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PERSPECTIVE

Understanding the value of imperfect science from national estimates of bird mortality from window collisions

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ABSTRACT

The publication of a U.S. estimate of bird–window collisions by Loss et al. is an example of the somewhat contentious approach of using extrapolations to obtain large-scale estimates from small-scale studies. We review the approach by Loss et al. and other authors who have published papers on human-induced avian mortality and describe the drawbacks and advantages to publishing what could be considered imperfect science. The main drawback is the inherent and somewhat unquantifiable bias of using small-scale studies to scale up to a national estimate. The direct benefits include development of new methodologies for creating the estimates, an explicit treatment of known biases with acknowledged uncertainty in the final estimate, and the novel results. Other overarching benefits are that these types of papers are catalysts for improving all aspects of the science of estimates and for policies that must respond to the new information.

Keywords: Estimates, window collisions, mortality

Comprendre la valeur d'une science imparfaite à partir des estimations nationales de mortalité d'oiseaux dues aux collisions contre les fenêtres

RÉSUMÉ

La publication d'une estimation des collisions d'oiseaux contre les fenêtres aux États-Unis par Loss et al. est un exemple de l'approche quelque peu controversée de l'utilisation des extrapolations pour obtenir des estimations à grande échelle à partir d'études à petite échelle. Nous passons en revue l'approche de Loss et al. et d'autres auteurs qui ont publié des articles sur la mortalité aviaire d'origine anthropique et décrivons les inconvénients et les avantages de publier ce qui pourrait être considéré comme une science imparfaite. Le principal inconvénient est le biais inhérent et impossible à quantifier de l'utilisation d'études à petite échelle pour extrapoler l'estimation à une échelle nationale. Les avantages directs incluent le développement de nouvelles méthodologies pour créer les estimations, un traitement explicite des biais connus avec une incertitude admise dans l'estimation finale, ainsi que de nouveaux résultats. D'autres avantages globaux sont que ces types d'articles sont des catalyseurs pour améliorer tous les aspects de la science des estimations et pour les politiques qui doivent répondre aux nouvelles informations.

Mots-clés: Estimations, collisions contre les fenêtres, mortalité

Replication, randomization, representativeness, and other underlying design principles are the hallmarks of well-designed, well-regarded, and well-received scientific studies. However, some important ecological issues are not neatly packaged for examination with an appropriately designed mensurative or experimental approach. Extrapolation is one technique that can be used with ad hoc data, but it comes with complexities that are absent from a purpose-built study. Such is the case for scaling up to a continental or national perspective for any widespread phenomenon, for example the estimate of bird mortality from window collisions by Loss et al. (2014) in this issue. While the Loss et al. (2014) study and others like it (e.g., Blancher 2013, Hobson et al. 2013, Loss et al. 2013, Machtans et al. 2013) come with significant caveats and criticisms, they provide a strong incentive to advance both science and policy to address the underlying problems for birds. It is worth considering the imperfect science necessary to get a national estimate of bird mortality from window collisions, as doing so will reveal some surprising benefits of such work.

Making national-scale inferences by extrapolating small samples is not novel in ecology or other contexts. Public opinion polls in Canada (http://www.ekospolitics.com) often sample less than 0.01% of the population. Approval ratings of American presidents can be based on samples of

0.001% of the population (http://www.gallup.com). The key to sound inference is in understanding how to derive a representative sample. Outcomes show that individual polls are often wrong by important margins, yet analyses such as Nate Silver's that consider the range and underlying biases of polling results can be quite accurate (http://fivethirtyeight.blogs.nytimes.com/methodology/). In the case of Loss et al. (2014) and similar papers, data representativeness is the underlying problem for the science of the issue, and it cannot be resolved using a random sample of respondents in a poll. In a previous paper, Loss et al. (2012) devoted significant effort to developing a transparent, repeatable method for selecting and including studies useful for extrapolating results of bird mortality from local studies to national scales. Longcore et al. (2012) applied such methods and presented sensitivity analyses to understand which parameters produced the greatest uncertainty in their estimate of mortality from collisions with communication towers. Blancher (2013) developed a Monte Carlo modeling approach that prioritized accuracy over precision to extrapolate to a national level bird mortality caused by cats, an approach that was adopted by Loss et al. (2013). This approach to a scientifically defensible extrapolation of bird mortality ensured that the results suitably accounted for sources and magnitudes of error or bias in the contributing data. Therein lies one of the imperfections of the national estimate of bird mortality from window collisions: The 95% confidence interval of the estimate is 3 times the lower bound (353 to 988 million). However, the first benefit of such an approach is that, on the basis of careful consideration of input data and model parameterization, it is reasonably probable that the true estimate lies within that range. The second benefit of the new approach is that readers will understand that the greatest source of uncertainty (75% of the total) is from a poor understanding of rates of mortality occurring at low-rise buildings. It is clearly stated where scientists need to focus research and monitoring attention to improve the precision of the estimate.

The Achilles heel of national bird-mortality estimates is that the underlying studies were never designed to be included in an extrapolation to a larger scale; this is an easy criticism to level as a reviewer. Estimation bias was not completely eliminated by the approaches detailed in Loss et al. (2014), and Calvert et al. (2013) provided additional examples of bias remaining partially or completely unknown in various estimates of human-induced avian mortality, including bird–window collisions. Accepting that these approaches have adequately dealt with bias as well as can be currently expected, the work provides another surprising benefit in the form of meticulous consideration of input data. In our opinion, Loss et al. (2014) understated the difficulty it took to gather, collate, and proof all of the disparate data for mortality at tall buildings. From their work, it is now apparent that improving mortality estimates in urban cores hinges on substantially improved data quality, requiring field-workers to structure their data collection and management processes as described by Loss et al. (2012, 2014). Improved estimates of mortality would not only allow more targeted conservation efforts in urban cores, but would also lead to the adjustment of estimates of the cumulative impacts of avian mortality from collisions with windows and other structures.

The Value of Extrapolations

Extrapolation-based studies such as that of Loss et al. (2014) and other U.S. and Canadian estimates of human-induced avian mortality constitute a class of estimation problems sometimes called Fermi problems. Enrico Fermi, the Nobel laureate physicist, was esteemed for his ability to solve seemingly impossible problems through the multiplication of a series of estimates (Weinstein and Adams 2008, Santos 2009); for instance, Fermi once asked and successfully answered the question of how many piano tuners there are in the city of Chicago (Morrison 1963). Because the sources of information for addressing this sort of extrapolation-based question are often highly varied, differing among other things in their origination date and locality as well as their quality, these calculations are only approximations (Starfield et al. 1994, Weinstein and Adams 2008, Santos 2009), and sometimes no more than first-order approximations. Nevertheless, Fermi approximations are often more accurate than expected because the multiplication of several estimated factors will include some factors that may be overestimated and other factors that are likely underestimated, canceling out potential error. The overall error of the estimate is likely to be the square root of the number of terms in the equation multiplied by the standard deviation on the log scale of the individual term errors; thus, a 4-term estimate where each term is correct within a factor of 2 would have a likely range of $2^{\sqrt{4}}$ or ¼ to 4× the real value. The results therefore retain acceptable accuracy, especially in the context of managing large-scale environmental issues (Jordan and Miller 1996), as long as there is no consistent bias in the error of the constituent terms.

Extrapolation-based approaches accomplish at least 3 laudable goals by being published through the peer-review process. First, they remain contentious enough in their assumptions, input data, methodology, and conclusions that they are instant catalysts for improved science on any given issue. Second, the novel and sometimes downright startling conclusions (e.g., for cats; Loss et al. 2013), especially between different sources (e.g., industrial forestry vs. wind power), create a policy catalyst for evolution in approaches used to manage populations, e.g., of migratory birds in the United States and Canada. Finally, computing gross estimates of mortality is a critical first step, but it quickly becomes apparent that the true parameter of interest is not the headline-grabbing total, but the species-by-species mortality estimate. Each of these benefits is discussed below, starting with a well-known example of an extrapolation approach.

Publication of population estimates in the North American Landbird Conservation Plan (Rich et al. 2004) using the methodology of Rosenberg and Blancher (2005) was, and remains, contentious for its use of Breeding Bird Survey (BBS) indices to calculate the estimates. Thogmartin et al. (2006) wrote a constructive review of the approach, including reiterating the basic point that the BBS was never designed to estimate population sizes (analogous to the design problems of studies used in Loss et al. [2014]). As a science catalyst, publication of those population estimates has succeeded. Recommendations from Thogmartin et al. (2006) were or are being addressed, including estimating species-specific detection radii (e.g., Confer et al. 2008, Hamel et al. 2009), examining habitat representativeness of BBS sampling (Niemuth et al. 2007, Harris and Haskel 2007, Matsuoka et al. 2011), conducting sensitivity analysis of the calculations (Thogmartin 2010), and many studies on detectability. Matsuoka et al. (2012) developed new species-specific detection distances to compute population estimates for many landbird species in Canada, forming an in-depth independent test of the Partners in Flight estimates. Most of this recent science has shown that the Rich et al. (2004) estimates were conservative. Publication of the population estimates has also catalyzed policy and management. These estimates have been well used for conservation planning and risk assessment, e.g., species-at-risk assessments, Joint Venture planning, Bird Conservation Region plans (e.g., Environment Canada 2013), and estimates of impact (e.g., Runge et al. 2009, Johnson et al. 2012, Longcore et al. 2013).

We expect that the mortality estimates in Loss et al. (2014) will enliven an already diverse and active area of research associated with bird–window collisions. The issues of covariate data quality, study design, detectability, replication, and representativeness of samples are enough to keep researchers busy for the next decade. Improving statistical models for dealing with input uncertainty and communicating outcomes will also improve the science (Harwood 2000). Developing full life-cycle population models that can determine the consequences of bird–window collisions and other human-caused mortality will require investments from many scientists all across the Americas.

Similarly, we expect that publication of Loss et al. (2014) and the other U.S. and Canadian estimates of human-induced avian mortality will alter conservation and management policy in these 2 countries. The previous paper by Loss et al. (2013), describing mortality of birds caused by cats, garnered national and international press coverage. Prepublication drafts of Canadian estimates of bird mortality from a variety of causes surprised many colleagues and managers, both because of the individual results and due to the 6 orders of magnitude range of the estimates among sources. For instance, environmental assessment of wind-power installations receives significant government investment in the United States and Canada, increasingly because of impacts to bats, but originally because of impacts to birds. An assessment of current results shows that wind farms typically kill few birds individually and relatively few in total compared with other sources of mortality such as cats, window collisions, and agriculture (Calvert et al. 2013). Yet these latter causes of bird mortality have received comparatively little government attention. We are not exonerating one sector at the expense of another (wind farm impacts *are* important for particular species; Smallwood and Thelander 2008), but such disparity merits policy consideration that Loss et al. (2014) and other papers will almost certainly precipitate. The difficulty with the bird–window collision issue is that it is a tragedy of the commons: tens of millions of homeowners and building managers each choosing to build or retain regular windows with no regard for their impacts are each responsible for a tiny slice of the cumulative problem of bird deaths. However, successful governance of a commons, in this case mitigation or reduction in mortality, requires clear delineation of the affected resource. Loss et al. (2014) and other papers like it are steps in that direction.

The final benefit of publication of extrapolation-based approaches, moving the focus to individual species and away from the grand totals, is required to enable conservation action. Longcore et al. (2013) carefully articulated the necessity of developing species-specific estimates of mortality to determine biological significance. Loss et al. (2014) developed an innovative method of using the limited species-specific data to give readers a vulnerability assessment using the population estimates of Rich et al. (2004). Any notion that mortality caused by collisions with windows affects essentially a random sample of the avian community has been dispelled. Why the Ruby-throated Hummingbird (*Archilochus colubris*), Brown Creeper (*Certhia americana*), Ovenbird (*Seiurus aurocapilla*), Yellow-bellied Sapsucker (*Sphyrapicus varius*), Gray Catbird (*Dumetella carolinensis*), Black-and-white Warbler (*Mniotilta varia*), and warblers in general are so disproportionately vulnerable to window collisions remains unanswered.

Where to Next?

The estimates of bird mortality from collisions with windows in Loss et al. (2014) may be imperfect, but past history of such extrapolations (starting with Banks [1979]) has shown that they are a catalyst for advancing the science of the issue and stimulating policy responses. Conservation often operates with considerable uncertainty; scientists can always improve how they incorporate and communicate uncertainty (Harwood and Stokes 2003). In spite of significant shortcomings of the population estimates in Rich et al. (2004), and their order-of-magnitude uncertainty, these estimates have found general acceptance and significant utility while simultaneously being improved. We think the work by S. Loss and colleagues will be received and acted upon similarly.

Ecologists and managers could pursue 2 courses of action for addressing bird collisions with windows. The science of the issue could be improved in myriad ways as Loss et al. (2014) describe, particularly by articulating which species are killed under what circumstances and why. Already there are mitigation solutions that work, but they have not been widely recognized or adopted. Continued research into solutions that will gain wide acceptance, and promoting these solutions, could dramatically lessen mortality associated with window collisions.

A sound understanding of the biological significance of mortality due to collisions with windows for each affected species requires reasonable estimates of both the magnitude of the stressor and each species' population size. This ratio of stressor magnitude to population size is the crux of the matter. Research of the breadth detailed in Faaborg et al. (2010), including increased understanding of population connectivity and the spatiotemporal variation that occurs in the migratory process, is essential to improving precision of estimates of both factors. This migratory perspective should remind readers that a (likely large) portion of the birds killed in the U.S. by collisions with windows during migration originated from breeding grounds in Canada; this observation reinforces the scope of cooperation required to address human-induced mortality of migratory birds. A thorough analysis of population impacts will eventually have to resolve population components and mortality sources along the entire migration path. While both the magnitude of the stressor and population sizes in the calculations of Scott Loss and colleagues carry significant uncertainty, the authors' methodical approach to a difficult-to-quantify issue demonstrates the value of imperfect science.

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