# Foreword

The title of Marc Kéry's book, *Introduction to WinBUGS for Ecologists*, provides some good hints about its content. From this title, we might guess that the book focuses on a piece of software, WinBUGS, that the treatment will not presuppose extensive knowledge of this software, and that the focus will be on the kinds of questions and inference problems that are faced by scientists who do ecology. So why WinBUGS and why ecologists? Of course, the most basic answer to this question is that Marc Kéry is an ecologist who has found WinBUGS to be extremely useful in his own work. But the important question then becomes, "Is Marc correct that WinBUGS can become an important tool for other ecologists?" The ultimate utility of this book will depend on the answer to this question, so I will try to develop a response here.

WinBUGS is a flexible, user-friendly software package that permits Bayesian inference from data, based on user-defined statistical models. Because the models must be completely specified by the user, WinBUGS may not be viewed by some as being as user-friendly as older statistical software packages that provide classical inference via methods such as maximum likelihood. So why should an ecologist invest the extra time and effort to learn WinBUGS? I can think of at least two reasons. The first is that all inference is based on underlying models (a basic constraint of the human condition). In the case of ecological data, the models represent caricatures of the processes that underlie both the data collection methods and the dynamics of ecological interest. I confess to knowing from personal experience that it is possible to obtain and "interpret" results of analyses from a standard statistical software package, without properly understanding the underlying model(s) on which inference was based. In contrast, having to specify a model in WinBUGS insures a basic understanding that need not accompany use of many common statistical software packages. So the necessity of specifying models, and thus of thinking clearly about underlying sampling and ecological processes, provide a good reason for ecologists to learn and use WinBUGS.

A second reason is that ecological data are typically generated by multiple processes, each of which induces variation. Frequently, such multiple sources of variation do not correspond closely to models available in more classical statistical software packages. Through my career as a quantitative

ecologist, hundreds of field ecologists have brought me data sets asking for "standard" analyses, suggesting that I must have seen many similar data sets and that analysis of their data should thus be relatively quick and easy. However, despite these claims, I can't recall ever having seen a data set for which a standard, off-the-shelf analysis was strictly appropriate. There are always aspects of either the studied system or, more typically, the data collection process that requires nonstandard models. It was noted above that most ecological data sets are generated by at least two classes of process: ecological and sampling. The ecological process generates the true patterns that our studies are designed to investigate, and conditional on this truth, the sampling process generates the data that we actually obtain. The data are thus generated by multiple processes that are best viewed and modeled as hierarchical. Indeed, hierarchical models appropriate for such data are readily constructed in WinBUGS, and hierarchical Bayes provides a natural approach to inference for such data. Relative ease of implementation for complex hierarchical models is a compelling reason for ecologists to become proficient with WinBUGS.

For many problems, use of WinBUGS to implement a complex model can result in substantial savings of time and effort. I am always impressed by the small amount of WinBUGS code needed to provide inference for capture–recapture models that are represented by extremely complicated-looking likelihood functions. However, even more important than problems that can be solved more easily using WinBUGS than using traditional likelihood approaches are the problems that biologists would be unable to solve using these traditional approaches. For example, natural variation among individual organisms of a species will always exist for any characteristic under investigation. Such variation is pervasive and provides the raw material for Darwinian evolution by natural selection, the central guiding paradigm of all biological sciences. Even within groups of animals defined by age, sex, size, and other relevant covariates, ecologists still expect variation among individuals in virtually any attribute of interest. In capture–recapture modeling, for example, we would like to develop models capable of accounting for variation in capture probabilities and survival probabilities among individuals within any defined demographic group. However, in the absence of individual covariates, it is simply not possible to estimate a separate capture and survival probability for each individual animal. But we can consider a distribution of such probabilities across individuals and attempt to estimate characteristics of that distribution. In WinBUGS, we can develop hierarchical models in which among-individual variation is treated as a random effect, with this portion of the inference problem becoming one of estimating the parameters of the distributions that describe this individual variation. In contrast, I (and most ecologists) would not know how to begin to

construct even moderately complex capture–recapture models with random individual effects using a likelihood framework. So WinBUGS provides access to models and inferences that would be otherwise unapproachable for most ecological scientists.

I conclude that WinBUGS, specifically, and hierarchical Bayesian analysis, generally, are probably very good things for ecologists to learn. However, we should still ask whether the book's contents and Marc's tutorial writing style are likely to provide readers with an adequate understanding of this material. My answer to this question is a resounding "Yes!" I especially like Marc's use of simulation to develop the data sets used in exercises and analyses throughout the book, as this approach effectively exploits the close connection between data analysis and generation. Statistical models are intended to be simplified representations of the processes that generate real data, and the repeated interplay between simulation and analysis provides an extremely effective means of teaching the ability to develop such models and understand the inferences that they produce.

Finally, I like the selection of models that are explored in this book. The bulk of the book focuses on general model classes that are used frequently by ecologists, as well as by scientists in other disciplines: linear models, generalized linear models, linear mixed models, and generalized linear mixed models. The learn-by-example approach of simulating data sets and analyzing them using both WinBUGS and classical approaches implemented in R provide an effective way not only to teach WinBUGS but also to provide a general understanding of these widely used classes of statistical model. The two chapters dealing with specific classes of ecological models, site occupancy models, and binomial mixture abundance models then provide the reader with an appreciation of the need to model both sampling and ecological processes in order to obtain reasonable inferences using data produced by actual ecological sampling. Indeed, it is in the development and application of models tailored to deal with specific ecological sampling methods that the power and utility of WinBUGS are most readily demonstrated.

However, I believe that the book, *Introduction to WinBUGS for Ecologists*, is far too modest and does not capture the central reasons why ecologists should read this book and work through the associated examples and exercises. Most important, I believe that the ecologist who gives this book a serious read will emerge with a good understanding of statistical models as abstract representations of the various processes that give rise to a data set. Such an understanding is basic to the development of inference models tailored to specific sampling and ecological scenarios. A benefit that will accompany this general understanding is specific insights into major classes of statistical models that are used in ecology and other areas

of science. In addition, the tutorial development of models and analyses in WinBUGS and R should leave the reader with the ability to implement both standard and tailored models. I believe that it would be hard to overstate the value of adding to an ecologist's toolbox this ability to develop and then implement models tailored to specific studies.

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