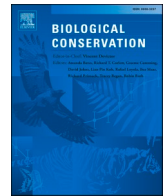




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# Birds seen and not seen during the COVID-19 pandemic: The impact of lockdown measures on citizen science bird observations

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## ABSTRACT

In early 2020, the rapid spread of the novel coronavirus disease 2019 (COVID-19) led multiple countries to introduce strict lockdown measures to contain the pandemic. Movement restrictions may have influenced the ability of the public to contribute to citizen science projects. We investigated how stay-at-home orders affected data submitted by birdwatchers in Italy, Spain and the United Kingdom (UK) to a widely-used citizen science platform, iNaturalist, depending on whether observations were collected in urban or non-urban areas. We found significant trends in the daily number of observations in all three countries, indicating a surge in urban observation during lockdowns. We found an increase in the mean daily number of urban observations during the lockdown in Italy and Spain, compared to previous years. The mean daily number of non-urban observations decreased in Italy and Spain, while remained similar to previous years in the UK. We found a general decrease of new records during the lockdowns both in urban and non-urban areas in all countries. Our results suggest that the citizen science community remained active during the lockdowns and kept reporting birds from home. However, limitations to movements may have hampered the possibility of birdwatchers to explore natural areas and collect new records. Our findings suggest that future research and conservation applications of citizen science data should carefully consider the bias and gaps in data series caused by the pandemic. Furthermore, our study highlights the potential of urban areas for nature activities, such as birdwatching, and its relevance for sustainable urban planning.

## 1. Introduction

The year 2020 witnessed a historic global health emergency caused by the spread of the novel coronavirus disease 2019 (COVID-19; [Zhu et al., 2020](#)). To slow down the pandemic, governments enforced strict lockdown measures, requiring citizens to stay at home ([Hale et al., 2020](#)). Movement restrictions imposed by lockdowns also affected citizen science projects. On the one hand, they limited the possibility of the public to contribute to field data collection ([Corlett et al., 2020](#); [Paul, 2020](#); [Rose et al., 2020](#)). On the other hand, they increased interest in “backyard” biodiversity. For example, many birdwatching associations encouraged the public to collect and share their data on birds observed from home windows and balconies (e.g. [EBN Italia, 2020](#); [Royal Society for the Protection of Birds, 2020](#); [SEO \(Sociedad Española Ornitológica\)-](#)

[BirdLife, 2020](#)).

To assess whether and how lockdowns have affected the spatial and temporal patterns of observations collected by the general public during the COVID-19 pandemic is a critical step to correctly use and interpret such data in future studies. This is particularly relevant for birds, considering that lockdown restrictions in Europe partially overlapped with spring migration ([www.eurobirdportal.org](http://www.eurobirdportal.org)) and the beginning of the breeding season, when species monitoring is particularly important ([Hudson et al., 2017](#)). For example, temporal fluctuations in the number of observations due to the introduction of lockdown restrictions could represent an issue for research aimed at identifying temporal trends in natural processes (e.g. migration, [Schubert et al., 2019](#)) and anthropogenic threats (e.g. wildlife-vehicle collisions, [Russo et al., 2020](#); [Valerio et al., 2021](#)). Likewise, a shift in the spatial pattern of observations from

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natural to urban areas, due to the impossibility for birdwatchers to move freely, could pose a problem for studies using such data to assess species distribution changes over time (e.g. [Enriquez-Urzelai et al., 2019](#); [Gillings et al., 2019](#); [Ramellini et al., 2019](#)). Moreover, lockdowns might have influenced the possibility of reporting new records (i.e. species never recorded before, with reference to spatial-grid units) by participants in citizen science projects, due to a decrease of observations in natural areas that were off-limits, following the stay-at-home orders.

In this study, we assessed spatial and temporal changes in citizen science data-collection during the COVID-19 lockdowns, and compared it to previous years. To this end, we analysed bird observations submitted to a popular open-access citizen science platform, iNaturalist ([www.inaturalist.org](http://www.inaturalist.org)), by users from Italy, Spain and the United Kingdom (UK), three countries that experienced similar restrictions over the same period of time. We hypothesised: (1) an increase in the daily observation trend in urban areas (where most of the population lives) and a decrease in non-urban areas (which were off limits for most citizens) in 2020 compared to previous years; (2) an increase in the daily mean number of bird observations in urban areas and a decrease in non-urban areas in 2020 compared to previous years; (3) an increase in the proportion of new records in urban areas and a decrease in non-urban areas in 2020 compared to previous years.

To test our hypotheses, we investigated whether temporal trends in the daily number of observations and the mean daily number of observations changed during the lockdown compared to the same period in years 2015–2019, both in urban and non-urban areas. Furthermore, we examined whether there was a change in the proportion of new records (i.e. species not recorded before, with reference to spatial-grid units) reported before and during the lockdowns.

## 2. Methods

### 2.1. Study area

For the purposes of our analysis we focused on Italy, Spain and the UK. These three countries were among the worst-hit during the first wave of the COVID-19 pandemic in terms of confirmed deaths per million inhabitants ([Johns Hopkins University Center for Systems Science and Engineering \(JHU CSSE\), 2020](#)). Furthermore, their respective governments adopted similar lockdown measures to restrict citizens' freedom of movement over almost the same period to curb the spread of the coronavirus ([Hale et al., 2020, Table 1](#)).

### 2.2. Species observation dataset

We downloaded bird observation data from iNaturalist ([www.inaturalist.org](http://www.inaturalist.org)), a popular open-access citizen science platform. For each country, we downloaded observations recorded from 01 January 2015 to 31 December 2020. This time interval represented a trade-off between performing a multiyear comparison (i.e. before and during the lockdowns) and avoiding years with too few data (i.e. prior to 2015). In addition to species name and location, observations uploaded to iNaturalist can include photographs that allow other participants to propose

or confirm species identification. We downloaded both observations with and without photos (i.e. both 'research-grade' and 'casual' observations), but excluded those for captive species. Furthermore, we filtered out observations with obscured coordinates, i.e. referring to conservation-sensitive species whose exact location is kept secret by the platform, and observations whose positional uncertainty exceeded 100 m.

### 2.3. Land cover characterization

We split bird observations into two categories: 'urban' and 'non-urban'. To this end, we first converted observations into spatial points (using the associated geographic coordinates) and then intersected observation points with the latest available Corine Land Cover raster layer (referring to 2018, with a resolution of 100 m, downloaded from <https://land.copernicus.eu/pan-european/corine-land-cover>). Bird observations falling within land cover classes 1.1.1 and 1.1.2 (i.e. continuous and discontinuous urban fabric, respectively) were labelled as 'urban'. These two classes represent areas where residential buildings are more concentrated and therefore where most of the population lives. Observations falling in any of all the other classes were instead labelled as 'non-urban'. Spatial analyses were performed using the packages "sf" ([Pebesma, 2018](#)) and "raster" ([Hijmans, 2020](#)) in R software version 4.0.0 ([R Core Team, 2020](#)).

### 2.4. Daily observation trends during lockdowns

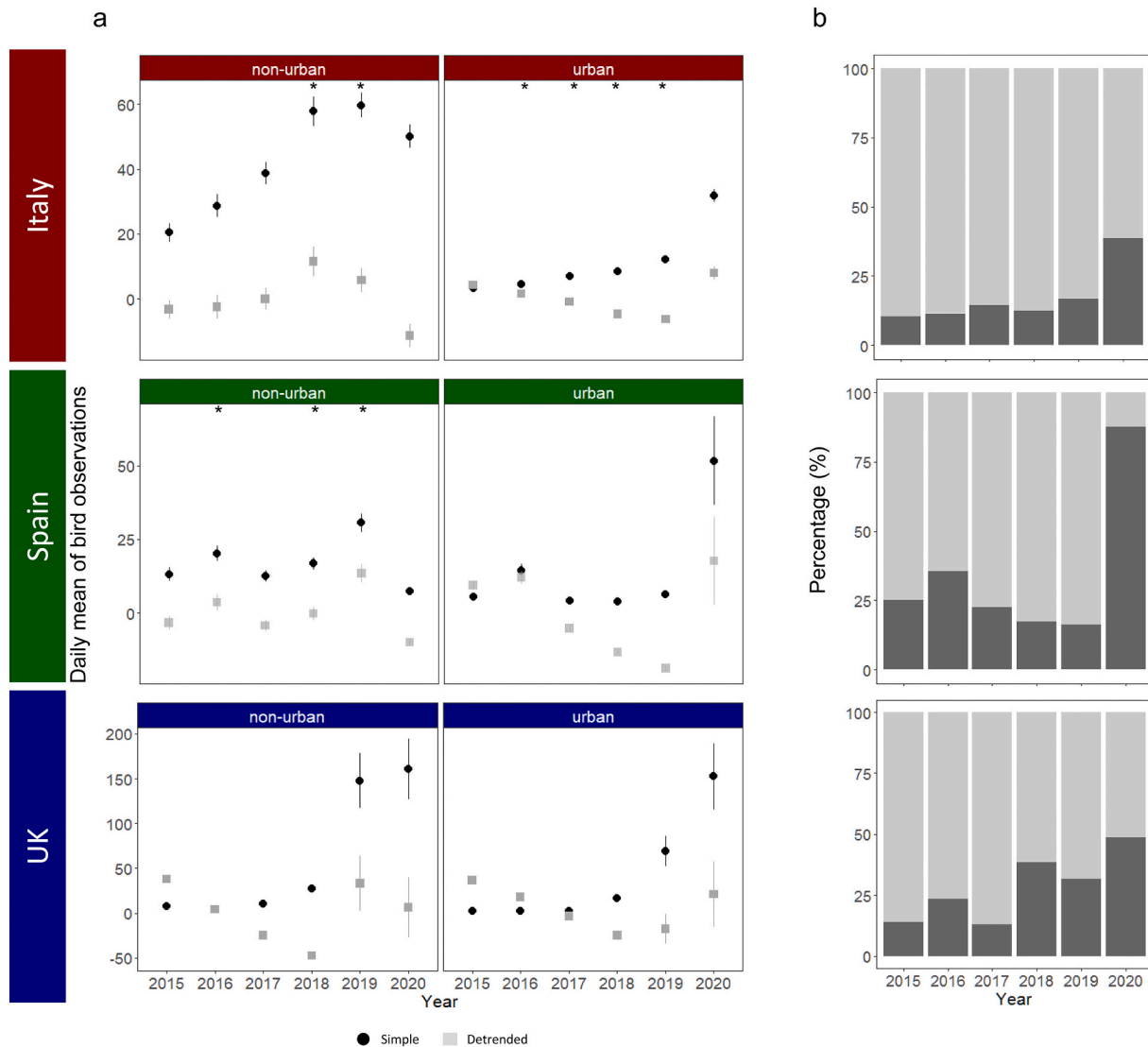
Temporal trends of bird observations may have changed during lockdowns, as people could have spent more or less time observing. We considered that the daily number of observations across a time series encompassing the lockdown dates may change following the implementation of lockdown restrictions, and according to country and land cover class. To detect such changes, we assessed yearly differences in temporal trends of the daily number of bird observations in 2020 compared to the previous five years by employing generalised additive models (GAMs). These models estimate the effect of a variable by using flexible smooth functions that do not impose parametric assumptions ([Hastie and Tibshirani, 1990](#)). The shape of the smooth is then determined by the data and not restricted to a specific form. The degrees of freedom of the smooth represent loosely the number of parameters used to fit the function ([Fewster et al., 2000](#)). Higher degrees of freedom allow the smooth to accommodate non-linear trends and can be specified to reflect hypothesised relationships or automatically set using generalised cross-validation ([Zuur et al., 2009](#)). For this analysis we considered the entire dataset of bird observations recorded from 01 January 2015 to 31 December 2020. The daily number of bird records, for each country and land cover class, was smoothed with a thin plate function of the days (numbered consecutively assuming 1 January = 1) grouped by year. Since the year was treated as a categorical variable, we included it also as a parametric predictor in the models. We checked the k-index to choose when a scaled t (Gaussian for heavy-tailed data) error distribution best fitted the data ([Wood, 2017](#)). We also included a continuous autoregressive term in the model formula to account for day-

**Table 1**

Summary of the restrictions introduced by the governments of Italy, Spain and the UK during the strictest phase of the national lockdowns.

Country	Restrictions	Dates <sup>a</sup> and legal references
Spain	Citizens allowed to leave their homes only to buy food, medicine or essential goods, to go to work if it was not possible to work from home, or for medical and emergency reasons.	14 March 2020–1 May 2020 ( <a href="#">Real Decreto 463/2020</a> ; <a href="#">Orden SND/380/2020, n.d.</a> )
Italy	As in Spain, but with the possibility, in some regions, to take exercise outside in the immediate surroundings of private homes and for a limited amount of time.	10 March 2020–3 May 2020 ( <a href="#">DPCM of 09 March 2020</a> ; <a href="#">DPCM of 26 April 2020</a> )
UK	As in Italy, but with green urban areas kept open exclusively for physical exercise in the immediate surroundings of private homes and for a limited amount of time. No other activities permitted in green areas.	24 March 2020–12 May 2020 ( <a href="#">UK Government, 2020a</a> ; <a href="#">2020b</a> )

<sup>a</sup> Starting from the first full day of application of the restrictions.



**Fig. 1.** a) Mean daily number (black circles) and detrended mean daily number (grey square) of bird observations uploaded to iNaturalist during the days of the national lockdown in 2020 (Table 1) and for the same dates in the previous five years in Italy, Spain and the UK, by land cover class. Asterisks at the top of each plots indicate significant differences ( $p > 0.05$ ) with the year 2020 for the detrended daily means, following Games-Howell pairwise comparisons. b) Percentage of urban (dark grey) and non-urban (light grey) bird species observations uploaded to iNaturalist before (2015–2019) and during the COVID-19 lockdown (2020) in Italy, Spain and the UK.

to-day autocorrelation in bird observations, when the model residuals showed  $\rho$  values  $\geq |0.1|$  (Venables and Ripley, 2002). In order to provide a detailed picture of bird observations during each year, we approximated weekly changes by allowing up to 52 knots to the smoothing function. Model fit was assessed using the  $R^2$  and by visually assessing residuals. Analyses were conducted using the “mgcv” (Wood, 2018) and “pracma” packages (Borchers, 2019) in R version 4.0.0 (R Core Team, 2020).

### 2.5. Differences in bird observations from urban and non-urban areas

To investigate whether there was a change in the spatial pattern of bird observations recorded across a period of time spanning the lockdowns, we computed the mean daily number of bird observations across years from 2015 to 2020, within countries (i.e. Italy, Spain and the UK) and land cover classes (i.e. urban vs. non-urban). We tested whether the mean for year 2020 was different from previous years across countries and land cover classes, using Welch’s ANOVA, after detecting heteroscedasticity in the data with a Levene test. For this analysis, we only

considered observations recorded during the days of the lockdowns in 2020 (Table 1) and for the same dates in the previous five years. To account for the increasing usage of iNaturalist over the years (iNaturalist, 2020), we first assessed whether the number of users increased over years (see observer analysis in Appendix A). Then, we detrended the daily means for each country and land cover class prior to comparison using the function ‘detrend’ with default settings in the R package “pracma” (Borchers, 2019). Since we had no expectations on whether the daily means would increase or decrease in 2020, we employed a two-sided test. Pairwise comparisons of means were performed using the Games and Howell (1976) test.

### 2.6. Changes in the proportion of new records

We expect the increase in the usage of iNaturalist (2020) to be mirrored by an increase in the proportion of new records (i.e. species not recorded before, with reference to spatial-grid units) across years. Consequently, we investigate whether a change occurred during the days of the lockdowns in 2020 (Table 1) compared with the same period

**Table 2**

Parametric coefficients estimated by the generalised additive models assessing temporal trends in bird observations retrieved from the platform iNaturalist. SE = standard error. Asterisks indicate significant values ( $p < 0.05$ ).

	Non-urban		Urban	
	Estimate	SE	Estimate	SE
<b>Italy</b>				
2015	16.58*	1.45	2.77*	0.26
2016	8.32*	2.04	0.39	0.35
2017	17.79*	2.04	1.73*	0.34
2018	26.55*	2.04	3.51*	0.33
2019	30.13*	2.04	6.74*	0.33
2020	37.03*	2.04	11.55*	0.33
<b>Spain</b>				
2015	4.28*	0.66	3.84	2.19
2016	2.88*	0.91	1.57	2.90
2017	3.88*	0.88	1.01	2.79
2018	9.75*	0.88	0.71	2.75
2019	20.51*	0.88	2.57	2.71
2020	23.86*	0.87	13.80*	2.69
<b>UK</b>				
2015	6.11	7.72	2.08	9.36
2016	0.58	10.47	0.75	12.57
2017	3.18	10.38	0.76	11.97
2018	12.59	10.19	6.16	11.31
2019	63.71*	10.18	28.02*	11.28
2020	83.17*	10.19	54.83*	11.29

of time in the previous five years, for each country and land cover class. In order to avoid potential errors arising from species misidentification, we considered only observations for which identification was confirmed by other iNaturalist users through inspection of attached photographs. We matched each of these observations with three different Lambert azimuthal equal-area grids provided by the European Environment Agency (<https://www.eea.europa.eu/>), with resolutions commonly adopted in ornithological atlases: i.e.  $1 \times 1$  km,  $10 \times 10$  km, and  $100 \times 100$  km. Then, for each year, country and land cover class, and separately for each spatial grid, we determined the number of new records uploaded to iNaturalist compared to the total set of records uploaded during the previous year. We used records for year 2015 as a baseline to calculate the number of new records for the following years. Finally, we calculated the yearly relative percent change in new records as:

$$\frac{N_t - R_{t-1}}{R_{t-1}} \times 100 \quad (1)$$

where  $N$  represents the number of new records added in year  $t$  compared to year  $t-1$ , and  $R$  represents the total number of records uploaded in year  $t-1$  (i.e. any species in any grid unit).

### 3. Results

#### 3.1. Summary of species observations

The entire dataset consisted of 257,026 bird observations for the period 01 January 2015–31 December 2020. The country with most observations was the UK ( $n = 106,792$ ; 41.6% of the total), followed by Italy ( $n = 96,290$ ; 37.5%) and Spain ( $n = 53,944$ ; 21.0%). Of the totality of records, 23,045 (9.0% of the total) were recorded during the 2020 lockdown days and 32,821 (12.8%) during the same dates in the previous five years (see Table S1 for details). From 2015 to 2019, during the same dates of the 2020 lockdown, the proportion of observations from urban areas ranged from 10.5% to 16.8% of the total in Italy, from 16.1% to 35.4% in Spain, and from 14.0% to 38.4% in the UK (Fig. 1b). During the 2020 lockdown, there was a strong spatial shift, with 38.8% of the observations coming from urban areas in Italy, 87.6% in Spain and 48.7% in the UK.

#### 3.2. Daily observation trends during lockdowns

The GAMs identified significant parametric predictors for year 2020 in all countries and land cover classes (Table 2), indicating an overall increase in observations in year 2020 compared to previous years. Coefficient estimates for Italy indicated a larger increase in observations in urban areas than in non-urban areas compared to previous years. The smoothing parameters, indeed, were significant in years 2016–2020 for non-urban areas and in years 2017–2020 in urban areas. Temporal trends showed a peak in observations during lockdown in urban areas, clearly larger than that for similar dates in previous years, and not mirrored in non-urban areas (Fig. 2). These models score a  $R^2$  of 0.28 and 0.47 for non-urban and urban areas, respectively. Estimates for Spain indicated that in urban areas there was a marked increase in observations compared to previous years, while non-urban areas showed estimates similar to previous years. The smoothing parameters for non-urban areas were significant for years 2015 and 2017–2020, while for urban areas only in 2020. In particular, temporal trends indicated a clear surge in urban observations during lockdown, while a considerable drop was found during the same dates in non-urban areas (Fig. 2). These models scored a  $R^2$  of 0.23 and 0.39 for non-urban and urban areas, respectively. As for Italy and Spain, in the UK estimates indicated a larger effect in urban areas compared to non-urban areas for year 2020. However, the overall fit of the GAMs was not reliable due to the low number of observations in years before 2020. Indeed, the smoothing parameters were significantly estimated only for years 2019–2020 in non-urban areas and for 2020 in urban areas. Temporal trends indicated that non-urban areas still experienced a spike in observations during lockdown dates, although smaller than the increase observed for urban areas (Fig. 2). These models scored a  $R^2$  of 0.33 and 0.27 for non-urban and urban areas, respectively.

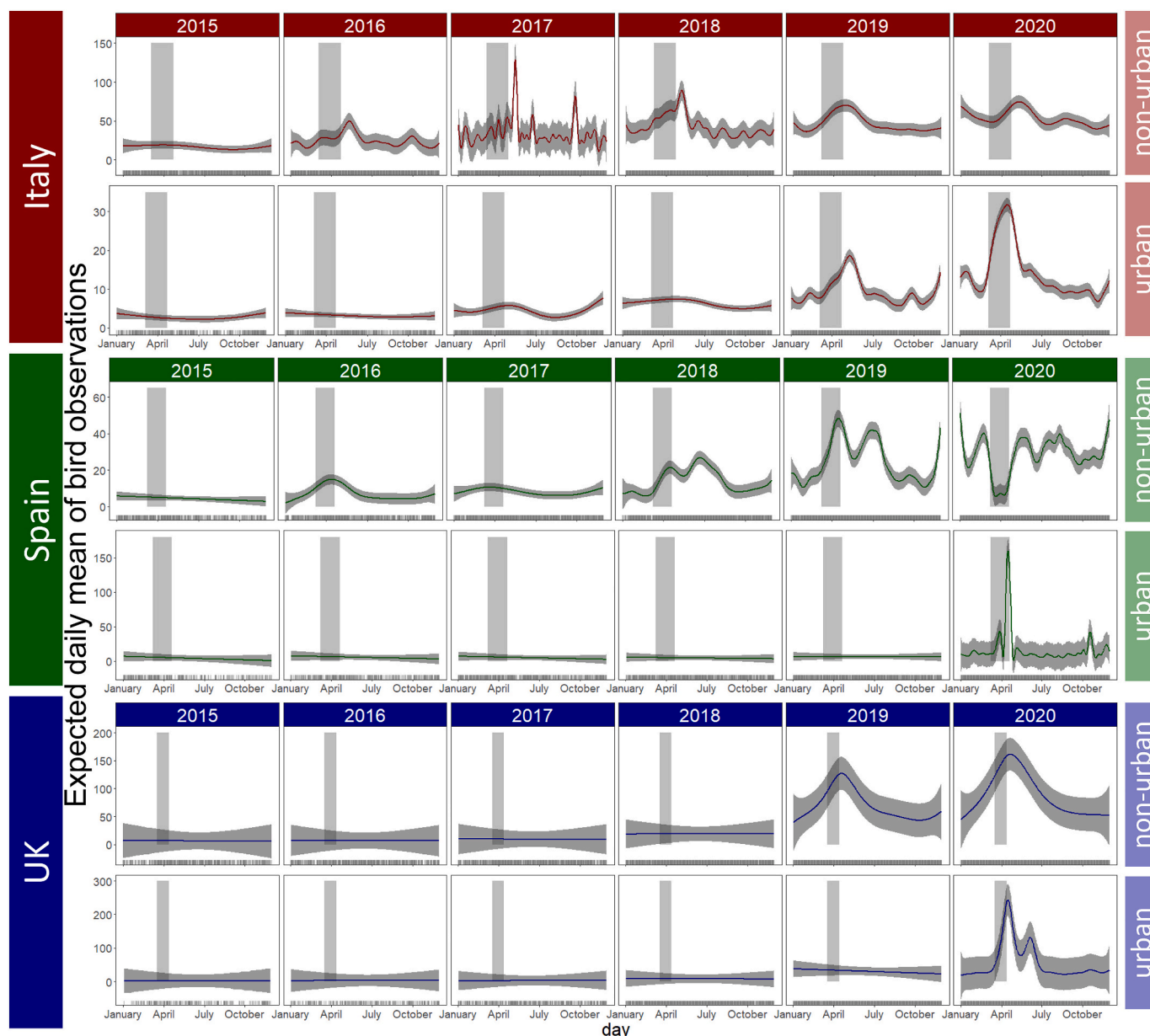
#### 3.3. Differences in bird observations from urban and non-urban areas

The ANOVA identified significant differences in the detrended mean daily number of bird observations among years, within countries and land cover classes (Fig. 1a). The variability in observations was influenced by the lockdown in both positive and negative way, depending on the land cover class and country (see Tables S2–S4 in supplementary materials). In 2020 there was a significant increase in observations collected in Italy in the urban land cover class compared to the years 2016–2019 ( $F = 33.13$ ;  $p < 0.001$ ), while a significant decrease was found for non-urban observations compared to years 2018–2019 ( $F = 3.96$ ;  $p = 0.002$ ). Results for Spain were partly similar to Italy in non-urban areas, with a significant decrease in 2020 compared to 2016 and 2018–2019 ( $F = 16.15$ ;  $p < 0.001$ ). We did not find significant differences in urban areas in 2020, compared with the previous years, while significant differences emerged among previous years ( $F = 93.85$ ;  $p < 0.001$ ). Comparison including the UK did not show any significant difference in 2020 in either urban or non-urban areas, with significant differences found only among previous years ( $F = 93.17$ ;  $p < 0.001$  and  $F = 103.33$ ;  $p < 0.001$ , respectively).

#### 3.4. Changes in the proportion of new records

A total of 31,369 research-grade observations were considered in this analysis (14% of the total). Overall, the percent change of new urban and non-urban records found in each cell across years for the three countries did not show a consistent pattern (Fig. 3). Focusing on 2020, we perceived a major disruption in new records being reported from non-urban areas, especially in Italy and Spain, in contrast to previous years, when a general positive change was reported across all grid extents. In regards to new urban records, Italy experienced an increase in 2020 compared with the two previous years for  $1 \times 1$  km and  $10 \times 10$  km cells. In Spain, there was a general increase of new urban records across years until 2020, when this trend halted in all grid extents.





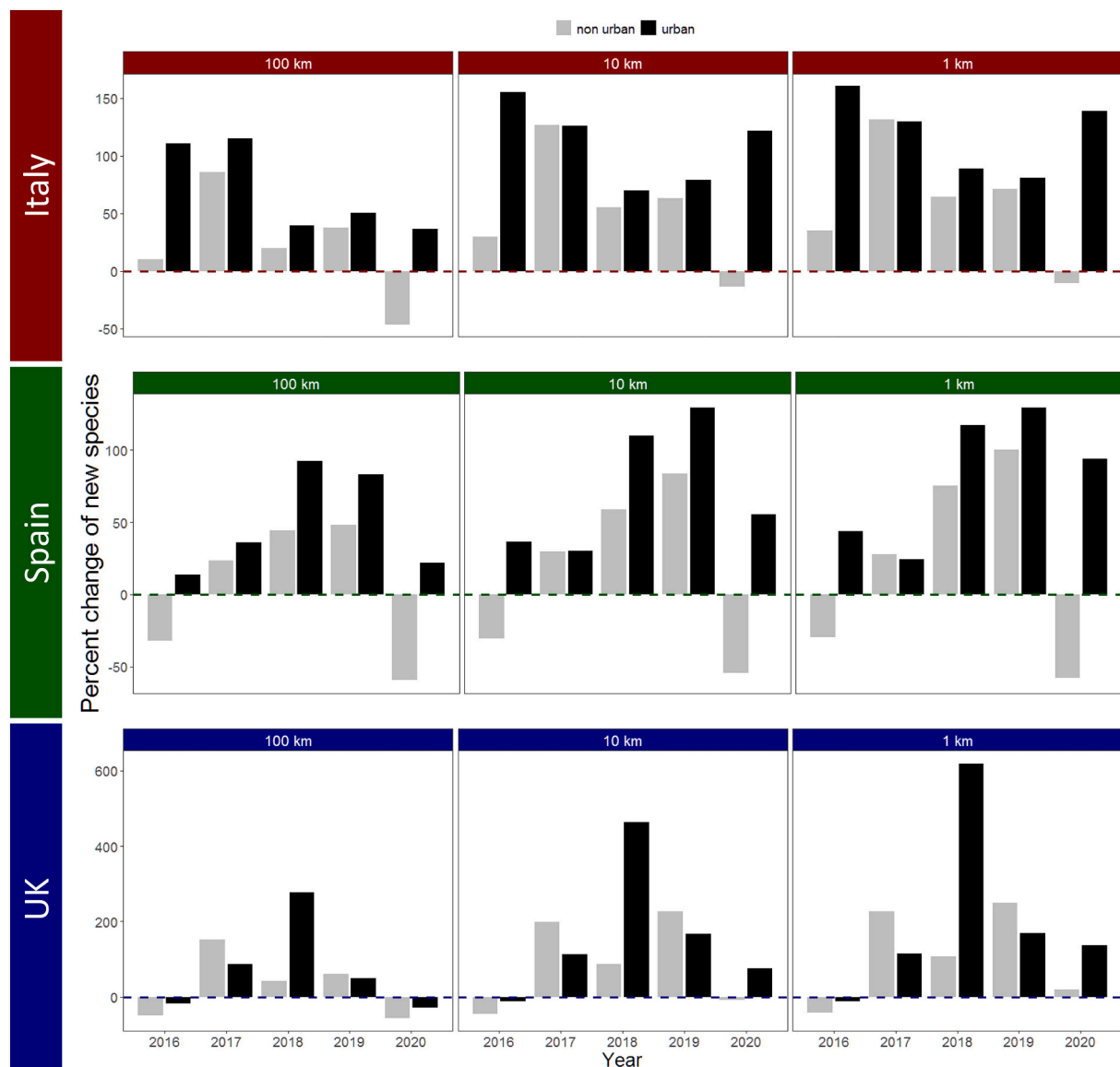
**Fig. 2.** Temporal trends in the daily number of bird observations in Italy, Spain and the UK, in urban and non-urban areas, for the respective years. Days are measured consecutively assuming January 1<sup>st</sup> = 1. Shaded areas indicate lockdown periods and are imposed on previous years to highlight same days. Temporal trends were analysed by employing generalised additive models, smoothing over 52 knot points, to approximate weekly changes.

Finally, no clear patterns were observed in the percent change of new records from the UK, apart from a generalised decrease from both urban and non-urban areas across all grid extents in 2020.

#### 4. Discussion

Overall, no major disruption was found in bird data collection during the lockdown period, since most of the comparisons indicated that numbers were similar to or slightly lower than in previous years in non-urban areas, and similar to or greater than previous years in urban areas. The total number of observations uploaded to iNaturalist has shown a sharp increase in recent years (iNaturalist, 2020) and a similar trend was also found in 2020. Considering that the mean daily number of observers did not change significantly over the years (Appendix A), the increase in usage is linked to the increase in the mean number of observations uploaded. The increase in the absolute number of observed resulted in the majority of users uploading few observations per day. However, we

observed a clear shift in the spatial pattern of observations, with a notable increase of data from urban areas especially in Spain and Italy (Fig. 1). These results suggest that the limitation of movement did not discourage iNaturalist users from making the most of their home confinement by directing their attention towards neighbourhood avifauna. On the other hand, such results could also be partly due to the engagement of those who do not usually participate in citizen science, as suggested by the surge in observations during iNaturalist's City Nature Challenge (24–27 April 2020). Indeed, some could have viewed bird-watching from home as an occasion for solace and a source of entertainment during the hard times of the lockdown, as suggested by Rose et al. (2020). Interestingly, lockdown measures seem to have influenced observers in Spain and Italy in a similar way, contrasting with the UK where we did not find any major effect. To this point, we highlight that UK citizens were allowed to visit urban parks or other natural places during the lockdown, contrary to citizens in Italy and Spain (Shoari et al., 2020). However, given the general increasing trend observed



**Fig. 3.** Relative change in the number of new bird species records added to iNaturalist before (2016–2019) and during the COVID-19 lockdown (2020), for each country (Italy, Spain and the UK), land cover class (urban and non-urban), and grid spatial resolution (1, 10 and 100 km). The year 2015 is excluded as it represents the baseline to calculate the relative change of the following years.

across previous years, the partial decrease in non-urban observations in Italy and Spain suggests a potential loss of data due to movement restrictions impeding exploration of non-urban areas.

Therefore, our findings highlight a potential source of bias in the citizen science data collected during the lockdown in the three countries considered in this study (i.e. oversampling of urban areas and under-sampling of non-urban areas). Considering the global scale of the pandemic, similar shortcomings could also emerge from other geographical locations (e.g. Rose et al., 2020). Furthermore, the consequences of the pandemic could extend far beyond the period of strict lockdown due to several other factors that could still be reducing citizen mobility and outdoor data collection (e.g. local restrictions, economic difficulties, personal choices to reduce the spread of the virus). Therefore, identifying and understanding the shortcomings in the series of citizen science data collected during the COVID-19 pandemic on a wider spatio-temporal dimension is critical for their incorporation in future scientific studies. Inter-annual variability in citizen science, time series records and pseudo-replications can be accounted for using appropriate statistical techniques (Bird et al., 2014; Gonsamo and D'Odorico, 2014).

For instance, spatio-temporal clustering may be used to correct for effort and detection and improve species distribution modelling (Fink et al., 2010), or filtering techniques based on temporal clustering to remove pseudo-replicates (Valerio et al., 2021). Although current techniques are suited to dealing with (extreme) bias in citizen science data, we stress that disruption in bird observations in 2020 as a consequence of the COVID-19 pandemic might require further consideration.

We identified significant surges in the number of daily observations during the lockdown in all three countries (Fig. 2). Besides the expected peak in urban areas, only in Spain there was a considerable drop in non-urban areas in 2020. In Italy the trend was similar to the year before, although the number of observations did not increase as expected and the peak was slightly delayed in non-urban areas, probably due to the relaxation of confinement measures. In the UK, trends showed peak of observations similar between years 2019 and 2020 in non-urban areas, indicating little influence of lockdown measures on the general trends. In urban areas, instead, the peak during lockdown days was evident in 2020. In general, however, the low usage of iNaturalist in previous years limited the ability of the model to draw significant estimates and provide

reliable comparisons with previous years.

No increase was found in the percentage change of new urban records in 2020, except for Italy when comparing with 2018 and 2019 (at 1-km and 10-km resolution) (Fig. 3). Therefore, despite several instances of remarkable new records from urban areas (e.g. *Aquila chrysaetos* in Milan; Viganò, 2020), the numbers indicated a general loss of possible new records. In particular, the loss of potential new non-urban records was not compensated by the gain in new urban records. Interestingly, for almost every year and country, we found a higher percent increase of new records in urban vs. non-urban areas. This appears to conflict with the fact that bird species diversity decreases along the urbanization gradient (Melles et al., 2003; Hedblom and Söderström, 2010; Canedoli et al., 2018), although local factors such as the presence of urban forests, parks or cemeteries can have positive effects on bird diversity (Čanádý and Mošanský, 2017; Canedoli et al., 2018). Similarly, affluent areas in cities usually host a more diverse bird assemblage than less-affluent areas, which is also related to a denser urban green infrastructure (Chamberlain et al., 2019) and to a larger occurrence of bird observations (Lopez et al., 2020).

Further studies are necessary to ascertain whether the urban observation of species previously considered absent or rare in this kind of environment during the lockdowns was due to a higher abundance of individuals, to a temporal change in the availability of ecological niches as a result of the reduction in anthropogenic disturbance (Derryberry et al., 2020; Rutz et al., 2020), to an increased detectability of birds following a decrease in environmental noise levels (Apol et al., 2020), or to a reflection of a larger number of observers present. Nonetheless, we note that similar processes were observed as a result of a reduction in human disturbance on other occasions (e.g. the nuclear disaster of Fukushima; Lyons et al., 2020) and the unprecedented situation generated by lockdowns, also referred as ‘anthropause’ (Rutz et al., 2020) or the ‘Global Human Confinement Experiment’ (Bates et al., 2020), may reveal new dynamics related to species distributions.

#### 4.1. Conservation implications

Understanding the long-term consequences of the COVID-19 pandemic on biodiversity conservation will require time. While the lack of funding deriving from the expected post-pandemic economic crisis could jeopardize conservation efforts around the world (Evans et al., 2020), increased public awareness about the causes of new disease emergence (Wu, 2021) could also prompt some governments to strengthen environmental policies (Corlett et al., 2020; Di Marco et al., 2020). Likewise, Manenti et al. (2020) showed a combination of both positive (e.g. reduced human disturbance) and negative (e.g. reduced monitoring) short-term effects of large-scale lockdowns on wildlife conservation. Here, we suggested another possible positive result, that is, the possibility of increased public interest in urban biodiversity and its preservation.

The usefulness of citizen science data in biodiversity conservation projects has been discussed in many instances (e.g. Kobori et al., 2016; McKinley et al., 2017; Horns et al., 2018). However, the involvement of citizens in scientific projects also provides a further benefit for biodiversity, i.e. an overall increase in public awareness of environmental problems (Couvét et al., 2008; Dickinson et al., 2012). The idea that birdwatching or, more generally, contact with nature, has a function as a therapeutic activity, with beneficial effects on psychological well-being (Chang et al., 2020; Shoosmith et al., 2021) is mirrored by the fact that iNaturalist users remained active in three major countries of Europe despite a pandemic. Therefore, emphasizing the role of citizen science could lead to higher levels of public engagement and hence to greater benefits for biodiversity conservation. In the recent ‘World Scientists’ Warning to Humanity’ (Ripple et al., 2017), scientists listed several collective actions needed in our society for a transition to a more sustainable world. One action consisted of society-driven individual behavioural changes, supported by more extensive nature education and

society-wide engagement in nature appreciation. Given that most of the world’s population lives in cities (World Bank, 2020), greater public engagement in urban biodiversity could result in more public awareness of the ongoing environmental crisis. The therapeutic aspect of urban birdwatching, however, should not remain a privilege of the affluent, as recent research suggests (Chamberlain et al., 2019). Therefore, alongside traditional conservation measures in non-urban areas, creating bird-friendly cities (Sneep et al., 2016) where the public has the possibility to appreciate nature directly (Cherry et al., 2018) should be viewed as a means of achieving sustainability goals.

#### 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. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.biocon.2021.109079>.

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