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Supplementary Information for

Identifying engaging bird species and traits with community science observations

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This PDF file includes:

Supporting Information Text

Code. The code used to process the data, perform the analyses, and make the figures all can be found at:
https://github.com/sastoudt/charismatic-birds

An interactive R Shiny application can be found in the subfolder "shiny-app" in the GitHub repository. It can be run locally or by running the following command in any R session:

```
shiny::runGitHub("charismatic-birds", username = "sastoudt", subdir = "shiny-app", ref = "main")
```

Dropped species. The nine species dropped due to convergence issues in the first stage were: chestnut-sided warbler, double-crested cormorant, Swainson's thrush, red crossbill, black-throated blue warbler, western kingbird, Nashville warbler, ash-throated flycatcher, and Cassin's kingbird.

Figure S1 helps motivate the exclusion of the small number of species that had extremely negative overreporting indices. Without these values, the distribution of overreporting indices is less dramatically left-skewed.

These dropped species tended to have overall reporting rates from the bottom 50% of the distribution but showed no pattern in other species traits considered in this study (Figure S4). This suggests that outliers were the result of low-information conditions. Indeed, these primarily arose from cases of few or no iNaturalist observations in many of the hexes where the bird was reported in eBird. This could be partially explained by the fact that iNaturalist has far fewer total bird observations such that many rare or underreported species will never appear in the dataset in certain hexes, and therefore a rate difference cannot be reliably estimated in spite of the fact that a parametric bootstrap of median differences consistently predicts an extreme difference.

Table S1 aims to aid the interpretation of results from the cross-species meta-analysis when low-information outliers were excluded. Mass, color, and the proxy for species range were all significant. The effects for mass and color are positive while the effect for the species range proxy is negative.

The meta-analysis results are impacted by the inclusion of the 49 low information outliers. Table S2 aims to aid the interpretation of results from the meta-analysis when low information outliers were included. The significance of color is lost and the significance of the proxy for overall prevalence is gained. The signs for mass and proxy for spatial range do not change though they get much more extreme.

The 49 low-information outliers were: Abert's towhee, alder flycatcher, Arctic tern, Bachman's sparrow, bank swallow, Bicknell's thrush, black rosy-finch, black swift, black-chinned sparrow, boreal owl, Cassin's vireo, Connecticut warbler, Cordilleran flycatcher, dusky flycatcher, eastern whip-poor-will, elf owl, flammulated owl, gray flycatcher, greater sage grouse, Hammond's flycatcher, Henslow's sparrow, hepatic tanager, hoary redpoll, Hudsonian godwit, Kentucky warbler, king eider, king rail, Lucy's warbler, mountain plover, mountain quail, Nelson's sparrow, parasitic jaeger, Philadelphia vireo, pinyon jay, red knot, red phalarope, red-cockaded woodpecker, sage thrasher, Smith's longspur, stilt sandpiper, Swainson's warbler, Vaux's swift, Virginia's warbler, white-headed woodpecker, Williamson's sapsucker, yellow rail, yellow-bellied flycatcher, and yellow-billed loon.

Endangerment. We considered whether a species' endangerment status predicts its overreporting rate. We retrieved endangerment statuses for all species from the IUCN Red List of Threatened Species (1). Of the 424 species included in the meta-analysis, 399 were listed as Least Concern, 17 were listed as Near Threatened, 5 were listed as Vulnerable, and 2 (tricolored blackbird and whooping crane) were listed as Endangered. One species studied (black-necked stilt) was not listed.

Following the protocol used to identify order effects, we fit a separate meta-analysis examining the effects of endangerment, coding each listing status as a factor effect with "Not Listed" as the reference level. We did not find any statistically significant effects on our overreporting index based on species' endangerment status categories (see Table S3 for results with low information outliers removed and Table S4 for results from the full dataset). The uncertainties around the covariate estimates for each status were too large to make any formal conclusions.

While they accurately summarize the indices we estimated, these results are not necessarily extensible beyond the studied species. One reason for this is that our study design was not suited to endangered species. These species by definition are less abundant and usually have more restricted ranges. Therefore most species that were threatened or endangered did not meet the minimum qualification of positive IDs in at least 100 hexes in eBird. Others, such as those included in the final dataset and also some low-information outliers, suffered from insufficient data. We believe these findings are not generalizable to endangered species not included in the data, but we present them here to give the reader an idea of patterns present in the included data. However, a follow-up study specifically designed to look at endangerment status could use a similar approach and better target this question.

Phylogeny Interpretation. In this paper we chose to control for possible dependence between species based on phylogenetic relatedness. This allows us to start to disentangle whether, for example, colorful birds are overrepresented above and beyond what is expected based on their phylogenetic relationship to other overrepresented birds.

However, one might be less interested in why birds are over or underrepresented and instead more interested in the simple fact that they are over or underrepresented. In that case, the extra level of complexity of modeling the phylogenetic error is unnecessary. If we take out this piece of the model we get similar results in terms of effect sizes of species traits on the

overreporting index (see Table S5 for results with low information outliers removed and Table S6 for results from the full dataset). These results are slightly less conservative; now the proxy of overall prevalence was found to be statistically significant thanks to a slightly narrower level of uncertainty.

We used eBird's taxonomy to group species by order in the second-stage analysis (2).

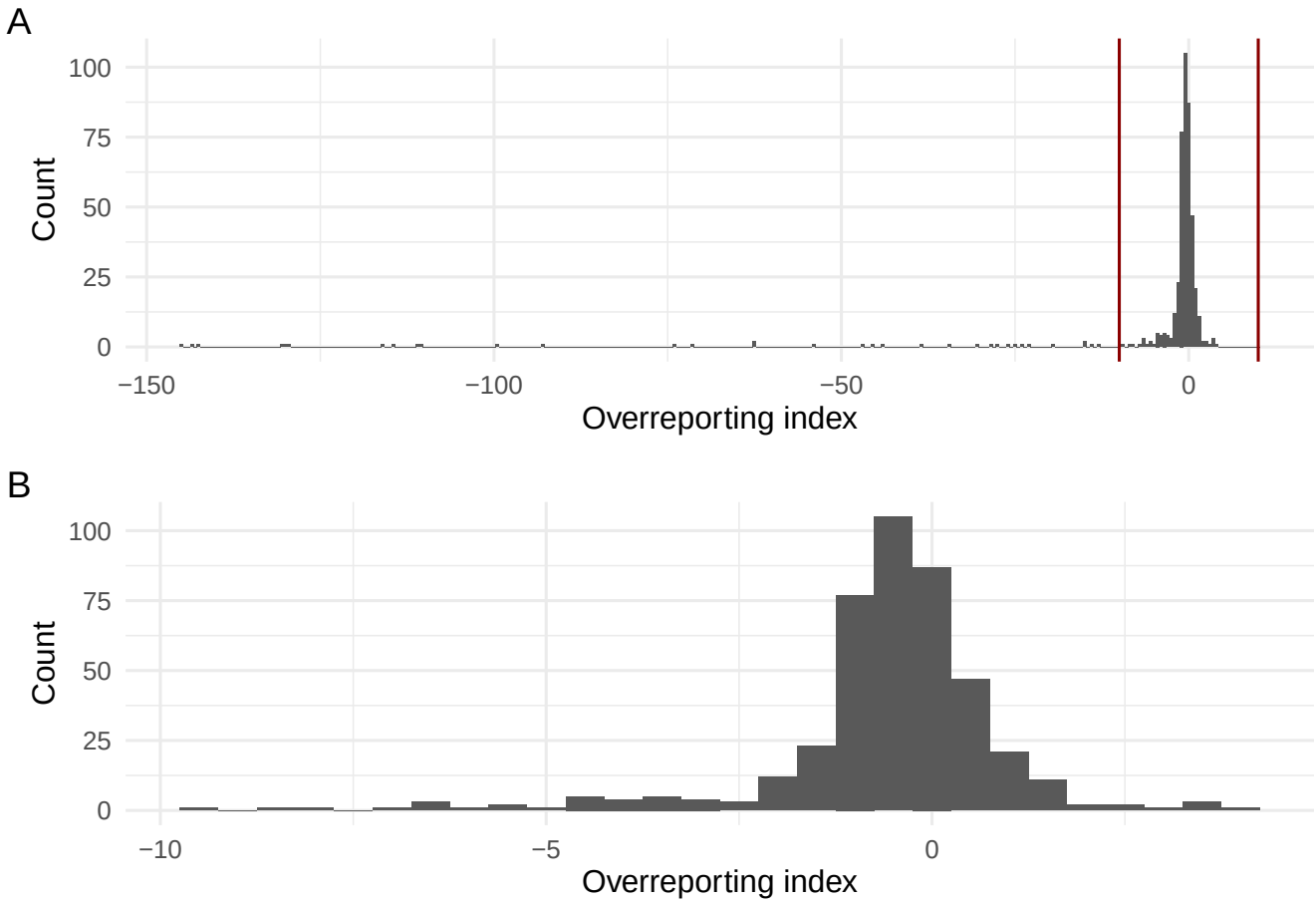

Fig. S1. Histograms of overreporting indices before and after filtering show that the bulk of the estimates are distributed near 0, with extreme values being spread over a large range. Most, but not all, of these extremely negative values were associated with large uncertainties. Red lines indicate the cutoff $(-10, 10)$. See the Materials and Methods section in the main manuscript for a discussion of how to interpret these extremely negative values.

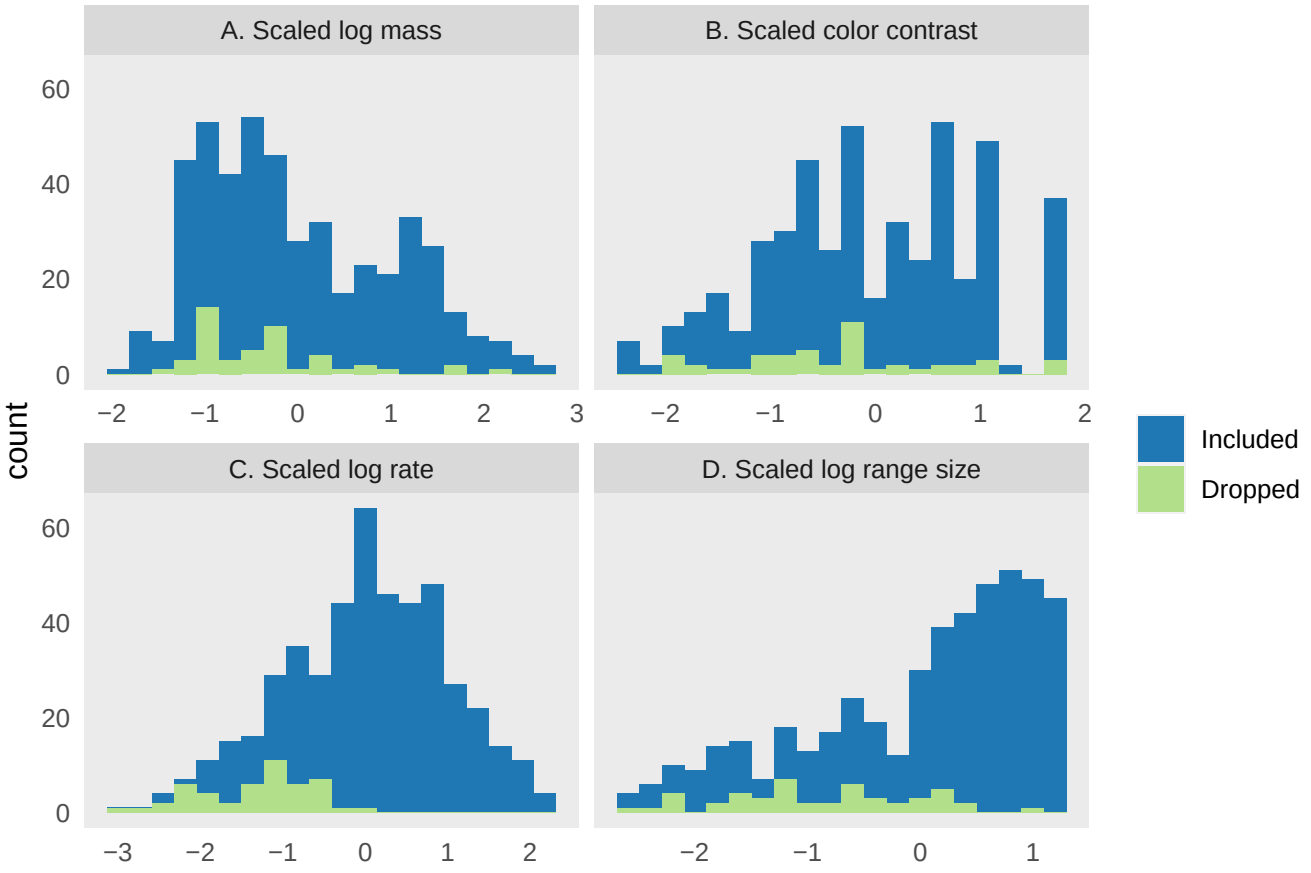

Fig. S2. Histograms of scaled species trait distributions, highlighting those species that were dropped; panel titles give x-axis labels. Dropped species tended to have lower reporting rates (C) overall, but did not show associations with other traits.

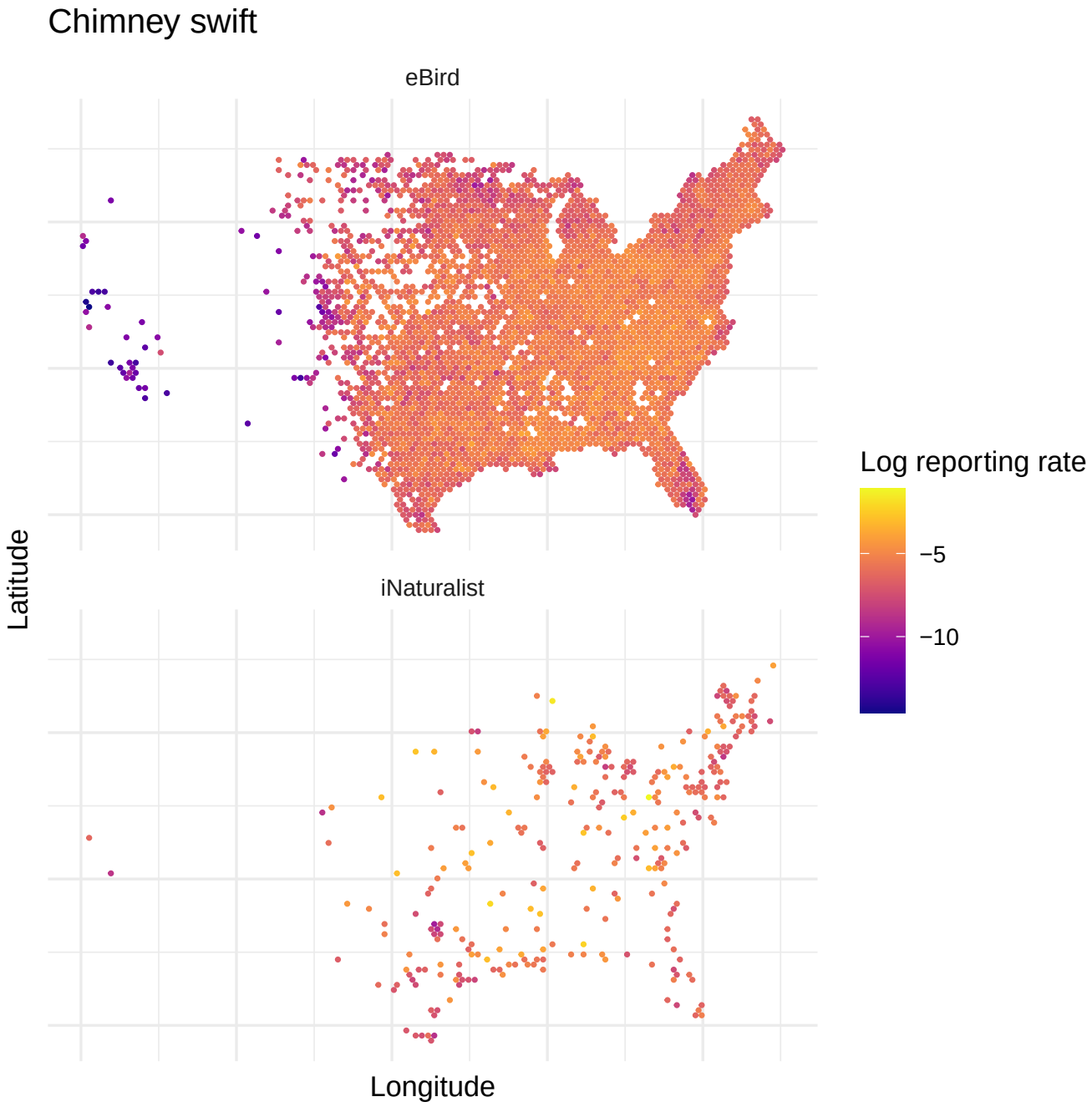

Fig. S3. Distribution of observations of chimney swifts (a highly underreported species; overreporting index and 95% CI $= -3.38 \pm 0.30$) in eBird complete checklists and iNaturalist. Each point represents a spatial hexagon in which an observer reported the species; hex points without data contained no observations of the species. In this example, the chimney swift is widely reported across the eastern U.S. in eBird (top), but in iNaturalist is reported in relatively few hexes.

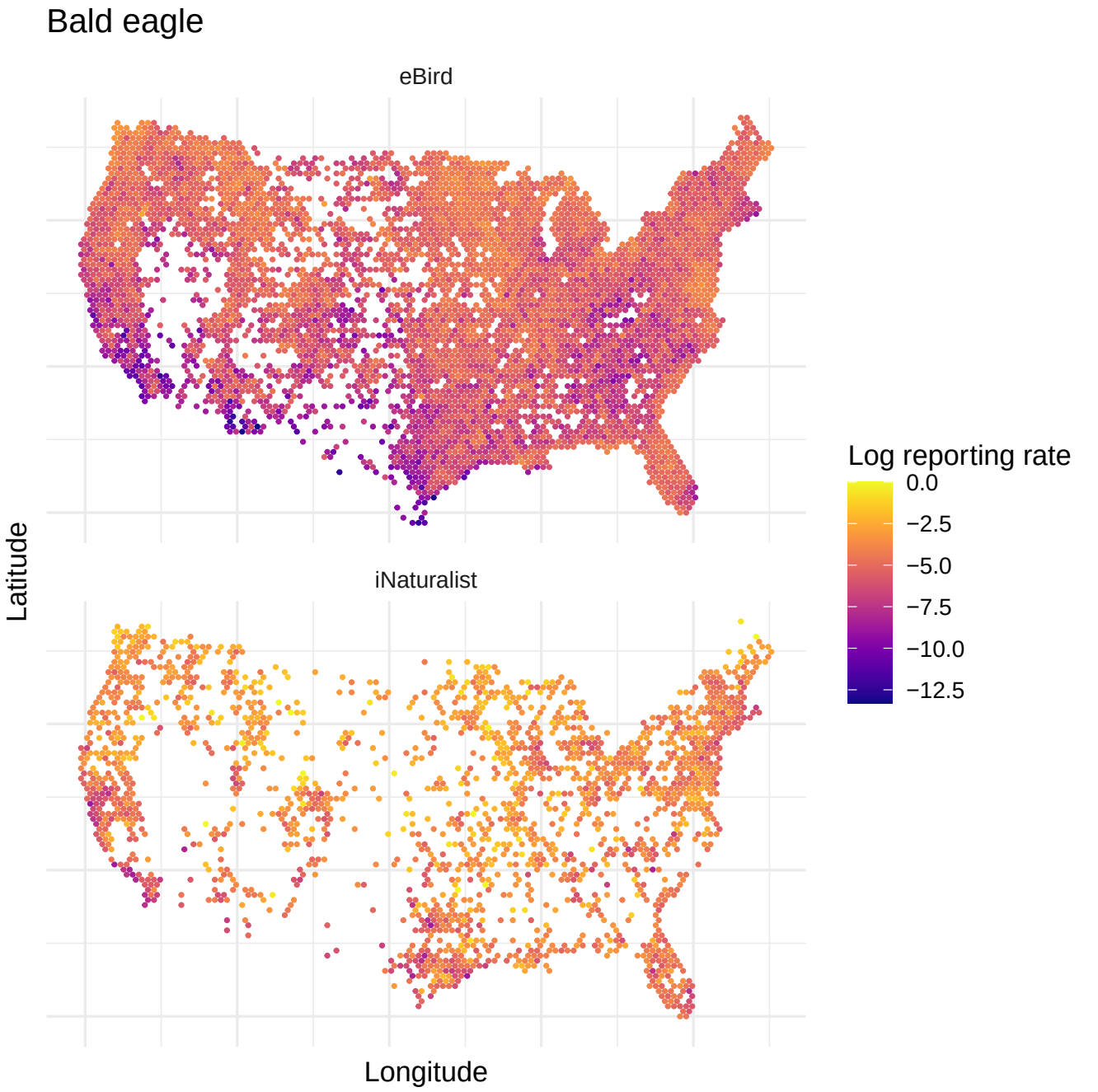

Fig. S4. Distribution of observations of bald eagles (a highly overreported species; overreporting index and 95% CI $= 0.97 \pm 0.03$) in eBird complete checklists and iNaturalist. Each point represents a spatial hexagon in which an observer reported the species; hex points without data contained no observations of the species. While the bald eagle was reported in more hexes overall in eBird, it was reported at a lower rate in those hexes.

Table S1. Meta-analysis coefficients and interpretations for species traits with low information outliers removed (overreporting indices greater than 10 or less than -10). All covariates except for the proxy of overall prevalence were found to be statistically significant.

Covariate	Effect Size	Interpretation
Scaled log mass	0.31 (0.15, 0.47)	An increase by one standard deviation of bird size on the log scale is associated with an expected 36% increase in the odds of overreporting.
Scaled color	0.12 (0.04, 0.19)	An increase by one standard deviation of bird color contrast is associated with an expected 12% increase in the odds of overreporting.
Scaled log number of hexes where reported	-0.13 (-0.25, -0.03)	An increase by one standard deviation of number of hexes on the log scale is associated with an expected 11% decrease in the odds of overreporting.
Scaled log proportion of eBird checklists where found	-0.08 (-0.19, 0.03)	An increase by one standard deviation of proportion of eBird checklists where a species is found, on the log scale, is associated with a 8% decrease in the odds of overreporting.

Table S2. Meta-analysis coefficients and interpretations for species traits with low information outliers included. All but color are statistically significant, but the effect sizes are very extreme on this scale, alluding to instability.

Covariate	Effect Size	Interpretation
Scaled log mass	4.81 (0.49, 9.14)	An increase by one standard deviation of bird size on the log scale is associated with an expected nearly 23-fold increase in overreporting.
Scaled color	0.23 (-1.47, 1.92)	An increase by one standard deviation of bird color contrast is associated with an expected 26% increase in the odds of overreporting.
Scaled log number of hexes where spotted	-4.35 (-6.50, -2.19)	An increase by one standard deviation of number of hexes on the log scale is associated with an expected nearly 78-fold decrease in the odds of overreporting.
Scaled log proportion of eBird checklists where found	5.96 (3.61, 8.31)	An increase by one standard deviation of proportion of eBird checklists where a species is found, on the log scale, is associated with a nearly 388-fold increase in overreporting.

Table S3. Meta-analysis coefficients and interpretations for endangerment categories with low information outliers removed (overreporting indices greater than 10 or less than -10). None of the categories were found to be statistically significantly different from the "least concern" group, which was set as the reference level.

Covariate	Effect Size
Endangered status	1.57 (-0.58, 3.72)
Near Threatened status	-0.25 (-0.63, 0.13)
Not Listed status	-0.02 (-1.29, 1.24)
Vulnerable status	-0.28 (-0.97, 0.42)

Table S4. Meta-analysis coefficients and interpretations for endangerment categories with low information outliers included and no phylogenetic random effect accounted for. None of the categories were found to be statistically significantly different from the "least concern" group, which was set as the reference level. We can see that the effect sizes and bounds are very extreme on this scale, alluding to the instability.

Covariate	Effect Size
Endangered status	-7.87 (-17.49, 1.75)
Near Threatened status	-2. 65 (-6.00 0.69)
Not Listed status	0.55 (-29.90, 30.99)
Vulnerable status	0.97 (-8.10, 10.03)

Table S5. Meta-analysis coefficients and interpretations for species traits with low information outliers removed (overreporting indices greater than 10 or less than -10) and no phylogenetic random effect accounted for. All covariates were found to be statistically significant.

Covariate	Effect Size
Scaled log mass	0.26 (0.18, 0.33)
Scaled color	0.11 (0.03, 0.19)
Scaled log number of hexes where reported	-0.14 (-0.25, -0.02)
Scaled log proportion of eBird checklists where found	-0.18 (-0.30, -0.06)

Table S6. Meta-analysis coefficients and interpretations for species traits with low information outliers included and no phylogenetic error accounted for. Only scaled log mass and scaled log proportion of eBird checklists where found are statistically significant. The latter has an effect size that is especially extreme on this scale, still alluding to the instability.

Covariate	Effect Size
Scaled log mass	1.20 (0.29, 2.11)
Scaled color	0.37 (-0.55, 1.29)
Scaled log number of hexes where spotted	-0.61 (-1.98, 0.75)
Scaled log proportion of eBird checklists where found	4.48 (3.00, 5.97)

References

1. IUCN, The IUCN Red List of Threatened Species. Version 2021-2, Technical report (2021).
2. eBird, The eBird taxonomy (2021) https://ebird.org/science/use-ebird-data/the-ebird-taxonomy.