frontiers | Frontiers in Bird Science

TYPE Field Grand Challenge
PUBLISHED 09 September 2022
DOI 10.3389/fbirs.2022.994063

Check for updates

OPEN ACCESS

EDITED AND REVIEWED BY
Christoph Randler,
University of Tübingen, Germany

*CORRESPONDENCE
W. Douglas Robinson
douglas.robinson@oregonstate.edu

RECEIVED 14 July 2022
ACCEPTED 15 July 2022
PUBLISHED 09 September 2022

CITATION
Robinson WD (2022) Grand challenges at the frontiers of bird science.
Front. Bird Sci. 1:994063.
doi: 10.3389/fbirs.2022.994063

Grand challenges at the frontiers of bird science

W. Douglas Robinson*

Oak Creek Lab of Biology, Department of Fisheries, Wildlife and Conservation Sciences, Oregon State University, Corvallis, OR, United States

KEYWORDS

birds, ornithology, conservation, ecology, migration

Birds stun us with their feats of flight. Their beauty, jaw-dropping vocal performances, courtship displays and even their ingenuity capture our attention. We share the planet with feathered creatures who signal trouble ahead and, all at once, reveal incredible resilience to change. Our fascination with birds engenders concern that they prosper despite human influences on our shared environment. Birds possess a gravitational pull on our attention. Birds matter.

Despite the disproportionate attention birds receive, we have much to learn about them. An abundance of scientific studies on birds–wild, captive and domesticated alike–reveals that their overall complexity as biological organisms and, particularly their mobility, raises challenges. Characterizing the cutting edge of knowledge in any field of study is the grand challenge of all grand challenges. It is analogous to Heisenberg's uncertainty principle. By the time you identify it, it has already moved and you are wrong. To reduce the chances of mischaracterizing the current edge of knowledge, one can prognosticate and extrapolate. What are the directions we are heading in scientific studies of birds? Are looming technological solutions about to remove former barriers and allow rapid progress soon? With continual reduction in size and improvements in power and precision of tracking devices, for example, we stand to radically improve our understanding of avian movements and migration (Bridge et al., 2011). As the genomic, proteomic and transcriptomic revolution proceeds in concert with advances in computer science in the coming decades, numerous insights into the evolutionary history and biological functions of birds will be revealed. Many discoveries will be unexpected.

Any one view of where a field of study is headed is necessarily biased toward the subdisciplines slightly better understood by the author than sub-fields rarely visited. With this admission in mind, I humbly offer a tiny sample of the grand challenges to be addressed in the next few decades in bird science.

Improving the scientific value of collaborations between professionals and bird enthusiasts

Ornithology has a long history of important contributions from non-professionals. Various monikers have been applied to such people, such as community or citizen scientists, amateur ornithologists, bird enthusiasts, and birders. Regardless of one's preferred term, the essential point is that hundreds of thousands of people across the world do not get paid to study birds yet have incredible knowledge about birds. Today, with continually increasing access to the internet, sharing that knowledge with other people who care about birds is easier than ever. Global bird observation databases such as eBird (and many others in various countries across the world), gather species lists, counts, locations, details on observer effort and even photographs and sound recordings by the millions (Wood et al., 2011). The temptation and opportunity to answer pressing ecological questions with such data is strong. The temporal coverage and spatial extent of surveys dwarf what any group of professionals could ever achieve on their own.

The variety of questions that could be addressed with such data is massive. Free availability of species lists with numbers of birds counted at millions of locations presents apparent opportunities to characterize abundance and track changes across time and space. But the very traits of birds that attract us to them, their sounds and their visibility, are balanced against traits that inhibit attainment of accurate counts. Many individuals (immatures, females) and even entire species are small, quiet, and hardly visible at all. Counting birds accurately, therefore, poses serious challenges (Robinson et al., 2018). Quantitative biologists continue to develop sophisticated survey and analytical techniques to estimate bird numbers by accounting and adjusting for the difficulties of detectability (Hutto, 2016; Gomez et al., 2018). Modern techniques (e.g., recording distance of birds from observers, time of detection, number of time intervals in which each bird was detected) allow adjustment of raw counts to more closely approximate true abundance (Farnsworth et al., 2002; Royle et al., 2004). However, most community science count data lack the additional variables necessary to correct counts. Without corrections, characterization of relative abundance (numbers of each species compared with other species present or with the same species at different locations) and density (numbers per unit area) from simple raw count data may be wildly inaccurate.

A grand challenge is to determine the extent to which the massive amount of simple count data in public databases can be integrated with information from much smaller professional data sets and adjusted for detectability problems to improve accuracy of abundance estimates. Recent comparisons of counting accuracy between professional and enthusiast counts show differences can be severe (Robinson et al., 2021b). At least for some kinds of surveys, especially shorter duration stationary counts, detectability offsets derived from professional data and then applied to enthusiast-generated data generate remarkably similar density estimates (Sólymos et al., 2013; Hallman and Robinson, 2020a). The extent to which such methods apply across habitats, seasons, and observer skill levels needs further evaluation.

Also on the horizon are opportunities to learn more about the development of field skills over time. Many worry that community science databases possess too many errors and will generate misleading results about the biology of birds. Current evidence is reasonably clear that careful filtering to select data only most relevant to a particular research question and only from the most experienced observers produces results that align well with results generated from highly trained professionals (Steen et al., 2019). In some cases, more than 90% of community data goes unused after the filtering process (Hallman and Robinson, 2020b). Yet those 90% can be used for thousands of other questions, such as learning how birders improve their skills through time, how the adoption of and contributions to community science differ across geography, and other aspects of the human dimensions of biodiversity interests. Dismissing the mass of data entirely because some fraction of it does not align well with professional measurements of bird populations overlooks an opportunity to learn about human engagement with birds, citizen science and the environment. Studying ways to educate and motivate enthusiasts to generate more reliable and accurate data is certainly a major challenge that can be addressed in the next decade.

Making the old new again: Foundations of natural history and the value of legacy

Ornithology is anchored in a long history of natural history studies. As with bird counting, the internet has facilitated the development and sharing of databases that aggregate natural history data on birds. Sharing of such databases has allowed many novel investigations of evolutionary patterns of trait divergence, convergence and overall diversification of life strategies (Livezey et al., 2016; Tobias et al., 2022). Yet, sample sizes of trait measurements are often small for many taxa, particularly for species endemic to the most biodiverse places on earth, so there remains much to learn in terms of geographic variation in natural history traits. Furthermore, some natural history information is nearly or entirely absent for most species, such as details of dietary items and how diets vary across time and space (Sherry et al., 2020; Sherry, 2021). The paucity of such information hamstrings our efforts to understand population declines in the thousands of species that consume insects. We know, for example, that evidence indicates aerial insectivores have declined faster than many other groups of birds (Bowler et al., 2019). The declines may be linked to evidence that insects are declining globally (Wagner, 2020; Montgomery et al., 2021). Unfortunately, the fundamentally important work of documenting diets of birds does not garner the same respect as testing an ecological hypothesis *du jour*. As a field of study, we need to discover better ways to reward those who develop the skills and knowledge to study natural history rigorously (Tewksbury et al., 2014). Further, the level of sophisticated knowledge required to study insectivore diets is substantial. Like so many scientific topics, encouraging collaborations among experts, such as ornithologists and entomologists co-creating a database of avian diet information, should be a priority to ensure rapid and reliable progress. Perhaps the increasing improvements in eDNA technology will revitalize the level of respect practitioners of dietary studies enjoy (Ruppert et al., 2019; Hoenig et al., 2022).

Similarly, the documentation of habitat choice in birds has largely fallen out of favor. Yet, with many global climate models predicting substantial migration and even disappearance of some habitats over the next century, anticipating which bird species will be most negatively affected by such changes relies upon basic natural history data. What habitats contain the majority of each species' individuals and, more importantly, what is the range of habitat characteristics that each species occupies? Ecological plasticity is expected to promote winners in a changing environment (Charmantier et al., 2008), yet the number of species for which habitat breadth has been rigorously quantified is surprisingly small. The wide availability of data from remote sensing methods, which characterize the reflectance data associated with habitat cover, provides opportunities to rigorously describe the range of habitats occupied (Hopkins et al., 2022). When combined with the massive distributional information in citizen science databases, especially when contributors have identified the precise geo-referenced locations where birds were detected, rapid progress can be made quantifying habitat choices of birds (Rousseau and Betts, 2022). Characterizing how such choices vary temporally and spatially, then linking to vegetation models predicting long-term changes, can provide us with tools to reliably predict changes in bird distributions and population sizes. Such data also allow us to look backward in time, modeling past abundances and distributions, which can provide important perspective on the establishment of current conservation priorities (Hallman et al., 2021).

Prediction of responses to environmental change requires more than information on habitat choice and current distributions (Johnston et al., 2019). Improving our understanding of the physiological limits of birds still needs additional research. The fundamental work of characterizing thermal tolerance zones and associations with body mass and evolutionary histories is well-established (Bakken, 1992; Swanson, 2010). Many bird species are remarkably resilient to warming or cooling conditions, thanks in part to their mobility, but their foods may not be so resilient. Thus, integrated studies that combine physiological information from birds with data on expected responses of major dietary items are still needed. Likewise, bird populations are probably constrained more by diseases than we currently appreciate. Workings of the avian immune system, especially in wild bird populations, require much more study. Importantly, our understanding of the fundamental biology of birds, foundational to protection of wild populations, stands firmly on a long history of detailed scientific studies of captive and domesticated birds. Better integration of information from poultry science and other studies of captive or domesticated birds with data from wild birds could reveal new insights into the challenges and constraints facing wild bird populations.

Benchmarking bird populations across the globe

Akin to views of natural history, the value placed on carefully constructed baseline measurements of bird populations is lower than it should be. Continual concerns for declining bird populations in the face of climate dynamism and human-caused habitat alteration are difficult to appease without adequate baselines. As all populations are dynamic through time, attribution of causes of declines are too often speculative. The establishment of rigorously quantified benchmark measurements of community richness and species' abundances based on precisely repeatable methods provides our best chance to characterize changes and definitively understand their causes (Robinson and Curtis, 2020; Robinson et al., 2020). Notwithstanding proliferation of new analytical techniques that can use portions of massive citizen science databases to address abundance changes, concerns about noise, error and bias pose formidable barriers when studying organisms that are inherently difficult to count accurately. Intentionally designed benchmark inventories provide opportunities to understand change with a much greater level of rigor. Yet, benchmark surveys of individual communities may be challenging to publish in many journals, in part because of biases against "basic monitoring" information derived largely from concerns that such studies might not be cited quickly or frequently enough to elevate journal impact factors. The appreciation for the value of establishing transgenerational collaborations, where benchmark surveys are designed specifically so that people scores or hundreds of year from now will repeat them, needs elevation (Robinson et al., 2021a). Paraphrasing the famous cosmologist Carl Sagan, who often spoke about human-caused long-term influences on climate: Caring about what you leave for the next generation is the grown-up way to think about things. Fortunately, new opportunities for archiving benchmark data and metadata in searchable databases and also for publishing data papers in journals less obsessed with impact factors are improving (Costello and Wieczorek, 2014). Finally, benchmark measurements need not focus only on abundance estimation. Archival of genetic samples in museums provides future scientists opportunities to utilize rapidly improving technological tools to compare future samples of genetic material with archived material and then to identify shifts in gene frequencies and other aspects of the biochemical machinery that respond to environmental dynamism (Garcia and Robinson, 2021).

Tracking birds

Like bird survey data, the donation of "simple" observations of birds moving through time and space to public databases, such as movebank.org, creates new opportunities to learn more about avian movements and migration faster than at any time in history (Kays et al., 2022). The integration of movement data across dozens of species and geographic zones promises to reveal remarkable new insights into avian navigational clues, effects of weather and climate shifting on migration routes and timing, the preponderance of previously poorly known molt-migration strategies, much better quantification of mortality rates, insights into movements of nomadic and irruptive species, mitigation strategies for bird and aerial vehicle conflicts and countless other fascinating questions.

Many challenges remain in the study of bird movements and migration. Among the many, two I will note are the persistent need for ever-smaller tracking devices that can be applied to the smallest birds and, for those same tiny devices, abilities to transmit data without the researcher having to recapture the bird (Bridge et al., 2011). These have been formidable challenges partly because power technologies (batteries, in particular) are still too heavy if one wishes to follow birds for more than a few days. Passively obtaining data from transmitters requires that the devices have sufficient power to communicate with tower arrays, such as the rapidly proliferating arrays of motus antennas, or cellular communication networks. The latter would be ideal, but the power demands of linking with the cellular network are not trivial, in part because towers are often still relatively widely spaced, extending the time required to find and then handshake with towers to transfer data. Some devices may be detected from space, such as with the ICARUS project or similar lower-orbit satellites (Jetz et al., 2022), but the challenges of piercing through significant anthropogenic noise sources on the planet's surface remain formidable. A grand challenge ahead involves the idea that our cellular devices and the related infrastructure with which they interact, can all be listening to and communicating with each other (Rose et al., 2015). This so-called internet of things opens the possibility that towers, widely spaced as they presently are, might be augmented by the roaming masses of cell phones listening for birds and accepting and transferring locational data to researchers, possibly an "internet of wings."

In summary, the motivation and desire for more information on birds is high. We live in one of the most exciting times in history for the study of birds.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Bakken, G. S. (1992). Measurement and application of operative and standard operative temperatures in ecology. *Am. Zool* 32, 194–216. doi: 10.1093/icb/32.2.194

Bowler, D. E., Heldbjerg, H., Fox, A. D., de Jong, M., and Böhning-Gaese, K. (2019). Long-term declines of European insectivorous bird populations and potential causes. *Conserv. Biol.* 33, 1120–1130. doi: 10.1111/cobi.13307

Bridge, E. S., Thorup, K., Bowlin, M. S., Chilson, P. B., Diehl, R. H., Fléron, R. W., et al. (2011). Technology on the move: recent and forthcoming innovations for tracking migratory birds. *BioScience* 61, 689–698. doi: 10.1525/bio.2011.61.9.7

Charmantier, A., McCleery, R. H., Cole, L. R., Perrins, C., Kruuk, L. E. B., and Sheldon, B. C. (2008). Adaptive phenotypic plasticity in response to climate change in a wild bird population. *Science* 320, 800–803. doi: 10.1126/science.1157174

Costello, M. J., and Wieczorek, J. (2014). Best practice for biodiversity data management and publication. *Biol. Conserv.* 173, 68–73. doi: 10.1016/j.biocon.2013.10.018

Farnsworth, G. L., Pollock, K. H., Nichols, J. D., Simons, T. R., Hines, J. E., and Sauer, J. R. (2002). A removal model for estimating detection probabilities from point-count surveys. *Auk* 119, 414–425. doi: 10.1093/auk/119.2.414

Garcia, N. C., and Robinson, W. D. (2021). Current and forthcoming approaches for benchmarking genetic and genomic diversity. *Front. Ecol. Evol.* 9, 622603. doi: 10.3389/fevo.2021.622603

Gomez, J. P., Robinson, S. K., Blackburn, J. K., and Ponciano, J. M. (2018). An efficient extension of N-mixture models for multi-species abundance estimation. *Methods Ecol. Evol.* 9, 340–353. doi: 10.1111/2041-210X.12856

Hallman, T. A., and Robinson, W. D. (2020a). Comparing multi- and single-scale species distribution and abundance models built with the boosted regression tree algorithm. *Landscape Ecol.* 35, 1161–1174. doi: 10.1007/s10980-020-01007-7

Hallman, T. A., and Robinson, W. D. (2020b). Deciphering ecology from statistical artefacts: competing influence of sample size, prevalence and habitat specialization on species distribution models and how small evaluation datasets can inflate metrics of performance. *Divers. Distributions* 26, 315–328. doi: 10.1111/ddi.13030

Hallman, T. A., Robinson, W. D., Curtis, J. R., and Alverson, E. R. (2021). Building a better baseline to estimate 160 years of avian population change and create historically informed conservation targets. *Conserv. Biol.* 35, 1256–1267. doi: 10.1111/cobi.13676

Hoenig, B. D., Snider, A. M., Forsman, A. M., Hobson, K. A., Latta, S. C., Miller, E. T., et al. (2022). Current methods and future directions in avian diet analysis. *Ornithology* 139, ukab077. doi: 10.1093/ornithology/ukab077

Hopkins, L. M., Hallman, T. A., Kilbride, J., Robinson, W. D., and Hutchinson, R. A. (2022). A comparison of remotely sensed environmental predictors for avian distributions. *Landsc. Ecol.* 37, 997–1016. doi: 10.1007/s10980-022-01406-y

Hutto, R. L. (2016). Should scientists be required to use a model-based solution to adjust for possible distance-based detectability bias? *Ecol. Appl.* 26, 1287–1294. doi: 10.1002/eap.1385

Jetz, W., Tertitski, G., Kays, R., Mueller, U., Wikelski, M., Åkesson, S., et al. (2022). Biological Earth observation with animal sensors. *Trends Ecol. Evol.* 37, 293–298. doi: 10.1016/j.tree.2021.11.011

Johnston, A. S. A., Boyd, R. J., Watson, J. W., Paul, A., Evans, L. C., Gardner, E. L., et al. (2019). Predicting population responses to environmental change from individual-level mechanisms: towards a standardized mechanistic approach. *Proc. Biol. Sci.* 286, 20191916. doi: 10.1098/rspb.2019.1916

Kays, R., Davidson, S. C., Berger, M., Bohrer, G., Fiedler, W., Flack, A., et al. (2022). The Movebank system for studying global animal movement and demography. *Methods Ecol. Evol.* 13, 419–431. doi: 10.1111/2041-210X.13767

Livezey, K. B., Fernández-Juricic, E., and Blumstein, D. T. (2016). Database of bird flight initiation distances to assist in estimating effects from human disturbance and delineating buffer areas. *J. Fish Wildl. Manag.* 7, 181–191. doi: 10.3996/082015-JFWM-078

Montgomery, G. A., Belitz, M. W., Guralnick, R. P., and Tingley, M. W. (2021). Standards and best practices for monitoring and benchmarking insects. *Front. Ecol. Evol.* 8, 1–18. doi: 10.3389/fevo.2020.579193

Robinson, W. D., and Curtis, J. R. (2020). Creating benchmark measurements of tropical forest bird communities in large plots. *Condor*. 122, 1–15. doi: 10.1093/condor/duaa015

Robinson, W. D., Errichetti, D., Pollock, H. S., Martinez, A., Stouffer, P. C., Shen, F.-Y., et al. (2021a). Big bird plots: benchmarking neotropical bird communities to address questions in ecology and conservation in an era of rapid change. *Front. Ecol. Evol.* 9, 697511. doi: 10.3389/fevo.2021.697511

Robinson, W. D., Hallman, T. A., and Curtis, J. R. (2020). Benchmarking the avian diversity of Oregon in an era of rapid change. *Northwestern Naturalist* 101, 180–193. doi: 10.1898/1051-1733-101.3.180

Robinson, W. D., Hallman, T. A., and Hutchinson, R. A. (2021b). Benchmark bird surveys help quantify counting accuracy in a citizen-science database. *Front. Ecol. Evol.* 9, 568278. doi: 10.3389/fevo.2021.568278

Robinson, W. D., Lees, A. C., and Blake, J. G. (2018). Surveying tropical birds is much harder than you think: a primer of best practices. *Biotropica* 50, 846–849. doi: 10.1111/btp.12608

Rose, K., Eldridge, S., and Chapin, L. (2015). *The Internet of Things: An Overview Understanding the Issues and Challenges of a More Connected World*. Geneva, Switzerland: Internet Society.

Rousseau, J. S., and Betts, M. G. (2022). Factors influencing transferability in species distribution models. *Ecography* 2022, e06060. doi: 10.1111/ecog.06060

Royle, J. A., Dawson, D. K., and Bates, S. (2004). Modeling abundance effects in distance sampling. *Ecology* 85, 1591–1597. doi: 10.1890/03-3127

Ruppert, K. M., Kline, R. J., and Rahman, M. S. (2019). Past, present, and future perspectives of environmental DNA (eDNA) metabarcoding: A systematic review in methods, monitoring, and applications of global eDNA. *Glob. Ecol. Conserv*. 17, e00547. doi: 10.1016/j.gecco.2019.e00547

Sherry, T. W. (2021). Sensitivity of tropical insectivorous birds to the anthropocene: a review of multiple mechanisms and conservation implications. *Front. Ecol. Evol.* 8, 1–20. doi: 10.3389/fevo.2021.662873

Sherry, T. W., Kent, C. M., Sánchez, N. V., and Sekercioglu, Ç. H. (2020). Insectivorous birds in the neotropics: ecological radiations, specialization, and coexistence in species-rich communities. *The Auk* 137, ukaa049. doi: 10.1093/auk/ukaa049

Sólymos, P., Matsuoka, S. M., Bayne, E. M., Lele, S. R., Fontaine, P., Cumming, S. G., et al. (2013). Calibrating indices of avian density from non-standardized survey data: making the most of a messy situation. *Methods Ecol. Evol.* 4, 1047–1058. doi: 10.1111/2041-210X.12106

Steen, V. A., Elphick, C. S., and Tingley, M. W. (2019). An evaluation of stringent filtering to improve species distribution models from citizen science data. *Divers Distributions* 25, 1857–1869. doi: 10.1111/ddi.12985

Swanson, D. L. (2010). Seasonal metabolic variation in birds: functional and mechanistic correlates. *Curr. Ornithol.* 17, 75–129. doi: 10.1007/978-1-4419-6421-2_3

Tewksbury, J. J., Anderson, J. G. T., Bakker, J. D., Billo, T. J., Dunwiddie, P. W., Groom, M. J., et al. (2014). Natural history's place in science and society. *BioScience* 64, 300–310. doi: 10.1093/biosci/biu032

Tobias, J. A., Sheard, C., Pigot, A. L., Devenish, A. J. M., Yang, J., Sayol, F., et al. (2022). AVONET: morphological, ecological and geographical data for all birds. *Ecol. Lett.* 25, 581–597. doi: 10.1111/ele.13898

Wagner, D. L. (2020). Insect declines in the anthropocene. *Annu. Rev. Entomol.* 65, 457–480. doi: 10.1146/annurev-ento-011019-025151

Wood, C., Sullivan, B., Iliff, M., Fink, D., and Kelling, S. (2011). eBird: engaging birders in science and conservation. *PLoS Biol* 9, e1001220. doi: 10.1371/journal.pbio.1001220