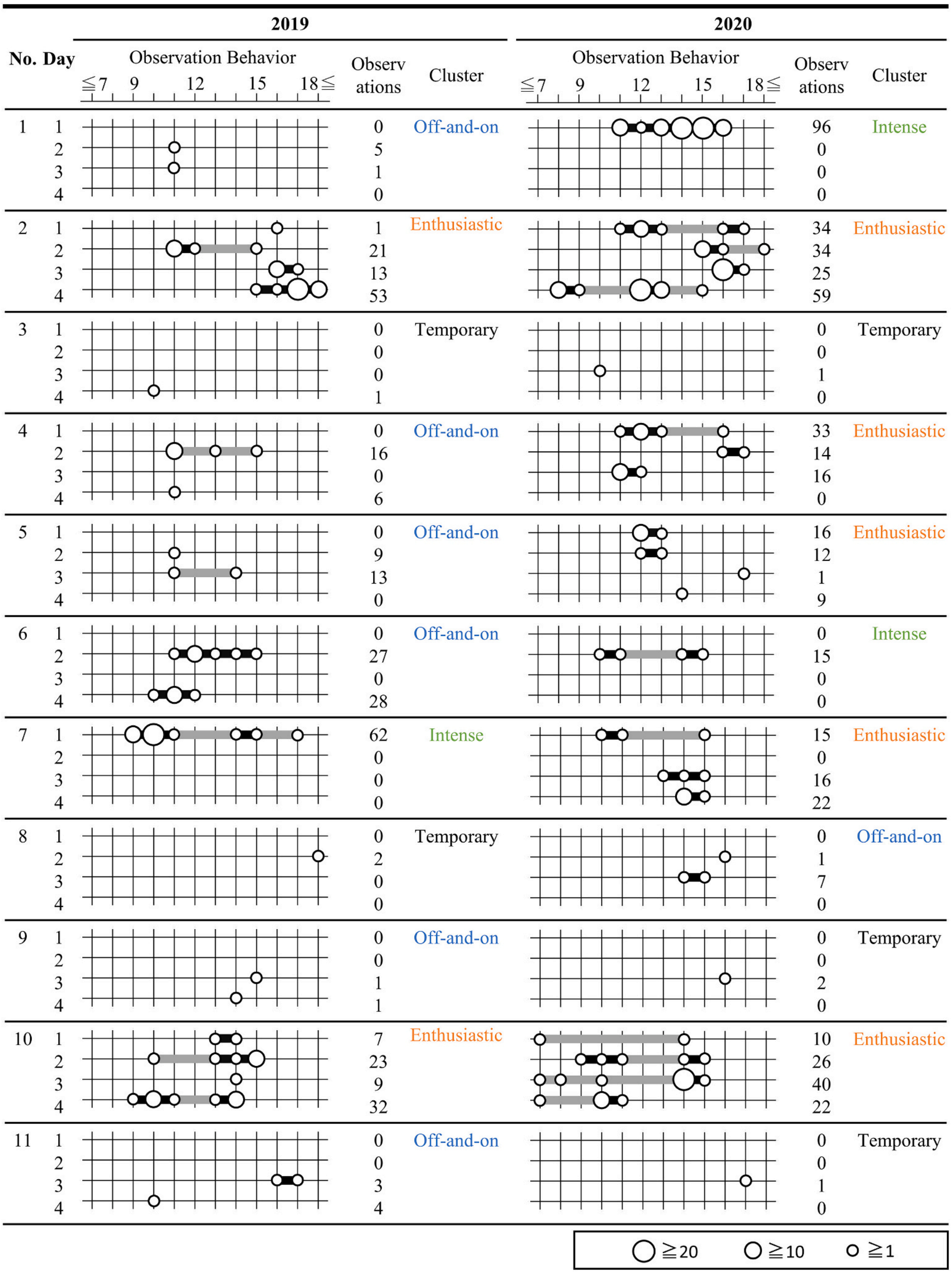
4.1. *Impact of COVID-19 on participation*

Fewer people participated in the CNC Tokyo citizen science project during the COVID-19 pandemic (2020) than participated in 2019, and each participant made fewer observations on average. However, when we traced the behavior of individual participants, some participants actively made observations in both 2019 and during the pandemic in 2020. Additionally, there were many new participants in 2020 even though no social events were held as a part of the CNC Tokyo. Only 11 people participated in both 2019 and 2020. Because of reduced travel during the pandemic, participants primarily reported observations in small green areas near their homes.

The change in participation in CNC Tokyo is probably related to the desire not to stay outdoors for a long time during the COVID-19 pandemic, the increase in distractions and stresses in people's lives and the reductions of in-person social interactions. It is said that Japanese people alter their behaviors to meet the expectations of others (Hashimoto et al., 2008)—i.e., they were sometimes afraid of being morally blamed for not following public health recommendations when they participated by recording biodiversity observations outside. In-person interaction among participants is one of the main motivations for participation in citizen science (Bruyere and Rappe, 2007), and people overall are less motivated by online-only interactions (Maund et al., 2020). The people who did participate during the pandemic may have participated as a hobby or for learning. During the pandemic, hobbies and walks have become activities for distraction (Lades et al., 2020). For that reason, it is important to keep greenspace and parks

Table 3

Engagement of eleven participants who joined in both 2019 and 2020. The size of the circle indicates the number of observations, and the line connecting the circles indicates the observation time. Gray line is the interval time.



		2019		2020	
No.	Day	Observations	Cluster	Observations	Cluster
1	1	0	Off-and-on	96	Intense
	2	5		0	
	3	1		0	
	4	0		0	
2	1	1	Enthusiastic	34	Enthusiastic
	2	21		34	
	3	13		25	
	4	53		59	
3	1	0	Temporary	0	Temporary
	2	0		0	
	3	0		1	
	4	1		0	
4	1	0	Off-and-on	33	Enthusiastic
	2	16		14	
	3	0		16	
	4	6		0	
5	1	0	Off-and-on	16	Enthusiastic
	2	9		12	
	3	13		1	
	4	0		9	
6	1	0	Off-and-on	0	Intense
	2	27		15	
	3	0		0	
	4	28		0	
7	1	62	Intense	15	Enthusiastic
	2	0		0	
	3	0		16	
	4	0		22	
8	1	0	Temporary	0	Off-and-on
	2	2		1	
	3	0		7	
	4	0		0	
9	1	0	Off-and-on	0	Temporary
	2	0		0	
	3	1		2	
	4	1		0	
10	1	7	Enthusiastic	10	Enthusiastic
	2	23		26	
	3	9		40	
	4	32		22	
11	1	0	Off-and-on	0	Temporary
	2	0		0	
	3	3		1	
	4	4		0	

accessible for individuals (Slater et al., 2020).

Across the world, 83 cities participated both in 2019 and 2020. However, the situation of the pandemic and lockdown for COVID-19 differed depending on the country and city, so participation differed among cities. According to the City Nature Challenge website (2019, 2020), among 83 cities, the number of participants decreased in 42 cities, the number of observations decreased in 47 cities, and the number of species decreased in 36 cities. The number of observations and participants declined substantially more in Tokyo relative to other cities, but the number of species was only declined marginally more than other cities (City Nature Challenge, 2019, 2020). The pandemic situation in Japan was relatively mild in April, and the Japanese Government took no compulsory measures (Tashiro and Shaw, 2020). Future research should compare the major factors in behavioral change in Tokyo compared to other cities in the world.

4.2. Impact of changing participation pattern on documenting biodiversity

Despite declines in participation, CNC Tokyo documented similar numbers of species in 2019 and 2020. This reflected an increase in the ratio of people with a strong interest in the project and who were familiar with iNaturalist, as evidenced by the increase in the ratio of enthusiastic participants. Accurate species identification requires high quality photographs and records and sufficient experience (Kosmala

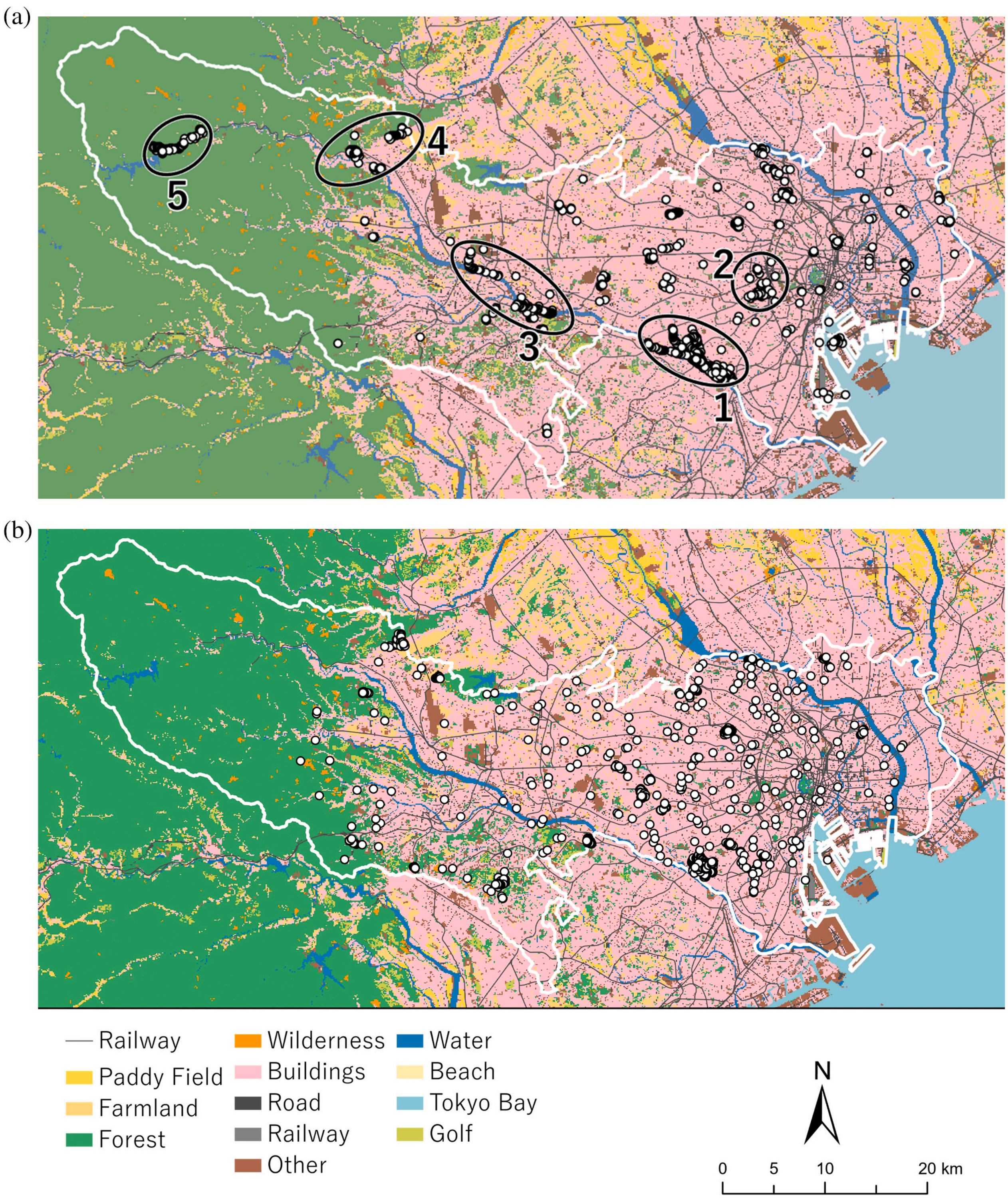


Fig. 2. Distribution of observations in (a) 2019 and (b) 2020. The white outline represents the Tokyo Prefecture. Clusters of observation made in 2019 are labeled 1–5 are described in more detail in the text (Points 1–5). GIS datum of land use and railways were downloaded from digital national land information by Ministry of Land, Infrastructure, and Transportation in Japan, and edited by the authors.

et al., 2016). The fact that participants had additional free time likely led to the increase in the identification rate of species. People may have been able to spend more time identifying species observed by CNC participants in Japan and all over the world. If so, identification during stay-at-home periods may have unintentionally helped increase the amount of "Research Grade" data available for conservation monitoring programs.

The geographic distribution of observations changed from cluster-like in 2019 to scattered during the pandemic, likely because participants made observations near their homes during the pandemic. The scattered observations likely reduced geographic bias. In 2019, observations were concentrated in large parks and riverbeds where participants expected to see a variety of species; small green spaces, such as gardens and shrines in residential areas, may have been ignored.

Moreover, we note that the number of species did not change very much between years, suggesting that increasing the number of observers doesn't necessarily increase the number of species, and that the sampling pattern in 2020 was more efficient to observe many species.

4.3. Impact of changing participation pattern on conservation and documenting biodiversity

This study provides important insights into factors that influence how we can use citizen science to collect biodiversity data more effectively. Conservation depends on documenting biodiversity, and particularly detecting biodiversity change related to human activities. Citizen science activities like the CNC are one of the best ways for us to document biodiversity, particularly in urban areas and on private lands, because professional scientists have difficulty accessing there (Spear et al., 2017) and they cannot devote as much time as volunteers often can. Projects like the CNC can document biodiversity in these areas and may be able to show how wildlife in these areas was affected by the pandemic and how they shift after the pandemic is over, providing important information for conservation biologists and conservation organizations (Corlett et al., 2020). On the other hand, this study revealed a change in the way individuals participated in citizen science during the COVID-19 pandemic. Increases in species identification and reduced geographic bias, which occurred during the pandemic, represent positive changes in documenting urban biodiversity. However, significant decrease in the number of observations and decreases in observations in large green spaces could reduce the benefits of the 2020 CNC Tokyo data for conventional conservation monitoring and activities. Scientists using these data to study changes in plants and animals over time should account for the significant changes in participant behavior (e.g., spatial distribution) caused by the COVID-19 pandemic.

4.4. Citizen Science during and after COVID-19

During the COVID-19 pandemic, citizen science organizers had to redesign some programs, particularly those that involve in-person interactions. Citizen science during the pandemic can provide a productive recreational activity (Rose et al., 2020) at a time when many people cannot pursue their usual hobbies and when some people have extra time because of teleworking, suspension of work, school closures, and restrictions on going out. The CNC is a project that people can do without crowding, and if they are interested in nature, it can meet the needs of these potential participants. They can participate for short periods of time, as in the temporary observers in our analysis, or can participate more deeply like the enthusiastic observers.

Citizen science projects like the CNC can help to avoid disruption of scientific monitoring during the pandemic (Corlett et al., 2020) and evaluate the short-term impact of COVID-19 on the local environment (Bates et al., 2020).

Moreover, this study points to ways to improve short-term citizen science projects even in non-pandemic situations. For example, increases in time to identify species and knowledge about species and the iNaturalist platform seemed to contribute to higher identification rates. Offering trainings and scheduling longer citizen science events that provide more time to identify species could help increase identification rates in future CNC events and other bioblitzes.

In contrast, if the COVID-19 pandemic becomes more serious or another pandemic arises, it may not be possible to make citizen science observations of biodiversity outdoors. In this case study from Tokyo, it was safe for people to leave their homes if they followed health and safety guidelines. However, this might not be the case everywhere. Citizen science must not be a venue for the spread of infectious diseases, and it is important that leaders and participants fully understand the characteristics of infectious diseases and carefully choose their policies.

CRediT authorship contribution statement

Keidai Kishimoto: Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing – Original Draft, and Visualization. **Hiromi Kobori**: Investigation, Resources, Writing – Review & Editing, Supervision, Project admission, and Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors would thank Taku Iwaki, Young-sik Ham, Dai Togane, and all the participants of CNC2019-Tokyo and CNC2020-Tokyo, and organizations including Tokyo City University, Biodiversity Academy (BDA), NPO Setagaya Mizube Design Network, and Futako-Tamagawa Area Managements. We would thank Abe Miller-Rushing, Libby Ellwood, Theresa Crimmins and Tara Miller for editing, and Hiroko Oka for proof reading. Also, we are grateful to Alison Young and Lila Higgins who organize City Nature Challenge.

Funding

This work was supported by JSPS KAKENHI Grant Number JP18H01073.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2021.109001.

References

Aristeidou, M., Scanlon, E., Sharples, M., 2017. Profiles of engagement in online communities of citizen science participation. Comput. Human Behav. 74, 246–256. https://doi.org/10.1016/j.chb.2017.04.044.

Bates, A.E., Primack, R.B., Moraga, P., Duarte, C.M., 2020. COVID-19 pandemic and associated lockdown as a "global human confinement experiment" to investigate biodiversity conservation. Biol. Conserv. 248, 108665. https://doi.org/10.1016/j.biocon.2020.108665.

Boakes, E.H., Gliozzo, G., Seymour, V., Harvey, M., Smith, C., Roy, D.B., Haklay, M., 2016. Patterns of contribution to citizen science biodiversity projects increase understanding of volunteers' recording behaviour. Sci. Rep. 6, 33051. https://doi.org/10.1038/srep33051.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., Wilderman, C.C., 2009. Public participation in scientific research: defining the field and assessing its potential for informal science education. A CAISE Inquiry Group Report. Washington, D.C.: Center for Advancement of Informal Science Education (CAISE).

Bruyere, B., Rappe, S., 2007. Identifying the motivations of environmental volunteers. J. Environ. Plan. Manag. 50, 503–516. https://doi.org/10.1080/09640560701402034.

City Nature Challenge, 2019. 2019 LEADERBOARD. URL. https://citynaturechallenge.org/leaderboard-2019/ accessed 8.18.20.

City Nature Challenge, 2020. Collective Results 2020. URL. https://citynaturechallenge.org/collective-results-2020/.

Corlett, R.T., Primack, R.B., Devictor, V., Maas, B., Goswami, V.R., Bates, A.E., Koh, L.P., Regan, T.J., Loyola, R., Pakeman, R.J., Cumming, G.S., Pidgeon, A., Johns, D., Roth, R., 2020. Impacts of the coronavirus pandemic on biodiversity conservation. Biol. Conserv. 246, 108571. https://doi.org/10.1016/j.biocon.2020.108571.

Crimmins, T.M., Posthumus, E.E., Schaffer, S.N., Prudic, K.L. COVID-19 impacts on participation in large scale community science projects in the United States. Biol. Conserv. (This issue, under review).

Day, B.H., 2020. The value of greenspace under pandemic lockdown. Environ. Resour. Econ. 76, 1161–1185. https://doi.org/10.1007/s10640-020-00489-y.

Follett, R., Strezov, V., 2015. An analysis of citizen science based research: usage and publication patterns. PLoS One 10, e0143687. https://doi.org/10.1371/journal.pone.0143687.

Hashimoto, K., Ko, K., Fujinaga, H., Lutz, R., 2008. Predictive ability of the theory of planned behavior for mental health outcomes in Japanese vs. Chinese student. Journal of Health Science 30, 27–37. https://doi.org/10.15017/10779 (in Japanese with English abstract).

Heberling, J.M., Isaac, B.L., 2018. iNaturalist as a tool to expand the research value of museum specimens. Appl. Plant Sci. 6, e01193 https://doi.org/10.1002/aps3.1193.

Ichikawa, K., Okubo, N., Okubo, S., Takeuchi, K., 2006. Transition of the satoyama landscape in the urban fringe of the Tokyo metropolitan area from 1880 to 2001. Landsc. Urban Plan. 78, 398–410. https://doi.org/10.1016/j.landurbplan.2005.12.001.

Ito, Y., Nonaka, R., 2020. People defend themselves in weekends [freely translated from Japanese]. The Asahi Shimbun 25 (in Japanese).

Kobori, H., Dickinson, J.L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., Kitamura, W., Takagawa, S., Koyama, K., Ogawara, T., Miller-Rushing, A.J., 2016. Citizen science: a new approach to advance ecology, education, and conservation. Ecol. Res. 31, 1–19. https://doi.org/10.1007/s11284-015-1314-y.

Kosmala, M., Wiggins, A., Swanson, A., Simmons, B., 2016. Assessing data quality in citizen science. Front. Ecol. Environ. 14, 551–560. https://doi.org/10.1002/fee.1436.

Lades, L.K., Laffan, K., Daly, M., Delaney, L., 2020. Daily emotional well-being during the COVID-19 pandemic. Br. J. Health Psychol. 25, 902–911. https://doi.org/10.1111/bjhp.12450.

Larson, L.R., Cooper, C.B., Futch, S., Singh, D., Shipley, N.J., Dale, K., LeBaron, G.S., Takekawa, J.Y., 2020. The diverse motivations of citizen scientists: does conservation emphasis grow as volunteer participation progresses? Biol. Conserv. 242, 108428. https://doi.org/10.1016/j.biocon.2020.108428.

Le Quéré, C., Jackson, R.B., Jones, M.W., Smith, A.J.P., Abernethy, S., Andrew, R.M., De-Gol, A.J., Willis, D.R., Shan, Y., Canadell, J.G., Friedlingstein, P., Creutzig, F., Peters, G.P., 2020. Temporary reduction in daily global CO2 emissions during the COVID-19 forced confinement. Nat. Clim. Chang. 10, 647–653. https://doi.org/10.1038/s41558-020-0797-x.

Leong, M., Trautwein, M., 2019. A citizen science approach to evaluating US cities for biotic homogenization. PeerJ 7, e6879. https://doi.org/10.7717/peerj.6879.

Maund, P.R., Irvine, K.N., Lawson, B., Steadman, J., Risely, K., Cunningham, A.A., Davies, Z.G., 2020. What motivates the masses: understanding why people contribute to conservation citizen science projects. Biol. Conserv. 246, 108587. https://doi.org/10.1016/j.biocon.2020.108587.

McKinley, D.C., Miller-Rushing, A.J., Ballard, H.L., Bonney, R., Brown, H., Evans, D.M., French, R.A., Parrish, J.K., Phillips, T.B., Ryan, S.F., Shanley, L.A., Shirk, J.L., Stepenuck, K.F., Weltzin, J.F., Wiggins, A., Boyle, O.D., Briggs, R.D., Chapin, S.F., Hewitt, D.A., Preuss, P.W., Soukup, M.A., 2015. Investing in citizen science can improve natural resource management and environmental protection. Issues Ecol. 19, 1–27.

Muhammad, S., Long, X., Salman, M., 2020. COVID-19 pandemic and environmental pollution: a blessing in disguise? Sci. Total Environ. 728, 138820. https://doi.org/10.1016/j.scitotenv.2020.138820.

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., Crowston, K., 2012. The future of citizen science: emerging technologies and shifting paradigms. Front. Ecol. Environ. 10, 298–304. https://doi.org/10.1890/110294.

NHK, 2020. Crowding with People in Park in Tokyo Clarified by Analysis of Bigdata Within Declaration of State of Emergency [Freely Translated from Japanese]. NHK, URL. https://www3.nhk.or.jp/news/html/20200419/k10012395371000.html. accessed 9.12.20.

Pellissier, V., Schmucki, R., Pe'er, G., Aunins, A., Brereton, T.M., Brotons, L., Carnicer, J., Chodkiewicz, T., Chylarecki, P., del Moral, J.C., Escandell, V., Evans, D., Foppen, R., Harpke, A., Heliölä, J., Herrando, S., Kuussaari, M., Kühn, E., Lehikoinen, A., Lindström, Å., Moshøj, C.M., Musche, M., Noble, D., Oliver, T.H., Reif, J., Richard, D., Roy, D.B., Schweiger, O., Settele, J., Stefanescu, C., Teufelbauer, N., Touroult, J., Trautmann, S., Strien, A.J., Swaay, C.A.M., Turnhout, C., Vermouzek, Z., Voříšek, P., Jiguet, F., Julliard, R., 2020. Effects of Natura 2000 on nontarget bird and butterfly species based on citizen science data. Conserv. Biol. 34, 666–676. https://doi.org/10.1111/cobi.13434.

Ponciano, L., Brasileiro, F., 2014. Finding volunteers' engagement profiles in human computation for citizen science projects. Hum. Comput. 1, 245–264. https://doi.org/10.15346/hc.v1i2.12.

Robinson, L., Tweddle, J., Postles, M., West, S., Sewell, J., 2013. Guide to running a BioBlitz 2.0.

Roger, E., Klistorner, S., 2016. BioBlitzes help science communicators engage local communities in environmental research. J. Sci. Commun. 15 (03), A06. https://doi.org/10.22323/2.15030206.

Rose, S., Suri, J., Brooks, M., Ryan, P.G., 2020. COVID-19 and citizen science: lessons learned from southern Africa. Ostrich 91, 188–191. https://doi.org/10.2989/00306525.2020.1783589.

Rudd, H., Vala, J., Schaefer, V., 2002. Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green spaces. Restor. Ecol. 10, 368–375. https://doi.org/10.1046/j.1526-100X.2002.02041.x.

Sakurai, R., Kobori, H., Nakamura, M., Kikuchi, T., 2015. Factors influencing public participation in conservation activities in urban areas: a case study in Yokohama. Japan. Biol. Conserv. 184, 424–430. https://doi.org/10.1016/J.BIOCON.2015.02.012.

Slater, S.J., Christiana, R.W., Gustat, J., 2020. Recommendations for keeping parks and green space accessible for mental and physical health during COVID-19 and other pandemics. Prev. Chronic Dis. 17, E59 https://doi.org/10.5888/pcd17.200204.

Spear, D.M., Pauly, G.B., Kaiser, K., 2017. Citizen science as a tool for augmenting museum collection data from urban areas. Front. Ecol. Evol. 5, 86. https://doi.org/10.3389/fevo.2017.00086.

Takeuchi, K., Brown, R.D., Washitani, I., Tsunekawa, A., Yokohari, M., 2003. Satoyama: The Traditional Rural Landscape of Japan. Springer Japan, Tokyo.

Tashiro, A., Shaw, R., 2020. COVID-19 pandemic response in Japan: what is behind the initial flattening of the curve? Sustainability 12, 5250. https://doi.org/10.3390/su12135250.

Terry, C., Rothendler, M., Zipf, L., Dietze, M.C., Primack, R.B. Effects of the COVID-19 pandemic on noise pollutuin in three protected areas in metropolitan Boston (USA). Biol. Conserv. (this issue, under review).

The Yomiuri Shimbun, 2020. People's Concern About Congestion in Park During COVID-19 [Freely Translated From Japanese]. The Yomiuri Shimbun 27 (in Japanese).

World Health Organization, 2020. Strengthening Preparedness for COVID-19 in Cities and Urban Settings: Interim Guidance for Local Authorities. Geneva.