CITIZEN SCIENCE:
THEORY AND PRACTICE

Citizen Science and the Pandemic: A Case Study of the Christmas Bird Count

CASE STUDIES

CADE COLDREN

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ABSTRACT

Citizen science has contributed much to our knowledge of North American birds, with programs like Christmas Bird Count (CBC) providing valuable data on population dynamics, winter distribution, irruption patterns, range expansions, invasion dynamics, community ecology, and the effects of climate change. However, the novel coronavirus pandemic of 2020 had the potential to restrict participation and detrimentally impact the scientific value of 2020 count results. CBC data from throughout North America for 2020 were compared to trends from the previous ten years. Participation was reduced in several ways, including number of counts, number of participants, and spatial distribution of counts. However, based on a subset of states and provinces, number of species recorded was not impacted. Care should be taken when using 2020 CBC data for studies requiring fine-scale geographic resolution.

CORRESPONDING AUTHOR:

Cade Coldren

Dept. of Natural Resources Management, Texas Tech University, Lubbock, TX, US

cade.coldren@ttu.edu

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Citizen science has contributed much to our knowledge of North American birds through the years, including programs such as Christmas Bird Count (CBC), Breeding Bird Survey (Sauer et al. 2003), Project FeederWatch (Bonter and Greig 2021), and NestWatch (Phillips et al. 2021). All these programs have allowed a greater understanding of the status and long-term health of avian populations, and this knowledge can be important for informing decisions and strategies for management and conservation of populations.

The largest and longest running of these programs is CBC, run by the National Audubon Society (Bock and Root 1981). Run entirely by volunteers, participants count all birds seen or heard within the count circle (diameter of 24 km) on the count day in December or early January, so that the results are not just a species list, but also the numbers of each species seen that day. Participants are assigned specified routes within the count circle to reduce the possibility of birds being counted multiple times. The amount of time each participant commits to counting varies and can range from less than an hour up to the entire day. Inexperienced observers are often paired with more experienced ones. Feeder counts can even be included in count totals, if coordinated properly with count compilers. Thus, CBC counts lack the rigorous protocols used with some other citizen science projects, but they have nonetheless proven useful for large-scale studies of population dynamics (i.e., Hagan 1993), winter distribution (i.e., Lepthien and Bock 1976), irruption patterns (i.e., Yunick 1984), range expansion (i.e., Kricher 1981), invasion dynamics (i.e., Gammon and Maurer 2002), community ecology (i.e., Koenig 2003), and the effects of climate change (i.e., La Sorte and Thompson 2007).

With the arrival of the novel coronavirus pandemic in the spring of 2020, citizen science programs world-wide were impacted. Some programs saw increases in participation (Basile et al. 2021; Crimmins et al. 2021), while others saw decreases (Rose et al. 2020; Kishimoto and Kobori 2021), but participation changes depended on how the program was structured (Crimmins et al. 2021). These effects were seen globally (Rose et al. 2020; Crimmins et al. 2021; Dorler and Heigl 2021; Kishimoto and Kobori 2021; Sanchez-Clavijo et al. 2021; Stenhouse et al. 2022), but were most pronounced during the strictest lockdowns during the spring and early summer of 2020. Within the United States, restrictions varied by state (Drill et al. 2022), particularly by December, when CBC was scheduled. Take, for example, the differences between California and Alabama. Guidelines from the California Department of Public Health (2020) included a Limited Stay at Home Order (issued 21 November) requiring all non-essential activities in higher-risk counties to stop between 10 pm and 5 am, as well as instructing the public to stay at home except for essential needs and activities and to limit gatherings to those who live in your household. In contrast, the Alabama Public Health Department (2020) stated via a press release prior to the holiday season that the public should protect others by "staying at home as much as possible, wearing facial coverings as much as is practical, washing hands, avoiding large gatherings…". Thus, a range of guidelines and restrictions were in place at the time CBC data were collected, with differing potential to impact participation, depending on the location. The National Audubon Society recognized the risks to participants, as well as differing restrictions, and modified their guidelines in order for a count to be conducted (National Audubon Society 2020). A count was permitted if 1) local regulations allowed, 2) all in-person compilation gatherings were canceled, 3) it required the use of social distancing and/or masks at all times in the field, 4) carpooling was used only within existing familiar or social groups, and 5) all activities complied with current state and municipal guidelines. Regarding the integrity of the data, they felt "there will be little to no impact on the scientific value" of the data "by missing or altering one count season" (National Audubon Society 2020).

The primary objectives of this study were to investigate the potential impact of the pandemic on CBC participation and on the scientific value of the data collected in 2020. Questions addressed were as follows: Were the number of counts reduced in 2020? Were the number of participants reduced in 2020? Was the count effort impacted? Did the number of bird species recorded reflect changes in participation and effort compared with counts from previous years?

METHODS

To evaluate any potential impacts of the pandemic on participation in CBC, I obtained data from National Audubon Society's CBC website (National Audubon Society 2021) for count years 111–121 (corresponding to 2010 through 2020). The total number of counts was determined for each state in the United States and for each Canadian province, for each of the 11 count years. I selected a subset of states and provinces for detailed analyses since the total number of counts conducted in North America was sufficiently large that detailed analyses on all counts was deemed impractical. These states and provinces include Alabama, Alaska, California, Hawaii, Iowa, Maine, Maryland, Oklahoma, Quebec, Saskatchewan, and Wyoming (Figure 1), representing approximately 15% of Canadian provinces and 18% of US states. One state or province was chosen randomly within each major geographic region

Figure 1 Map of states and provinces used for detailed analyses of number of participants, effort, and number of species recorded.

of North America. This subset covers a range of legal restrictions due to the pandemic (Drill et al. 2022) and both rural areas and major population centers. For this subset, I collected data on the number of participants in each count, total effort for each count, and the number of species recorded per count. Effort was considered as the total number of hours committed, and as the number of hours per participant to help control for differences in number of observers by count. I did not consider evaluating the number of individual birds per count. Too many factors, such as weather and annual reproductive success, can influence the number of individual birds at a location in any given year, beyond the consideration of the number of people counting those birds.

Simple linear regression (JMP, Version 14.0.0, SAS Institute Inc., Cary, NC) was used to predict the expected value for 2020 for each of five metrics (number of counts, number of participants, total effort, effort per participant, and number of species recorded) based on trends from the previous 10 years. Predicted values were compared with actual values using one-tailed paired t-tests. Number of counts was tested for the US and Canada separately. Number of participants, effort, and number of species were tested separately for each of the states and provinces in the selected subset. To adjust for increased risk of Type I Errors, a Bonferroni Correction Factor was applied to this group of paired t-tests. For differences in spatial distribution, proximity analysis in ArcMap (ESRI, Inc., Redlands, CA, Version 10.5) was used to generate the distance between nearest counts for 2019 and 2020, for California and Saskatchewan. Student's t-test was used to test compare mean distance between years to evaluate whether a possible decline in the number of counts impacted the spatial distribution of those counts. Additionally, ArcMap was used to determine whether the spatial extent of counts in 2020 was restricted compared with 2019. For example, a restriction in coverage in the northerly direction was calculated as the latitude of the most northerly count in 2019 minus the latitude of the most northerly count in 2020. Similar restrictions in coverage were determined for the southern, eastern, and western cardinal directions.

RESULTS

NUMBER OF COUNTS

The number of counts conducted was less in 2020 than predicted for the United States (Predicted: 2028.87 ± 21.79; Actual: 1835; mean difference by state = –3.7093, $P < 0.0001$). Overall, this was a 9.6% decline. On a statewide basis, 42 states (84%) showed a decline (Table 1), with only seven (14%) increasing. In one state (Iowa), the actual number of counts matched the predicted value. Supplemental Table 1 shows the results for each state. The largest decline was seen in California, with a loss of 37.5 counts, followed by Wisconsin (15.3 counts), Oregon (14.7), and Minnesota (9.3). The declines in a majority of the states (73.8% of those declining) were outside the 95% confidence intervals (CI) of the predicted value. Of the states declining, 33.3% declined more than 10% (but less than 20%), while 16.7% declined by more than 20%. Conversely, only 7 states (14%) increased, with 57% of them outside the 95% CI. Only one state (New Hampshire) showed an increase of greater than 10%.

The Canadian provinces also showed a decline in number of counts (Predicted: 492.00 ± 23.89; Actual: 425; mean difference by state = –5.1538, $P = 0.0312$), representing a 13.6% decline. Ten provinces (76.9%) showed declines (Table 1). The majority of the declining provinces (70%) fell outside the 95% CI, with 60% showing declines of greater than 10% (but less than 20%), with 20% exhibiting declines of greater than 20%. Supplemental Table 2 shows the results for each province. The largest declines were seen in Saskatchewan and Ontario, with losses of 23.3 and 17.7 counts, respectively. Only three provinces had an increase in number of counts, and while all of them exceeded a 20% increase, two of the provinces (Northwest Territories and Nunavut) had so few counts overall that it inflated the percent of increase.

		UNITED STATES	CANADA
Declined	Total	42	10
	Outside 95% CI	31	7
	<10%	21	2
	10–20%	14	6
	>20%	7	2
Increased	Total	7	3
	Outside 95% CI	4	1
	<10%	6	0
	10–20%	0	0
	>20%	1	3
As predicted		1	0

Table 1 Number of states and provinces showing declines and increases in number of CBC counts in 2020 compared with that predicted based on trends of the previous 10 years. Results by state are in Supplemental Tables 1 and 2.

SPATIAL DISTRIBUTION

Figure 2 shows the spatial distribution of all counts in 2019 (prior to the pandemic) and in 2020 (during the pandemic) for Saskatchewan and California, two of the states and provinces with the greatest decline in number of counts for 2020. In Saskatchewan, the distribution of counts shows a much-reduced coverage in 2020 relative to 2019. While the mean distance between counts increased from 2019 to 2020 (Table 2), this increase was not significant ($t = 0.14$, $P = 0.89$). Instead, the impact was reflected in a restriction in area covered by the counts. The more sparsely populated northern portion remained uncovered but did exhibit a retraction of 54.887 km (with the northernmost count in 2020 being 54.887 km south of the northernmost count in 2019). The same type of retraction was seen in the other cardinal directions as well. In contrast, the spatial distribution for counts in California was not as strongly impacted, with the greatest effect seen in decreases in

		CALIFORNIA	SASKATCHEWAN
Mean distance between counts:	2019	32.697 km ± 1.2	47.799 km ± 4.5
(km ± SE)	2020	35.881 km ± 1.7	49.035 km ± 7.5
		($P = 0.13$)	($P = 0.89$)
Restriction in coverage:	North	0	54.887 km
	South	0	128.963 km
	East	34.950 km	105.431 km
	West	0	96.307 km

Table 2 Differences in spatial distribution of CBC counts in 2019 and 2020 for California and Saskatchewan, two regions exhibiting the greatest reduction in counts owing to the pandemic. Mean distance between counts was produced by proximity analysis in ArcMap. Restriction in coverage is the difference in spatial limit in 2019 compared with 2020 in each of the cardinal directions.

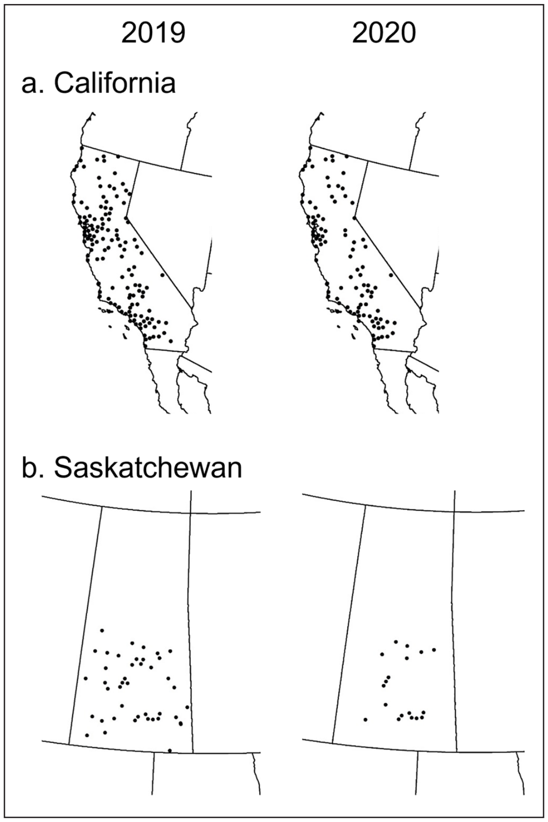

Figure 2 Spatial distribution of Christmas Bird Counts in California **(a)** and Saskatchewan **(b)** prior to the pandemic (2019) and during the pandemic (2020). Each circle represents one count.

counts in the area just east of San Francisco Bay. Statewide, the mean distance between counts increased in 2020; however, this difference was not significant ($t = 1.53$, $P = 0.13$). Regarding counts near the boundaries of the state, the only difference between 2019 and 2020 was a restriction of 34.950 km on the east, occurring in the southeastern part of the state.

NUMBER OF PARTICIPANTS

All states and provinces within the subset used for this metric showed a decline in the number of participants in 2020 compared with predictions based on trends of the previous 10 years (Table 3), with only one (California) being significant. With all counts included, Saskatchewan's decline was not significant. However, the number of participants in the Saskatoon count (SKSA) was substantially higher in 2020 (79 participants) than at any time in the previous 10 years (high of 61 participants). The reason behind this increase is not known to the author. Without SKSA, the decline in participants in Saskatchewan is closer to significant ($P < 0.05$). Thus, the pandemic appeared to have influenced the number of people willing or able to participate in a count in 2020.

EFFORT

Effort was considered as the total number of hours, by state or province, and as the effort per participant, in hours/participant. For total effort, most states and provinces in

STATE OR PROVINCE	PARTICIPANTS (NO. OF PEOPLE)	TOTAL EFFORT (HOUR)	EFFORT (HOUR/PERSON)	SPECIES RECORDED
Alabama	−0.846	3.323	0.193	2.037
Alaska	−1.296	−7.645	0.216	−0.453
California	−8.677***	6.912	0.716***	1.544
Hawaii	−3.457	−0.440	0.295	1.642
Iowa	−2.622*	11.617**	1.183***	2.574**
Maine	−0.381	13.161***	0.919**	2.773*
Maryland	−1.264	21.775**	0.858***	6.432***
Oklahoma	−1.983	11.335	1.020**	7.472**
Wyoming	−3.026*	−3.796	0.269	0.188
Quebec	−0.986	10.882*	0.492	4.280***
Saskatchewan	−0.641	6.967	0.165	−0.225
w/o SKSA	−3.157*	−0.990	0.156	−0.343

Table 3 Mean difference between actual values of numbers of participants and effort in Christmas Bird Count for 2020 and values predicted based on linear regression for the previous 10 years, for a subset of states and provinces. Negative numbers represent a decrease in 2020 relative to the expected values based on linear regression. With a Bonferroni Correction Factor applied, P-values < 0.001 are considered significant; other levels are shown for reference.

SKSA: Saskatoon count.

* P < 0.05; ** P < 0.01; *** P < 0.001.

the subset showed an increase in effort (Table 3), despite a decline in the number of participants. Only three (Alaska, Hawaii, and Wyoming) showed a decline in total effort, and none were statistically significant. Effort, as hours per participant, ranged from a mean of 1.606 in Hawaii to 3.962 in Iowa. It increased in every state and province in the subset analyzed, with three (California, Iowa, and Maryland) showing significant increases, and two others (Maine and Oklahoma) with marginally significant increases.

NUMBER OF SPECIES RECORDED

Most states and provinces in the subset showed an increase in the number of species recorded in 2020 relative to the previous 10 years (Table 3). Only two (Alaska and Saskatchewan) decreased, and each was nonsignificant. Of the nine that increased, two were significant (Maryland and Quebec), with three others (Oklahoma, Iowa, and Maine) showing strong, but nonsignificant, increases.

DISCUSSION

The pandemic did indeed appear to impact participation in CBC in 2020, both in the United States and in Canada, as seen in other parts of the world for other citizen science programs (Rose et al. 2020; Dorler and Heigl 2021; Kishimoto and Kobori 2021; Sanchez-Clavijo et al. 2021; Stenhouse et al. 2022). Significantly fewer counts were conducted in 2020 compared with the totals that would be expected based on trends of the previous 10 years. In a subsample of states and provinces, fewer individuals participated in 2020 compared with expected totals from the previous 10 years. However, the total effort measured as total number of hours by all participants and the amount of time contributed per participant increased. The motivation behind these increases in effort is not known, although several possibilities seem reasonable. The participants might have desired to compensate for the reduced number of participants in order to match previous years' totals, or to help preserve the scientific validity of the results. Alternatively, the participants might have been responding to the opportunity for more time watching birds outside the constraints of lockdowns and quarantine, as suggested by Rose et al. (2020) for projects in South Africa. These explanations are not mutually exclusive, and I suspect these, and potentially others, played a role in the observed increase in effort.

Regarding the validity of the data collected from 2020 counts, it appears that it was maintained in some ways, but not in others. The number of species recorded did not appear to be impacted, at least in the subset of states and provinces in which this metric was analyzed. This contrasts with the results of Sanchez-Clavijo et al. (2021) who found that fewer species were recorded by observers in Columbia, although their study used data from the strictest lockdown period. A reduction in species recorded would have had the potential to impact a variety of research studies, including range expansion, winter distribution, and irruption patterns, for example, if the species of interest was missed in a sufficient number of counts. That does not appear to be the case, based only on the number of species recorded. However, the utility of the 2020 data may have been negatively impacted for studies on the spatial distribution of species, although not for all states and provinces. California, for example, showed a reasonable coverage of the state, with the exception being in the extreme southeast corner, based on the lack of difference in mean distance between counts and only a retraction in the southeast corner, as seen in Table 2. Saskatchewan, on the other hand, showed a retraction in extent in all the cardinal directions. Thus, a study evaluating irruption patterns of a species may not be impacted by the reduction of counts in California, but the retraction in coverage area within Saskatchewan in 2020 leaves large areas with no data relative to 2019. Thus, care should be exercised on a state-by-state (or province-by-province) basis for future studies of winter distribution, irruption patterns, or range extensions, for example, in states or provinces where the geographic spread of counts in 2020 was significantly lower than in previous years.

Other aspects of a research project will also govern the utility of the spatial distribution data from 2020. The primary example is spatial scale, specifically the need for fine-scale geographic resolution. For example, the study by Yunick (1984) on the irruption patterns of Boreal Chickadees (*Poecile hudsonicus*) would have been impacted owing to a reduction in the number of counts, and thus the potential to undercount chickadees, and concurrently by the potential for retraction of coverage area, leaving parts of their possible irruption distribution uncounted. Conversely, the winter distributions of Golden-crowned Kinglets (*Regulus satrapa*) and Ruby-crowned Kinglets (*Corthylio calendula*) (Lepthien and Bock 1976) were studied at a spatial scale too coarse to have been affected by the observed reductions in counts owing to the pandemic.

Human behavior regarding the outdoors was altered during the pandemic, and is reflected in citizen science program participation, as well as the behavior of some wildlife species (Hentati-Sundberg et al. 2021; LeTourneux et al. 2021), all of which should be taken into consideration when using 2020 data from these programs. Participation increased in some programs, like eBird and iNaturalist (Basile et al. 2021; Crimmins et al. 2021), but declined in others (Rose et al. 2020; Kishimoto and Kobori 2021), including CBC as documented in this study. In general, there appeared to be an increased desire for more interactions with the outdoors (Gundelund and Skov 2021; Rose et al. 2020), which may explain the increases in effort seen in this study. However, restrictions from the pandemic appear to have restricted outdoor activities, resulting in more localized observations for citizen science programs. Several studies documented increases in urban wildlife observations but declines in more natural areas (Randler et al. 2020; Rose et al. 2020; Basile et al. 2021; Crimmins et al. 2021; Kishimoto and Kobori 2021; Sanchez-Clavijo et al. 2021; Drill 2022; Stenhouse et al. 2022). Overall, these changes in citizen science programs, both in terms of participation and results, suggest that care must be taken when using and interpreting the 2020 data. Other studies have reached a similar conclusion (Randler et al. 2020; Rose et al. 2020; Basile et al. 2021; Crimmins et al. 2021; Gillings et al. 2021; Hochachka et al. 2021). For avian studies, both Crimmins et al. (2021) and Hochachka et al. (2021) used eBird data and observed differences geographically, leading them to conclude that care must be taken when using these data. Rose et al. (2020) on the Southern African Bird Atlas Project, and Gillings et al. (2021) on the UK Breeding Bird Survey, found reductions in area surveyed during lockdowns. While these studies focused on breeding birds, and the CBC results reported here were on wintering birds, a common issue with the 2020 data are differences in geographic scope. Specifically for the CBC results shown here, care must be taken when research requires fine-scale geographic resolution for studies such as those investigating winter distributions, irruption patterns, and range expansions.

SUPPLEMENTARY FILES

The supplementary files for this article can be found as follows:

- **Supplemental Table 1.** CBC number of counts for the United States. DOI: https://doi.org/10.5334/cstp.473.s1
- **Supplemental Table 2.** CBC number of counts for Canada. DOI: https://doi.org/10.5334/cstp.473.s2

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COMPETING INTERESTS

The author has no competing interests to declare.

AUTHOR AFFILIATION

Cade Coldren orcid.org/0000-0002-3955-2190
Dept. of Natural Resources Management, Texas Tech University, Lubbock, TX, US

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