Comparison of the ability of eBird and Weather Radars to detect swallow and martin roosts

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Abstract

Swallows and martins (family: Hirundinidae) are highly specialized aerial insectivores which, like others of that guild, have been facing regional and continental population declines. After they finish breeding in North America, some migratory species of this family, particularly Tree Swallows (*Tachycineta albiventer*) and Purple Martins (*Progne subis*), aggregate overnight in communal roosts which can gather thousands to hundreds of thousands of individuals. These roosts are so dense that they are easily detected by networks of Weather Surveillance Radars which, together with citizen science, have recently risen as powerful tools for large-scale monitoring of avian populations. In this study, we aim to compare the ability of these two data sources to detect communal roosts of swallows and martins. To do this, we downloaded and processed all eBird checklists containing Hirundinidae species from 2013 to 2021 across the contiguous United States. Additionally, we employed a combination of machine learning and human supervision to detect and filter communal roosts from the Weather Surveillance Radar archive only on the 2,462 days where we had positive eBird checklists. Afterwards, we partitioned the areas sampled by the radar stations into 837 hexagons, and conducted a month-wise correlation study between the number of radar roosts and the number of effort-corrected eBird checklists within each hexagon. The results of this study can help us learn how to combine these two datasets to build a broader understanding of the communal roosting stage of swallows and martins. With this, we can better-inform conservation measures to revert their population declines.

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Introduction

Swallows and martins (family: Hirundinidae) are highly specialized aerial insectivores some of which partake in annual transcontinental migration (Belotti et al., 2023). In North America, studies have shown declining trends of avian aerial insectivore populations since 1970. (Smith et al., 2015). The drivers of these population trends are still unknown particularly for the migratory species of this guild. Recent technological advancements, like the use of machine learning and Weather Surveillance Radars, could provide relative abundance estimates at large spatial and temporal scales during the communal roosting stage of the annual cycle of swallows and martins. Additionally, with the increased computational power available now, we can analyze large citizen science datasets that can complement the information from the weather radars (Weisshaupt et al., 2020).

Weather Surveillance Radars have helped us study avian migratory patterns and communal roosting for the past 40 years. The radar network in the United States consists of 151 Doppler Weather Surveillance Radar stations continuously scanning the atmosphere (NOAA, 2022). Previous studies found that communal roost dispersal at dawn creates a ring-shaped high reflectivity signature on data rendered from the Weather Radar (Russell et al., 1998). By extracting data from regions where this signature is found, because reflectivity correlates with biomass density, we can obtain relative abundance estimates inside the roosts. Identifying specific avian species within these roosts, however, is still an open challenge. Moreover, weather radars lack the ability to sample the airspace close to the ground.

Citizen science data can help us overcome some of these drawbacks. Because datasets from platforms like eBird contain species identifications paired with georeferenced timestamps, they can be combined with data from the weather radars to address the taxonomic limitation of the weather radars. Because citizen observations are done on the ground, these datasets can also fill the sampling gap from the radars. Nonetheless, citizen science data can be biased by, for example, species traits, observer expertise, and distance to human populations (Callaghan et al., 2021, Rosenblatt et al., 2022). Such biases, in turn, can be addressed by the almost continuous spatial and temporal sampling performed by the radars.

In this study, we compared the ability of weather radars and eBird to capture communal roosts of swallows and martins. We expected to understand the relationship between the number of eBird checklists containing swallows and martins and the number of radar-detected roost dispersals throughout the contiguous United States. In addition, we examined whether this relationship varies by month. We hope this research can further our knowledge of the strengths and weaknesses of both tools, so that we can combine them for the advancement of bird conservation efforts.

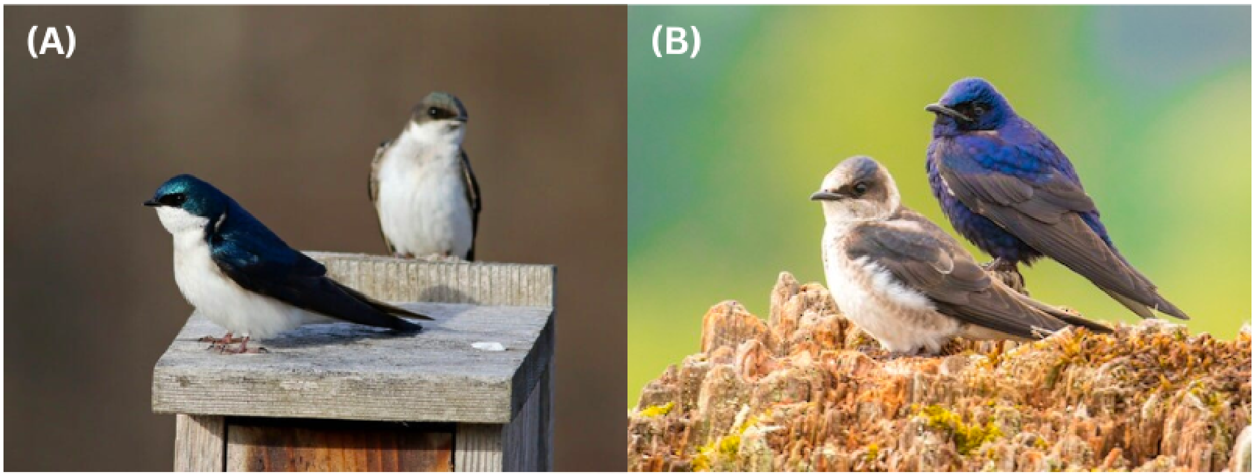

Figure 1. (A) Photo of adult Tree Swallows (*Tachycineta bicolor*). Tree Swallows have an iridescent blue-green back with a white underside. Females and males are not always distinguishable. (B) Photo of adult Purple Martins (*Progne subis*). Adult males are dark blue-purple overall with brown-black wings and tail. Females are duller with more gray accents and a white underside.

Research Questions and Hypotheses

Research Question: What is the relationship between the number of eBird checklists containing swallows and martins and the number of radar-detected roost dispersals? Does this relationship vary by month?

Hypothesis: We would expect these two variables to be positively correlated since the two tools are capturing a similar stage in the annual cycle of swallows and martins in North America.

Methods

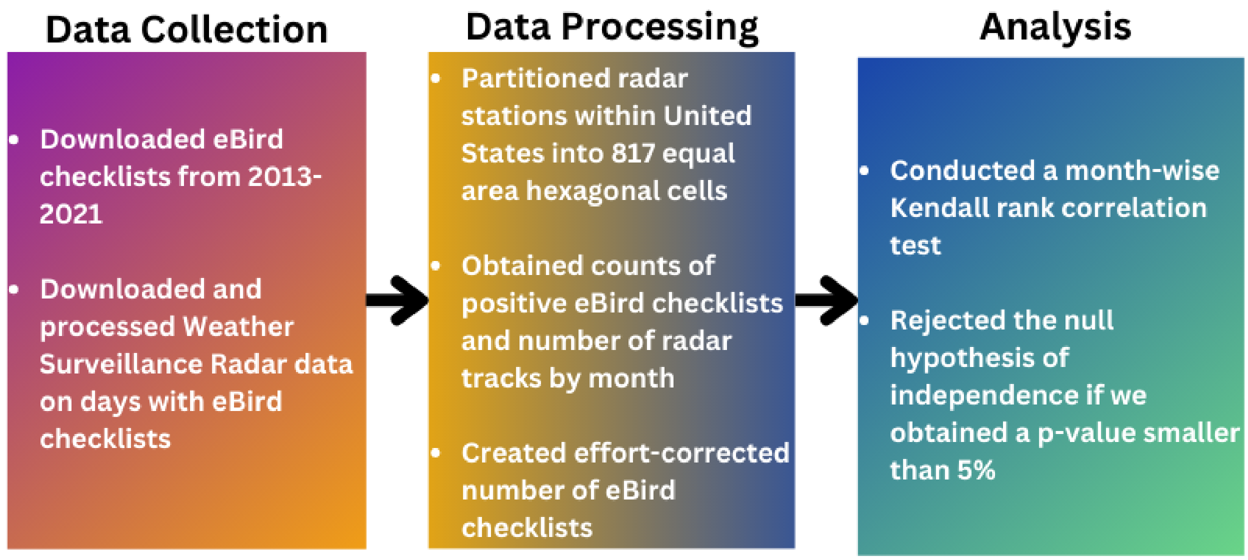

Figure 2. Diagram of project workflow depicting major steps in data collection, processing, and analysis.

Data Collection

(performed and written by Maria)

We selected four Hirundinidae species known to gather in communal roosts in North America: Tree Swallows (*Tachycineta bicolor*), Purple Martins *(Progne subis*), Barn Swallows (*Hirundo rustica*), and Cliff Swallows (*Petrochelidon pyrrhonota*). We downloaded all eBird checklists containing counts of more than 1000 individuals of at least one of our target species and with observation time before 10:00 am and after 4:00 pm of each day, when large counts are more likely due to the communal roosting behavior (hereon, we will call these "positive checklists"). We restricted our search to the United States and Canada, and looked only at records from 2013 to 2021. We paired each checklist to the nearest Weather Surveillance Radar Station, as long as it was within 200 km of a station. We then extracted and processed data from the Weather Surveillance Radar archive on the date and time when eBird checklists were recorded. We used a machine learning pipeline to detect and track roost dispersals. The results of this step were manually screened to avoid false positives due to weather and other sources of radar noise.

Data Processing

We partitioned the regions covered by the radar stations within the contiguous United States into 837 hexagonal cells. The distance between the center of each pair of hexagons is 100 km, so that all of them have the same area across all latitudes and longitudes. Within each hexagon, we obtain counts of positive eBird checklists and number of radar tracks by month. We also extracted the total number of eBird checklists, regardless of species identification, per hexagon per month. To account for effort-related biases in the number of positive eBird checklists, we divided it by the total number of checklists within each hexagon for each month.

Analysis

In the final analysis, we conducted a month-wise Kendall rank correlation test between the number of radar roosts and the effort-corrected number of eBird checklists within each hexagon. We used the function cor.test, available in base R version 4.2.1. We rejected the null hypothesis of independence if we obtained a p-value smaller than 5%.

Results

After filtering for eBird checklists occurring before 10:00 am and after 4:00 pm and containing counts of more than 1,000 individuals, we were left with 10,461 so-called positive checklists submitted on 2,462 days from 2013 to 2021 (see map in Figure 4A). Every month of the year had at least one checklist. We extracted and processed data from the Weather Surveillance Radars either for the same day of the checklist, if the latter occurred in the morning, or for the day after, if the checklist was submitted at night. After processing and screening, our final radar dataset had 6,869 unique roost dispersal events (see map in Figure 4B). The total number of checklists submitted to eBird on the 2,462 days with positive checklists was 79,318.

The maximum mean number of radar tracks and positive eBird checklists per hexagon were found in August when we obtained 3,30 (standard deviation: 14,46) radar tracks per hexagon, and 3,65 (standard deviation: 41,32) positive eBird checklists per hexagon. The minimum mean number of radar tracks per hexagon was during May (0,01 with standard deviation 0,09), whereas for the number of eBird checklists it was reached in June (0,13, with standard deviation of 1,00).

In our month-wise correlation tests between the number of radar tracks and the effort-corrected number of checklists we tend to see a correlation across all months (see Figure

3 and Table 1). The peak correlation coefficient was 0,79 in December, whereas the lowest was 0,14 in May. All the tests were statistically significant with a p–value of 5% or less.

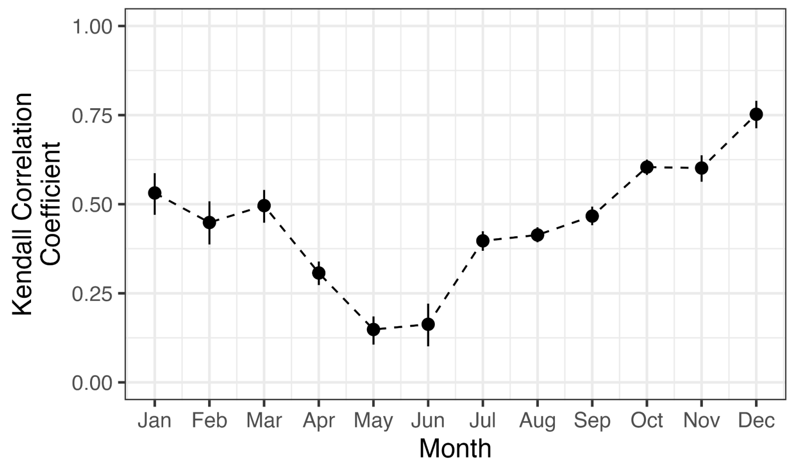

Figure 3. Plot of Kendall correlation coefficient between the number of radar tracks and the index for effort-corrected eBird checklists per hexagon. The perpendicular lines correspond to 95% confidence intervals.

Table 1. Correlation coefficient and p-value of positive eBird checklist and radar tracks per hexagon group by month.

Month	Correlation Coefficient	p-value	Number of Radar Tracks per Hexagon		Number of eBird Checklists per Hexagon	
			Mean	Standard Deviation	Mean	Standard Deviation
January	0.59	<0.00001	0.23	2.23	0.64	6.41
February	0.48	<0.00001	0.12	1.33	0.43	4.84
March	0.55	<0.00001	0.17	1.35	0.39	2.76
April	0.35	<0.00001	0.11	0.88	0.52	2.45
May	0.14	<0.00001	0.01	0.09	0.27	1.40
June	0.23	<0.00001	0.03	0.39	0.13	1.00
July	0.41	<0.00001	0.84	4.27	0.91	6.36
August	0.43	<0.00001	3.30	14.46	3.65	41.32
September	0.49	<0.00001	1.70	13.63	2.28	16.14
October	0.61	<0.00001	1.13	7.27	2.34	26.00
November	0.61	<0.00001	0.28	1.74	0.40	2.16
December	0.79	<0.00001	0.27	2.36	0.37	3.08

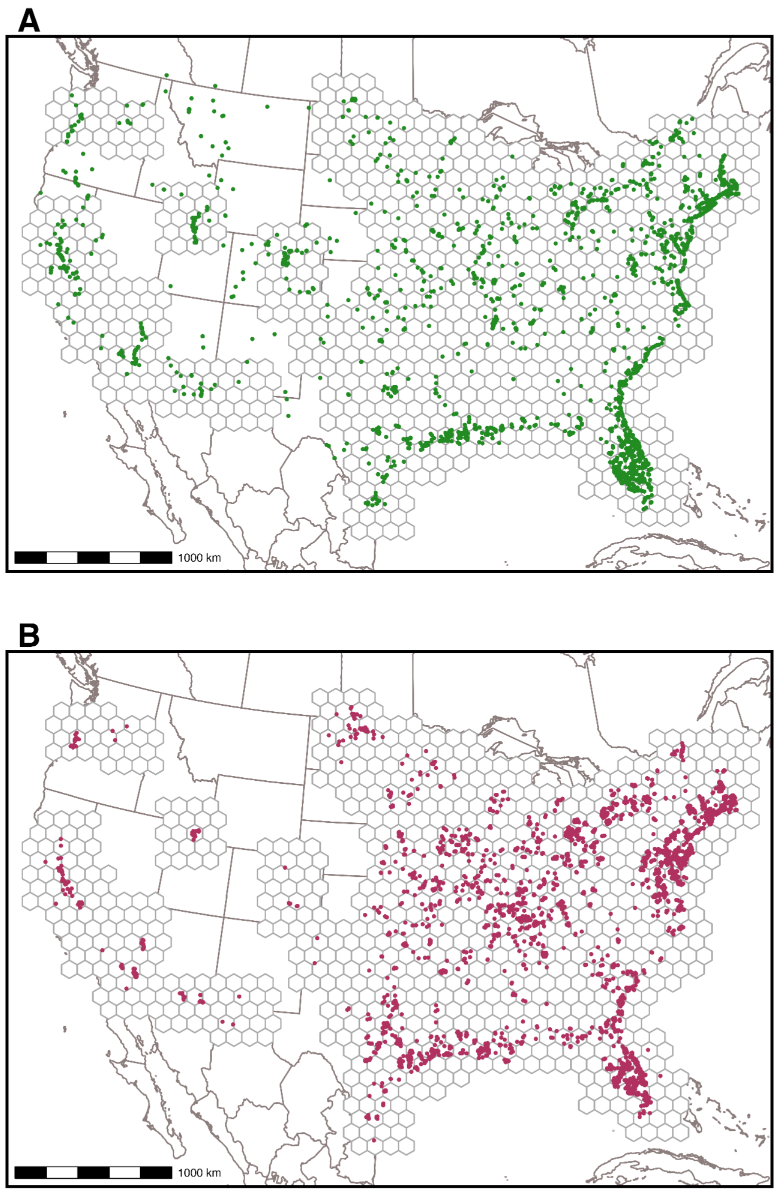

Figure 4. Maps of the contiguous United States partitioned into 837 equal-area hexagon cells. Points in green (A) represent eBird checklists with more than 1000 individuals of at least one of our target species. Points in red (B) represent single occurrences of communal roosts on Weather Surveillance Radar data from 2013 until 2021.

Discussion

Our results indicated, as expected, that there is a strong positive correlation between these two large-scale monitoring tools. This supports the hypothesis that eBird checklists with more than 1000 swallow and martin individuals are capturing the roosting stage of these species, since this is the annual stage we observe using Weather Surveillance Radars.

We observed, however, a relatively low correlation coefficient in May (see Figure 3 and Table 1). We hypothesize that this is due to the fact that it is most likely that this is the breeding season for all swallow and martin species we examined. The communal roosting behavior is usually not observed during the breeding season, as evidenced by the low mean number of radar tracks per hexagon in May. The positive eBird checklists from these months are likely due to aggregations other than roosting. On the other hand, between July and December, we see an increase in correlation coefficient (see Figure 3 and Table 1). We hypothesize that this increase is due to the end of the breeding season and the start of the roosting stage. During this period we see an increase in both the mean number of radar tracks and the mean number of positive eBird checklists per hexagon.

Conclusions

We have shown that both eBird and Weather Surveillance Radars are similarly capturing the communal roosting stage of swallows and martins. Further research is needed to understand how this similarity extends to subsets of eBird checklists containing each of our target species. With this, we could eventually combine eBird and weather radars to obtain regional species-specific relative abundance estimates and trends for the Hirundinidae family. This knowledge can help identify regions of concern that require targeted conservation measures and guide land use policies and management.

References

- Belotti, M. C., Deng, Y., Zhao, W., Simons, V. F., Cheng, Z., Perez, G., Tielens, E., Maji, S., Sheldon, D., Kelly, J. F., & Horton, K. G. (2023). Long-term analysis of persistence and size of swallow and martin roosts in the US Great Lakes. *Remote Sensing in Ecology and Conservation*. https://doi.org/10.1002/rse2.323

- Cornell Lab of Ornithology. 2019. All About Birds. Cornell Lab of Ornithology, Ithaca, New York. https://www.allaboutbirds.org Accessed on [2023].

- Callaghan, C. T., Poore, A. G., Hofmann, M., Roberts, C. J., & Pereira, H. M. (2021). Large-bodied birds are over-represented in unstructured citizen science data. *Scientific Reports*, *11*(1). https://doi.org/10.1038/s41598-021-98584-7

- Rosenblatt, C. J., Dayer, A. A., Duberstein, J. N., Phillips, T. B., Harshaw, H. W., Fulton, D. C., Cole, N. W., Raedeke, A. H., Rutter, J. D., & Wood, C. L. (2022). Highly specialized recreationists contribute the most to the citizen science project ebird. *Ornithological Applications*, *124*(2). https://doi.org/10.1093/ornithapp/duac008

- Russell, K. R., & Gauthreaux, S. A. (1998). Use of Weather Radar to Characterize Movements of Roosting Purple Martins. *Wildlife Society Bulletin (1973-2006)*, *26*(1), 5–16.

- Smith, A. C., Hudson, M.-A. R., Downes, C. M., & Francis, C. M. (2015). Change points in the population trends of aerial-insectivorous birds in North America: Synchronized in time across species and regions. *PLOS ONE*, *10*(7). https://doi.org/10.1371/journal.pone.0130768

- NOAA. (2022, June 12). *About our WSR 88-D radar*. About our WSR 88-D Radar. Retrieved April 4, 2023, from https://www.weather.gov/iwx/wsr_88d

- Weisshaupt, N., Lehtiniemi, T., & Koistinen, J. (2020). Combining citizen science and weather radar data to study large scale bird movements. *Ibis*, *163*(2), 728–736. https://doi.org/10.1111/ibi.12906

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