BOOK REVIEW

Bayesian Data Analysis in Ecology Using Linear Models with R, BUGS, and Stan. F. Korner-Nievergelt, T. Roth, S. von Felten, J. Guélat, B. Almasi, and P. Korner-Nievergelt. 2015. Elsevier, London, U.K. 316 pp. $76.39 paperback. ISBN 978-0-12-801370-0.

Bayesian Data Analysis in Ecology is an excellent statistical toolbox book that provides examples of ecological analyses that increase in complexity using frequentist and Bayesian methods. The book is intended for intermediate-level practitioners because there is minimal discussion of the theory and mathematics underlying either approach. The authors also assume that the reader already has working knowledge of Program R; although the book is full of useful R code snippets, there is not an introduction to the basic workings and data manipulation steps in R. However, for those already familiar with R and some graduate-level training in statistics (or those searching for such training), this book provides a valuable go-to resource for conducting frequentist and Bayesian statistical analyses of wildlife and ecological data.

Perhaps the greatest strength of this book is the sheer number of worked analyses that are relevant to wildlife biologists, presented within the context of frequentist and Bayesian approaches. The book begins with a brief discussion of why we need statistical models in general (Chapter 1), followed by a chapter on software and statistical terms and objects in R (Chapter 2: Prerequisites and Vocabulary). Chapter 3 briefly compares and contrasts the frequentist and Bayesian philosophies and outcomes. Chapter 4 (Normal Linear Models) illustrates how to apply either approach to one of the most familiar types of models: simple linear regression and its variants. Likelihood theory is discussed in Chapter 5, followed by Chapter 6, which emphasizes assessing model assumptions. At this point, the book delves into chapters and worked examples of increasingly complex models that are highly relevant to wildlife studies, including chapters on linear mixed effects models (Chapter 7), generalized linear models (Chapter 8), generalized linear mixed models (Chapter 9), model checking (Chapter 10), model selection and multimodel inference (Chapter 11), Markov Chain Monte Carlo simulation (Chapter 12), and modeling spatial data (Chapter 13). Chapter 14 (Advanced Ecological Models) quickly jumps through more advanced ecological models with wildlife applications, including hierarchical models for habitat selection, zero-inflated count models, occupancy estimation with imperfect detection, territory occupancy with unmarked individuals, and survival estimation from mark-recapture data. The remaining 3 chapters discuss assessing the influence of priors in Bayesian models (Chapter 15), a checklist for conducting data analysis (Chapter 16), and a description of how to present results in analysis write-ups (Chapter 17).

One recurring theme throughout the book is that statistical analysis is an art form, not a rote application of tools to data. Assumptions must be checked, structural problems must be dealt with, and above all, final statistical models must be assessed for appropriate fit given the original goals of the analysis. This is neither a simple nor straightforward task for many of the types of models used in wildlife ecology, and the authors provide several options for assessing model fit given the complexity of hierarchical, mixed, and generalized linear models. The book is notable for reinforcing this idea and for providing solutions that the reader can implement in their own analyses.

I was disappointed in the "Bayesian-lite" discussion throughout. For example, the authors do make a very poignant, albeit too brief, comparison between frequentist and Bayesian inference. Most non-statisticians misinterpret what the frequentist's 95% confidence interval (CI) actually is describing, assuming it means that there is a 95% percent chance that the true value lies within this range. This is incorrect. Rather, as the authors state, "The interpretation of the [frequentist] CI is this: If we repeat the study under the same conditions using the same sample size many times, 95% of these CI will contain the true population mean." In other words, 95% of the time the 95% CI will contain the true value; we can make no statement about whether it does so in any particular analysis. In contrast, one of the major benefits of Bayesian inference is that we can make direct probabilistic statements, such as "we are 95% sure that the true mean is within the Credible Interval" (credible interval is the Bayesian equivalent of the frequentist confidence interval). This comparison, among others, is valuable but was too brief and lost within the meat of the applied examples. A more thorough discussion comparing the philosophy, implementation, and inference of frequentist versus Bayesian approaches would have proven helpful in light of the intent of the book. Additionally, given the introductory approach, readers will have to look elsewhere to learn how to leverage the full power of Bayesian software and inference for complex ecological models.

Nevertheless, the book's brevity is also its strong point. Although it is neither a Bayesian nor frequentist textbook, it provides a gentle introduction to applying Bayesian techniques with fairly simple models. It also contains many excellent suggestions, cautions, and solutions that all practitioners would benefit from regardless of their chosen analytical pathway. And ultimately, it will have a permanent place on many bookshelves, including mine, for the sheer density of worked examples with detailed references to related sources for further exploration.

—**Seth Harju**, Biometrician/Wildlife Biologist, Heron Ecological, LLC, Kingston, ID 83839, USA.
E-mail: seth@heronecological.com