Supporting Information. Daniel Fink, Tom Auer, Alison Johnston, Viviana Ruiz-Gutierrez, Wesley M. Hochachka, and Steve Kelling. 2020. Modeling avian full annual cycle distribution and population trends with citizen science data. *Ecological Applications.*

Appendix S4: Subsampling procedures to estimate uncertainty of the occurrence and abundance estimates

We used the upper 5% trimmed mean to estimate the expected occurrence and abundance across the ensemble because it is a robust estimator that guards against positive bias. A straightforward, brute force approach to estimate the uncertainty for the ensemble mean can be computed by bootstrapping the ensemble trimmed means. However, because fitting the ensemble already entails fitting 100 base models, this approach is computationally prohibitive. Instead, we employed a subsampling approach (Politis *et al.* 2009), creating ensemble replicates by subsampling the base models.

We faced two challenges implementing this approach. First, the sample size, here, the ensemble support, was relatively small, 75–100. Second, the computational efficiency of the approach was very important because we needed to compute uncertainty estimates for up to 676M quantities per species (6.5M locations * 52 weeks * 2 estimates per location [1 for both occurrence & abundance] + 14M training & testing checklists * 2 estimates per checklist [1 for both occurrence & abundance]). To deal with these challenges we followed the computational strategy of Geyer (2013) and selected a set of parameter settings that balanced the quality of the interval estimates with the computational costs of generating them. We computed estimates of the upper 90th lower 10th confidence limits by subsampling with two different sizes and then computing a rate parameter correction to adjust for the original ensemble support. Following Geyer (2013), we subsampled with the square root of the ensemble support and the -1.5 power of the ensemble support.

To check these parameter settings, a small simulation test was run. We found that for sample sizes of 25 or less, the rate parameter estimates tended to be too small, resulting in intervals that were too small and had poor coverage. To mitigate this, we adjusted the rate parameter estimate upwards by 0.5 of the rate parameter's standard error, producing more conservative uncertainty estimates. In the cases where the rate parameter estimate was negative, subsampling was not performed and quantiles of the entire sample were used producing conservative uncertainty estimates. Note that ensemble support requirements for the occurrence and abundance estimates, between 75 and 100, excludes most of these small sample size complications.

Literature Cited

Geyer, C. J. (2013) 5601 Notes: The Subsampling Bootstrap, Available at: http://www.stat.umn.edu/geyer/5601/notes/sub.pdf . Last accessed 06 December 2017.

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