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Differential reporting of biodiversity in two citizen science platforms during COVID-19 lockdown in Colombia

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A B S T R A C T

The COVID-19 pandemic highlighted the potential of using data from long-term citizen science projects to answer questions about the impacts of unexpected events on biodiversity. We evaluate the suitability of data from the citizen science platforms iNaturalist and eBird to describe the effects of the "anthropause" on biodiversity observation in Colombia. We compared record distribution according to human footprint, sampling behaviors, overall and conservation priority species composition during the strictest phase of the COVID-19 lockdown in 2020 to the same periods in 2015–2019. Overall participation in both platforms during the lockdown was high when compared to previous years, but records were concentrated on highly-transformed regions, had lower sampling efforts, and fewer species were recorded. For eBird, species composition was similar to that observed in previous years, and records of species of conservation concern declined in proportion to the decrease in overall species richness across samples. For iNaturalist, the species pool sampled each year remained too dissimilar for comparisons. Once differences in observer behaviors are accounted for, data from these platforms can be used in unplanned comparisons of relatively common species, in regions with high levels of human transformation, and at narrowly defined geographical contexts. To increase the potential of citizen science to monitor rarer species, more natural areas, or be used in large-scale analyses, we need to build and strengthen more diverse networks of observers that can further promote decentralization, democratization, and cost-effectiveness in biodiversity research.

1. Introduction

Citizen science platforms are recognized for producing large quantities of data covering broader spatial and temporal extents than projects where data collection is restricted to experts (Callaghan et al., 2020). Therefore, citizen science data has immense potential to answer ecological questions and support decision-making (Kelling et al., 2019; MacPhail and Colla, 2020; Pocock et al., 2017). This role was highlighted during the "anthropause" brought about by lockdowns designed to contain the COVID-19 pandemic around the world in the first semester of 2020 (other manuscripts in this special issue). Before we can use this data to test hypotheses about the impact of human activities on our environment (Bates et al., 2020; Diffenbaugh et al., 2020; Rutz et al., 2020), we must account for lockdown effects on reporting behavior, and include them in analyses aiming to detect ecological effects of the pandemic on species occurrence.

Ecological studies designed to compare the state of biodiversity before and after events hypothesized to affect its attributes, must standardize sampling for both periods. Only then may differences in results be attributable to the event of interest (Smokorowski and Randall, 2017). When the COVID-19 pandemic started, researchers responded by designing studies to characterize biodiversity responses to changes in human behavior during and after the lockdown (Bates et al., 2020), but were challenged with obtaining comparable data from before. While data from long-term monitoring programs are ideally suited to quantify the effects of unexpected events on biodiversity (Lindenmayer and Likens, 2018), such programs are still very limited in terms of their spatial, ecological and taxonomic scopes, particularly in megadiverse

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low and middle income countries (Donald et al., 2021).

Observations from citizen science projects emerge as an alternative source of data for unplanned comparisons and trend calculation. However, these projects have a wide range of objectives, levels of participation, data types, and structures (Pocock et al., 2017). As people contribute their observations voluntarily, there is usually a lot of flexibility in data collection even within a particular platform, leading to high heterogeneity in recording behaviors. Depending on the type of inference we want to make based on the data, differences in the observation process may have strong effects that could lead to misleading conclusions if not properly accounted for (Burgess et al., 2017; Kelling et al., 2019).

To evaluate the potential and limitations of using citizen science data to answer questions about the effects of the "anthropause" on biodiversity in Colombia, we selected two popular citizen science platforms: iNaturalist and eBird. We analyzed how records changed during the strictest phase of the COVID-19 lockdown measures in 2020 when compared to the same time periods from 2015 to 2019. We focused our analyses on three key aspects of the data at a national level: where species were reported, what sampling behaviors were used to report it, and which species were reported.

Record distribution according to human footprint – in order to make large scale comparisons of species occurrence before and during the lockdown, sampling effort needs to be similarly distributed according to heterogeneity in human transformation, but citizen science data tends to be spatially aggregated around human settlements and roads (Johnston et al., 2020). Human Footprint Indices measure the impact that anthropogenic activities have on ecosystems (McGowan, 2016), so we evaluated how the distribution of citizen science records changed in relation to human footprint during the 2020 lockdown and in previous years. We expected the lockdown to restrict citizen scientists to more urban (high footprint) than natural (low footprint) areas. Under this condition, data collected in 2020 would be a sample of a different species pool than data collected in the previous years.

Sampling behaviors – citizen science has a lot of variation in terms of how much effort each participant invests in collecting and/or curating records, but larger cumulative efforts in a project will increase the chances of detecting rare species and of having representative community sampling. Even though lockdown conditions restricted the time that citizen scientists could spend outside, biodiversity got a lot of public attention during the beginning of the pandemic (Corlett et al., 2020; Gardner, 2020; Semana Sostenible, 2020). We evaluated how six behavior metrics that characterized levels and forms of participation changed between lockdown activities in 2020 and previous years. We predicted that overall participation in 2020 could be similar to previous years, but that metrics describing sampling behaviors would show variations that would need to be considered when performing analysis that require equivalent sampling conditions.

Recorded species – we asked how overall and conservation priority species composition changed between lockdown activities in 2020 and previous years. If overall samples at the national level showed low levels of similarity between years before the pandemic (2015–2019), this would be an indicator that variations in 2020 could more likely be the result of differences in the observation process than effects of the COVID-19 lockdown. On the other hand, if samples showed high levels of similarity before 2020, then it would be easier to attribute differences in the last year to the pandemic. Threatened and endemic species are usually harder to detect and located in more natural areas. If both our previous hypotheses were true, we expected to find decreases in the reports of conservation priority species that were attributable to changes in the observation process, rather than to impacts of the pandemic on species occurrence.

2. Materials and methods

2.1. Citizen science platforms: iNaturalist and eBird

iNaturalist is a joint initiative by the California Academy of Sciences and the National Geographic Society that connects users to a community of scientists and naturalists, helping them to document and identify biodiversity (Nugent, 2018). Projects created through iNaturalist are unstructured, which makes them more appealing to general audiences, but limits the type of analyses that can be performed with the collected data (Kelling et al., 2019). Any person that appreciates nature can use iNaturalist to upload their biodiversity records, even without previous knowledge about specific taxonomic groups. Voluntary species identification is carried out anywhere in the world by people with experience in the recognition of the taxon in question, but there are no required qualifications to determine who can curate data (iNaturalist, 2020).

eBird is a collaborative effort managed by the Cornell Lab of Ornithology that allows birdwatchers to gather and share information in the form of checklists while amassing a database on bird distribution, abundance, and habitat use (Sullivan et al., 2009). Using eBird requires previous knowledge of bird species so it is aimed at a narrower audience, and because it is a semi-structured citizen science project, it allows outputs to be corrected by measures of observer effort, providing datasets suited for a wider range of analyses (Kelling et al., 2019). Data quality is controlled in two stages; records first go through an automatic filter that is built according to accepted species distributions, and suspected errors are then reviewed by a team of national experts (The Cornell Lab, 2020).

2.2. Datasets used in this study

During the first iteration of the COVID-19 response mandate, Colombia went into a strict lockdown from March 24th to May 11th of 2020. International borders were closed, domestic travel was cancelled, and circulation of people and vehicles was completely restricted except in cases related to health services, food supply, and other essential services (MinInterior, 2020).

iNaturalist data recorded during the COVID-19 lockdown came from "*Naturalistas urbanos desde casa*" (NUC), a bio-blitz project that was created and advertised nationwide from March 25th to April 25th. This initiative challenged people to record the greatest amount of biodiversity around their homes during the lockdown. After the project closed, we eliminated observations of domestic and captive species, and downloaded all verifiable observations (those that have at least one photograph or audio record). To get comparable data from previous years, we used the same criteria to download observations for Colombia that were collected during the same one-month period from 2015 to 2019. These data include records spontaneously uploaded by users, records in user-created projects, and a large-scale urban bio-blitz that was organized in Bucaramanga from March 29th to April 1st of 2019 (dataset available upon request).

To compare patterns for eBird data we focused on results from the Global Big Day (GBD), an annual event that invites birdwatchers around the world to use eBird to report as many species and checklists as possible during 24 h (eBird, 2020a). Its popularity in Colombia has grown massively since 2015, and for the last four years, the country has occupied first place in number of species, and third in submitted checklists (eBird, 2020b). GBD always takes place on a Saturday in early May, and in 2020 it coincided with the strictest lockdown phase in Colombia, leading all involved organizations to promote birding from home during the event (Sierra, 2020).

GBD offered the unique opportunity to have a controlled pre and during lockdown dataset collected yearly with the common goal of registering all bird species in the country. It has been heavily advertised since 2017, leading to levels of participation that exceed any other citizen science event in Colombia. This surge in participation leads to yearly peaks for eBird submissions in terms of number of checklists, records, birders, site and species coverage (Fig. S1), promotion of best practices and reviewer efforts to curate the dataset. Even though using datasets for a longer period would have made results less likely to be affected by anomalies that occurred during GBDs, we expected changes in observer behavior to be more obvious during this day than they would be during all other days of the lockdown period. Data was obtained directly from eBird representatives after each event and includes only records that passed the two-stage review process (dataset available upon request).

Downloaded content from the two platforms was very different. The most noticeable differences were taxonomic scope (all possible taxa for iNaturalist vs. only birds for eBird), length of study period (one month vs. one day), and above-mentioned differences in data quality processes. iNaturalist records constitute single biodiversity observations without associated sampling effort, but require photographs or sound recordings to be verified. eBird records are arranged in species checklists that almost always have associated effort information, but do not require evidence to back up each sighting. Therefore, we do not compare patterns between the platforms, but rather focus on the opportunities and challenges each dataset has in our context of interest.

2.3. Record distribution according to human footprint

Individual observations on iNaturalist and checklists on eBird are georeferenced. To quantify the degree of disturbance associated with each observation or list, we mapped these points and extracted their corresponding value (an integer between 0 and 100) from a 300 m resolution Legacy-adjusted Human Footprint Index (LHFI) layer using ArcGIS Pro (ESRI, 2020). This LHFI layer is specific to Colombia and is the result of combining land-use type, rural population density, distance to roads, distance to settlements, fragmentation index of natural vegetation, biomass index relative to natural potential, and time of intervention on ecosystems (Correa Ayram et al., 2020). For points in 2015, we used the LHFI layer published for that year (Correa Ayram et al., 2020), whereas for 2016 to 2020 we used an unpublished layer updated for 2018 that was provided by the authors (Correa Ayram and Diaz-Timoté, n.d.). We used year as a categorical predictor variable, and logistic regressions to compare the proportion of records that came from dense human settlements (LFHI equal to or greater than 90 – Fig. S2) from 2015 to 2020. We used 2020 as the intercept in our models so that *p*-values associated with regression coefficients of all previous years became a test of whether pre-lockdown years had values that were statistically different from the values during the lockdown. Afterward, we compared the distribution of records with LHFI values less than 90 in 2019 vs. 2020 by performing a negative binomial regression on the counts of each LHFI value (after checking Poisson models for overdispersion). All analyses were conducted using R (R Core Team, 2013).

2.4. Sampling behaviors

Due to the inherent differences in the way data were collected, we used different response metrics to compare the levels and types of participation for both platforms. All comparisons were done via logistic regressions that used year as a categorical predictor variable, and 2020 as the intercept to highlight differences between the lockdown and previous years.

2.4.1. Observer effort (iNaturalist)

Because most users submitted between zero and five observations (Fig. S3), we used the proportion of observers that submitted more than five observations as a measure of the proportion of participants that attempted to characterize biodiversity around them.

2.4.2. Curator effort (iNaturalist)

We used the proportion of records that obtained research grade (confirmed identification by three curators) to characterize the effort that volunteers invested in identifying species submitted by observers, as this was a way of participating in the initiative without leaving the house.

2.4.3. Distance effort (eBird)

After applying a cutoff point of 10 km to the data, we used the proportion of checklists with distance equal to or less than 1 km (Fig. S3) to characterize effort. Because people can submit many checklists during GBD, this metric was not used to characterize individual effort, but rather how much observers were moving to build their lists. Additionally, we explored *duration effort* (with a 6-hour cutoff point and splitting lists done with efforts over 1 h – Fig. S4) and *group size* (splitting lists done by more than one observer – Fig. S4) to corroborate distance patterns.

2.4.4. Sampling protocol (eBird)

We compared the proportion of checklists that used stationary vs. traveling counts, which are the two most popular protocols used in eBird, as a way of seeing if sampling behavior varied due to movement restrictions during the lockdown.

2.5. Recorded species

To compare overall species composition among samples for each year we carried out a similarity analysis using Jaccard's index (Jaccard, 1901). We narrowed iNaturalist data to research grade observations of insects, plants, and vertebrates. We classified species from both datasets in accordance with their extinction threat category and restrictions in distribution, as a proxy for rarity and sensitivity to human intervention. Threatened species included critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) species; non-threatened included species classified as least concern (LC) or data deficient (DD); and endemic included all species whose geographical distribution is restricted to Colombia. Threat categories corresponded to global IUCN Red List categories (IUCN, 2020), while endemics were taken from recognized lists for each taxonomic group as follows: birds (Avendaño et al., 2017), mammals (Sociedad Colombiana de Mastozoología, 2017), amphibians (AmphibiaWeb, 2020), reptiles (Uetz et al., 2020), fish (DoNascimiento et al., 2018) and plants (Bernal et al., 2019). Despite insects being one of the most recorded groups in iNaturalist, Colombia does not have official sources of information about their level of threat or endemism, therefore this group was not sorted into categories.

We ran an analysis of deviance comparing log-linear models of the additive and interactive effects of the number of threatened/non-threatened and endemic/non-endemic species vs. year. We assumed that lack of independence between species group and year for 2020 would show if the lockdown had a disproportionate effect on the reporting of species of conservation priority. We decided against using species richness as a national-scale response because in a megadiverse and highly heterogeneous country like Colombia, there could be too many factors other than observer effort influencing this variable at a given time. Therefore, we include the raw numbers of individuals and species recorded by year and platform in our results only to highlight the potential that these tools have to detect a large number of species, but did not carry out statistically rigorous comparisons of richness among years.

3. Results

There was substantial participation in both platforms during the lockdown. NUC had 1146 participants who contributed 8734 observations in a month, while GBD had 2754 birders that contributed 7699 checklists in a day. When compared to the same periods of time in 2019, this meant a decrease in participation for iNaturalist (2372 participants, 20,674 observations) and a slight increase for eBird (2313 birders, 7173 checklists) (Fig. 1).

3.1. Record distribution according to human footprint

Visual comparisons of the spatial distribution of the data between 2019 and 2020 showed the latter as having more observations concentrated in areas of high LHFI values (urban and easily accessible), and fewer observations from areas with low LHFI values, such as those in eastern Colombia (Fig. S5). Underlying these patterns was a trend of a steady increase in the use of both platforms during the six-year period considered (with an exception of an especially high number of observations in 2019 for iNaturalist - Fig. 1), as well as a higher bias towards cities in iNaturalist than GBD datasets (Fig. S2). The proportion of records from highly transformed areas in the iNaturalist dataset was significantly higher in 2020 than in 2015–2018 but significantly lower than in 2019, although numerical differences in model coefficients were small (regression coefficients ± SE and *p*-values; 2020: −0.46±0.02, $p <$ 2E-16 vs. 2019: 0.09±0.03, $p = 0.0007$; Fig. 2, Table S1). Differences between 2020 and all previous years were larger for the eBird dataset (2020: -0.58±0.03, p < 2E-16 vs. 2019: -1.64±0.07, p < 2E-16), showing a clearer change in record distribution during the lockdown (Fig. 2, Table S1). In both cases, the subsequent regression of year vs. the count of points in each LHFI value below 90 (natural and rural settings) showed that observations from 2020 came from points with higher levels of human transformation (iNat: 0.02±0.005, $p = 0.0005$; GBD: 0.19±0.017, $p <$ 2E-16; Table S2).

3.2. Sampling behaviors

Observer effort for iNaturalist showed a generally increasing trend in its first five years but was significantly lower in 2020 than in 2019 (2020: −1.37±0.07, p < 2E-16 vs. 2019: 0.75±0.09, p < 2E-16), showing that on average fewer participants recorded more than five biodiversity observations during the lockdown (Fig. 2, Table S3). In terms of curator effort, from 2015 to 2017 records that reached research grade represented over half the data, but as platform use grew this proportion fell. However, this variable was significantly higher in 2020 than 2019 (2020: −0.22±0.02, p < 2E-16 vs. 2019: −0.48±0.03, p < 2E-16; Fig. 2, Table S3). A higher proportion of eBird checklists were done with distance efforts equal to or less than 1 km in 2020 than during all previous GBDs (2020: 0.26±0.04, $p =$ 6E-11 vs. 2019: −0.72±0.05, p < 2E-16; Fig. 2, Table S3), and the same was true for lists equal to or shorter than an hour, and those done by a single observer (Fig. S6, Table S3). From 2015 to 2019 traveling counts were more popular than stationary counts, but birdwatchers in 2020 significantly shifted their sampling strategy (2020: −0.16±0.03, $p =$ 8E-11 vs. 2019: 1.68±0.05, p < 2E-16; Fig. 2; Table S3).

3.3. Recorded species

The number of species recorded during the lockdown was lower than for the previous year. Citizen scientists contributed records of 1292 species during NUC (34% fewer than were recorded in iNaturalist for the same period in 2019, but 11% more than in 2018) and 1435 bird species during 2020s GBD (9% fewer than in 2019) (Table S4). Although we suspect that these patterns could be explained by the above-mentioned differences in sampling sites and effort, we did not correct raw numbers by observer effort because it could not be done in a standardized way for data coming from both platforms. The eBird dataset showed an increase in similarity values with time that was expected given increases in sample size and GBD's goal of registering as many bird species as possible. Sample composition during the lockdown was not very different to that of the two previous years. The case was different for iNaturalist, where similarity values were lower and did not show convergence in later years despite increases in sample size (Fig. 3).

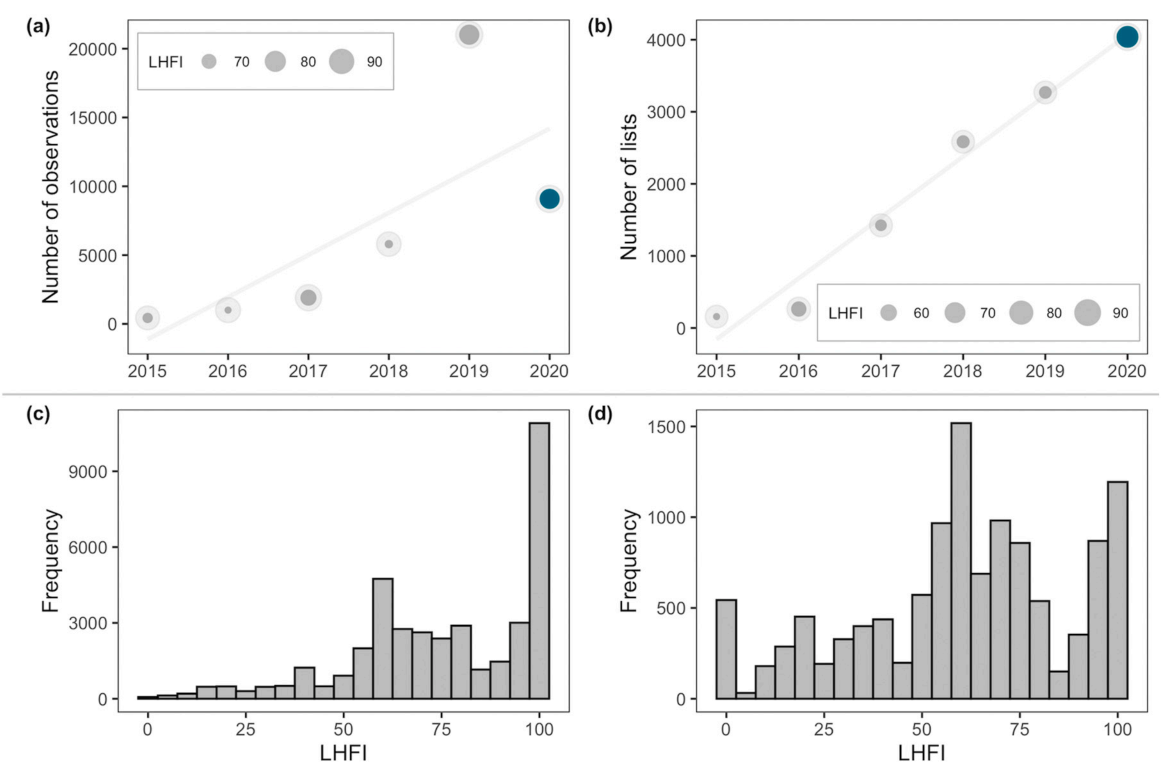

Fig. 1. Growth in use of citizen science platforms in Colombia from 2015 to 2020: a) March 25th-April 25th for iNaturalist, b) Global Big Days for eBird; turquoise dots highlight data collected during the lockdown. Distribution of citizen science observations during our study periods according to Legacy-adjusted Human Footprint Index (LHFI): c) iNaturalist records, d) eBird checklists. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

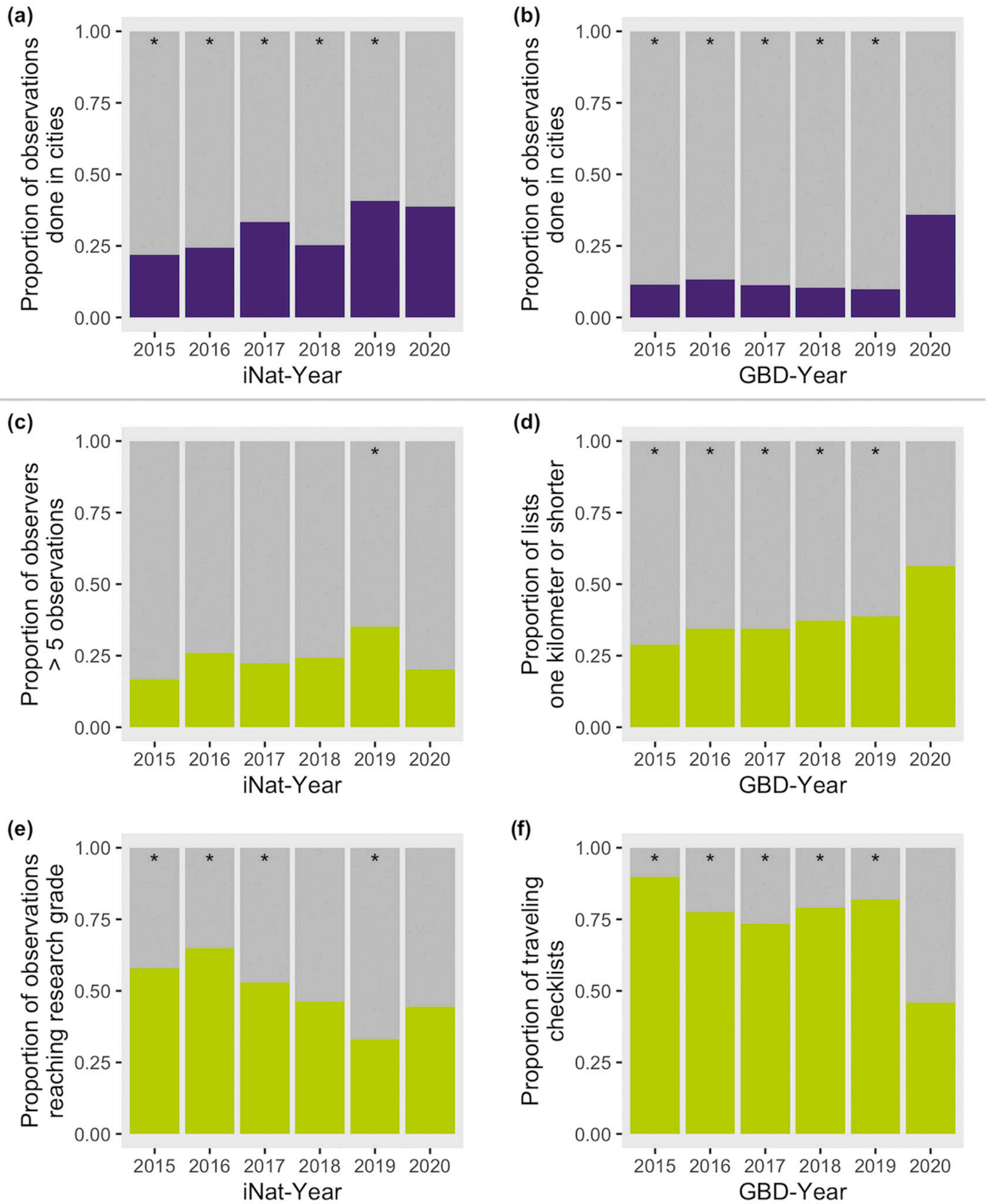

Fig. 2. a) Proportion of observations done at sites with LHFI values equal to or higher than 90 from March 25th - April 25th of 2015–2020 for iNaturalist; b) proportion of observations done at sites with LHFI values equal to or higher than 90 during Global Big Days of 2015–2020 for eBird; c) observer effort for iNaturalist; d) curator effort for iNaturalist; e) distance effort for eBird; f) sampling protocol for eBird; *indicate statistically significant differences between 2020 and pre-lockdown years.

There was a decrease in the number of threatened and endemic species reported between 2019 and 2020. For iNaturalist, threatened species went from 112 to 27, and endemic species from 257 to 109; for eBird, threatened species went from 154 to 129, and endemics from 56 to 47 (Fig. S7; Table S4). We found that threat status and endemism were statistically independent of year for eBird data (Threat*Year deviance: 7.68, $p = 0.18$; Endemism*Year deviance: 1.67, $p = 0.89$), but not for iNaturalist data (Threat*Year deviance: 34.14, $p =$ 2E-6; Endemism*-Year deviance: 39.86, p = 2E-7; Table S5). A closer look at the contingency tables for iNaturalist showed lower than expected threatened species recorded in 2020 and higher than expected endemic species recorded in 2019 (Fig. S8).

4. Discussion

During the strictest phase of the COVID-19 lockdown in Colombia, biodiversity records from citizen science platforms were concentrated in highly-transformed regions and were detected with lower sampling efforts. This may have resulted in fewer species being recorded, despite overall high participation that kept sample sizes similar to those obtained in previous years. Changes in species composition between 2019 and 2020 are consistent with longer-term trends from 2015 to 2019, and the detection of species of conservation concern did not decrease significantly when compared to overall richness.

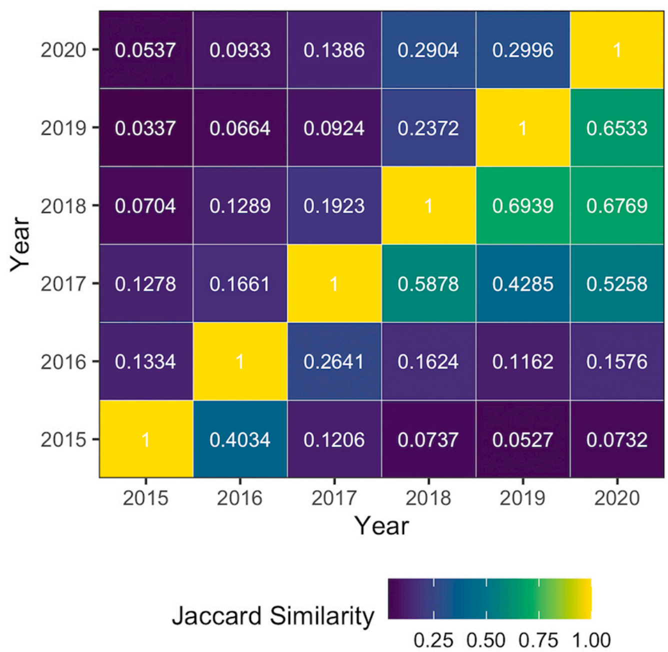

Fig. 3. Jaccard similarity values between samples from 2015 to 2020 for species reported in iNaturalist during March 25th-April 25th (upper diagonal) and in eBird during Global Big Days (lower diagonal).

4.1. Record distribution according to the human footprint

Biodiversity records during the lockdown were concentrated in regions with predominantly high human footprint values (mean > 75). For iNaturalist, this did not represent a huge shift, since data from previous years already came mainly from localities with LHFI values between 50 and 100 (Fig. S2). Higher use of iNaturalist in 2019 for urban areas was probably due to urban bio-blitz "*Naturalista Urbano Bucaramanga*". We expected NUC to raise nationwide observations to levels similar to this event, yet during the lockdown observations were fewer than expected from the background growth rate seen from 2015 to 2018. In contrast, from 2015 to 2019 the majority of GBD checklists consistently came from localities with LHFI values from 25 to 75. Even though some remote places were still sampled in 2020, we evidenced a strong shift towards birding in urbanized areas in response to the lockdown (Figs. 1 & 2), which coincides with the general pattern found for eBird data during April for other regions of the world (Hochachka et al., 2021).

This pattern suggests that both datasets are more likely to be useful for answering questions about the impacts of the "anthropause" in the urban and semi-urban contexts where we would expect to see the greatest effects of the changes in human behavior on biodiversity (Rastandeh and Jarchow, 2020; Rutz et al., 2020; Vardi et al., 2021); however, similar comparisons in more natural settings are less likely to detect biologically real patterns.

4.2. Sampling behaviors

Observer effort by participants in citizen science events that took place during the 2020 lockdown was generally lower than in previous years (Figs. 2 & S6). While this does not pose problems for using the data, it warrants care differentiating between effects of changes in human and animal behavior when reviewing 2020 wildlife sightings (Vardi et al., 2021). The eBird team encourages users to make shorter checklists to be able to use data in analyses that require high spatial resolutions (The Cornell Lab, 2020). However, we cannot determine if the observed patterns were a result of lockdown restrictions, of people implementing best practices, or a response to the event challenge being switched from recording the highest possible number of species to submitting the highest number of checklists. The shift from traveling to stationary counts indicates that many birdwatchers probably opted to follow the recommendation to make their checklists from home, reducing the spatial scope of the data for 2020 when compared to previous years. Therefore, some comparisons of GBD data before, during, and possibly after the lockdown will not be possible unless restricted to spatial units that were sampled similarly across years. Evidence from the U.S. and Europe also supports the idea that regional changes in observer effort must be considered when trying to extract biological insights from eBird data submitted during the COVID-19 pandemic (Hochachka et al., 2021).

Making use of ancillary data on sampling effort is fundamental to use citizen science records in evaluating changes in biodiversity trajectories through time (Johnston et al., 2020). Although the number of observations per observer can give an indication of the individual effort that iNaturalist users invested in documenting biodiversity (Milanesi et al., 2020), it did not allow us to make any inferences about the completeness or representativeness of the dataset. Despite data showing some observers carrying out impressive individual efforts during NUC (Fig. S3), our results show that most users probably documented what they considered unusual. Limited mobility meant they did not have access to places that would allow documentation of more species, therefore limiting most community-level analyses for this dataset. Changes in curator effort support the idea that the lockdown provided an opportunity for taxonomic experts to increase their participation in this platform. Still, it should be noted that we do not have information on the location of curators, and that their ability to identify species depends on the quality of evidence uploaded by users.

4.3. Recorded species

At the scale of our analyses, it is not possible to know whether changes in the raw number of species were due to changes in sampled locations and behaviors, or whether they represent biologically real effects of the lockdown on biodiversity. Despite having less variation in the types of communities sampled (those from highly-transformed habitats), because iNaturalist is not taxonomically restricted and data was not collected with a common goal during the study period, we found similarity values between years that were always below 0.3 (Fig. 3). This shows that a very different species pool is being sampled each year, severely limiting inferences that can be made about the effects of the lockdown on biodiversity at large scales. The case may be different if data are restricted to widespread taxa within particularly well-sampled cities (Callaghan et al., 2020; Vardi et al., 2021), but would have to be evaluated beforehand.

To understand variation in GBD results, it is important to note that since 2017 a grassroots initiative has encouraged Colombians to "win" this event by organizing people around the country to record the highest possible number of species. During 2017–2019 bird experts traveled from cities to remote locations to assist local efforts and target species of interest. Since national travel was banned during 2020, many bird observers expected the total species list to decrease to levels recorded before the group got organized. The smaller than expected difference between 2019 and 2020 shows the GBD initiative has been successful in its efforts to strengthen local birding capacities, and that the enthusiasm this event has awakened in Colombians carried through to 2020 despite the lockdown (Table S4). Similarity values above 0.6 for all comparisons between 2018, 2019 and 2020 suggest that because large sample sizes were maintained during the lockdown, differences discussed in the two previous sections did not have a strong impact on species recorded at large scales (Leong and Trautwein, 2019).

We were not surprised to find fewer threatened and endemic species in samples from 2020 when compared to previous years (Fig. S7). These species have generally lower detectability and reduced geographic ranges, so this result is coherent with reduced spatial extensions and lower observation efforts documented during the lockdown. For example, all endemic birds detected during GBD in 2019 but not in 2020 can only be found in hard to access localities in the Sierra Nevada de Santa Marta (*Anthocephala floriceps*, *Oxypogon cyanolaemus*, *Ramphomicron dorsale*, *Pyrrhura viridicata*, *Myiotheretes pernix*, and *Troglodytes monticola*), Magdalena Valley (*Phylloscartes lanyoni*), northwestern Pacific coast (*Bucco noanamae*) and Munchique National Park (*Eriocnemis mirabilis*) (Maria and Olivares, 1968; Paynter, 1997; Stiles et al., 1999). Since differences in the species pool being sampled between years are due to these rare species restricted to few inaccessible sites, we suggest GBD data should only be used to evaluate temporal trends in occurrence for those species that were detected every year, and that further insight may be gained from expanding analyses to longer time periods (Hochachka et al., 2021).

5. Conclusions

The COVID-19 lockdown seemed to increase global public awareness of the importance of biodiversity and its monitoring (Bates et al., 2020; Corlett et al., 2020; Rutz et al., 2020). The ease of using apps such as iNaturalist and eBird allowed for the collection of large datasets surrounding the places where observers live in Colombia. The special events that took place during this period presented a unique opportunity for biodiversity research during the "anthropause". Our results highlight outstanding challenges and opportunities for improvement in the use of these opportunistic datasets to answer ecological questions about the effects of sudden events on biodiversity. Studies about the effect of the lockdown on biodiversity should carefully limit their scale of inference to fully take advantage of citizen science data (Hochachka et al., 2012; Johnston et al., 2020).

It is not appropriate to use opportunistic citizen science datasets to characterize responses to the "anthropause" across all of Colombia, but areas of high human density have good potential for such comparisons. Contrasts should also exclude rare species associated with habitat types that were under-sampled. Regardless of where comparisons are made, analyses should account for differences in sampling effort and methods among years. The steps we took to review the data at a national level should be repeated before analyses at finer scales, and are generally applicable to citizen science datasets being used for unplanned comparisons of conservation relevance in other countries and ecological contexts.

Because the majority of biodiversity studies conducted by universities and research institutes tend to focus on natural and pristine regions (Martin et al., 2012), datasets provided by citizen science initiatives are a great complement to study the impact of human footprint on common and disturbance-adapted species. There are still technological difficulties associated with the use of digital platforms in rural regions (Pinzón Arias et al., 2020), so to increase the potential of citizen scientists to monitor species of higher conservation concern we need to come up with new strategies to engage people in these areas to participate more consistently (Brown and Williams, 2019). eBird has contributed and benefited from decentralization in bird knowledge (Sánchez-Clavijo et al., 2020), and GBD results in Colombia show that with relatively little but constant mentorship, citizen scientists can contribute to species monitoring in a wide diversity of regions and habitats.

A second step to strengthening local capacities to study biodiversity is to encourage a greater diversity of actors to create projects that help them answer ecological questions relevant to their decision-making processes (Acevedo-Charry et al., 2021). Many researchers worry about the effects that more users may have on data quality in these platforms (Burgess et al., 2017), but this issue can be improved in several ways. First, by promoting best practices for collecting, curating, processing, analyzing, and interpreting citizen science data (Kelling et al., 2019; Ruete et al., 2020). Second, by introducing fields in their user interfaces that allow for the collection of data about the sampling process associated with biodiversity observations (Gouraguine et al., 2019; Johnston et al., 2020).

The year 2020 will be remembered for the catastrophic events brought upon by the COVID-19 pandemic. There is evidence to support both positive and negative impacts of its associated lockdown on biodiversity (Bates et al. unpublished). With this study, we want to highlight important lessons that the pandemic taught us about broadening the scope of where we do science, who participates, and what kind of analyses we can undertake to evaluate the impacts of sudden events on biodiversity. Citizen science has the potential to become a cornerstone for biodiversity research and monitoring in megadiverse countries (Chandler et al., 2017; MacPhail and Colla, 2020), and the growing use of publicly available platforms indicates that many Colombians are interested in helping to document their biodiversity.

CRediT authorship contribution statement

SJMC, ADP, BGV, MHOR, JCRV and CSV: conceptualization, methodology, data curation, formal analysis and visualization for "*Naturalistas Urbanos desde Casa*" and iNaturalist data; LMSC, OAC, NOP and DO: conceptualization, methodology, data curation, formal analysis and visualization for Global Big Day and eBird data; JMOQ: supervision; LMSC: writing - original and final draft preparation; All co-authors: writing - reviewing and editing.

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.

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Appendix A and B. Supplementary data

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