

the system is close to a threshold, and how we can better manage social-natural resource systems with this knowledge. Scheffer is quite familiar with the relationships among scientific understanding, uncertainty, and policy, and he has no Pollyanna illusions about the difficulties in effecting changes against entrenched interests. While optimistic, Scheffer's suggestions regarding the application of principles of critical transitions to real-world problems are essentially practical; he well recognizes that understanding and managing change is just as much a human problem as it is a scientific or mathematical problem.

Aside from the extraordinarily well-written and well-organized qualities of this book, it is a handsome production. The text is copiously documented with endnotes collected by chapter at the end. American readers may discover important European references to leaven their possibly provincial knowledge of the literature on this topic. Nostra culpa! Besides the appendix illustrating mathematical treatments of some aspects of system dynamics, there is a glossary of terms specific to dynamical system theory, and a word index, not including authors of references. We noted only four trivial, and perhaps arguable, editorial errors.

We recommend this book as the best integration of the multiple rubrics (resilience, regime change, panarchy, complex-

ity, dynamical systems theory) found on the subject of critical transitions or abrupt change, and as an enjoyable as well as enlightening synthesis of a timely and important topic bearing on many of the crucial dilemmas of our time.

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Using R to explore ecological principles

Stevens, M. Henry H. 2009. **A primer of ecology with R. Use R!** Springer, New York. xvi + 401 p. \$64.95, ISBN: 978-0-387-89881-0 (acid-free paper).

Key words: ecological statistics; models; population ecology; R; textbook.

R is a powerful, open source, and free programming and statistical software environment for Windows, Mac, and Linux operating systems. It was first developed in 1996 and is enjoying a meteoric rise in popularity. It is likely that most ecologists have at least heard of R, perhaps even downloaded and installed it, and are contemplating “moving to it” for their research (to find R search the letter “r” on the internet). With the arrival of M. Henry H. Stevens’ book *A primer of ecology with R*, ecologists have an excellent guide to using R for exploring population and community models.

As the author states, this book is “geared toward graduate students” above the level of Nicholas Gotelli’s well known *A primer of ecology* (2008. Sinauer Associates, Sunderland, Massachusetts) and with similar coverage of topics, although in more depth and with explicit code to implement the models. Stevens also notes similarities to Joan Roughgarden’s *Primer of ecological theory* (1997. Benjamin Cummings, San Francisco, California), which is based on MATLAB. Another important and noteworthy text is Ben Bolker’s *Ecological models and data in R* (2008. Princeton University Press, Princeton, New Jersey), which introduces more modern approaches to statistical data analysis and model fitting.

The text is divided into three main sections covering, in order, single species models, two-species interactions, and finishes with four chapters on “special topics.” The book closes

with two appendices that introduce R and then take readers into the details of getting up and running with programming in R. Each chapter ends with a brief summary and a set of problems based on the models presented. Problems are helpful and lead the reader to a deeper understanding of the models.

Chapter 1 begins with density-independent growth. Interestingly, the chapter starts with a two-panel graph of data, followed by the text that begins “Between 1966 and 1971, Song Sparrow ... abundance ... increased ...” This seems to define the book’s approach of jumping right into the material. However, we soon pick up a few typos (e.g., Fig. 1b shows “Growth Rate” vs. “Count” and the legend states “Relative Annual Change vs. N” and Fig. 1.2 is referred to as Fig. 1.3 in the text). Although these are minor problems, they can cause concern to readers.

The chapter then moves to elementary geometric growth using R. We are provided code to produce a figure for N vs. time for geometric growth with $\lambda < 1.0$, $\lambda = 1.0$, and $\lambda > 1.0$, add text to the graph, and add a reference line for $\lambda = 1$. I mention these details because I don’t know of another way to so easily produce such informative graphics. The chapter then introduces exponential growth (continuous time), shows the reader how to write a function, and then provides the tools to write a stochastic simulation and view multiple iterations on a single graph.

Chapter 2 introduces demography and matrix algebra, including eigenanalysis with sensitivity and elasticity analyses. The latter part of the chapter confronts these models with data by estimating parameters and introduces bootstrapping. The chapter includes several boxes on working with matrices in R.

Chapter 3 tackles density-dependent growth using discrete and continuous models. Stevens introduces the reader to the discrete logistic equation, chaotic dynamics, a bifurcation plot, and sensitivity to initial conditions before covering the

continuous-time model. This chapter also includes a section on fitting models to data and takes the reader through a mixed-model analysis. In this exploration we are well introduced to the statistical tools and logic required to understand how increasing resources affects the growth rate of an alga within a food web. Chapter 4 deals with spatial population dynamics (source-sink dynamics, metapopulations, and applied problems) and introduces the use of stochastic simulations to evaluate extinction probabilities.

Part two has just two chapters, on competition and enemy-victim models. The latter includes coverage of the standard Lotka-Volterra model with stability analysis, Rosenzweig-MacArthur model, host-parasitoid dynamics, and the SIR model. For the predator-prey model, for instance, Stevens discusses the framework for the system of equations, helps the reader with the unit analysis of the coefficients, and then provides the model in a box (seven lines of code and a reference for help with the code solver). We learn about functional responses and how to graph them using R. The Jacobian stability analysis is shown using two lines of R code.

The final section on "special topics" includes four chapters, first covering food webs, the second covering multiple basins of attraction, the third covering competition, colonization, and niche partitioning, and the last chapter dealing with community composition and diversity, including a discussion of Hubbell's neutral theory of biodiversity.

In addition to the book, the author has provided an R "package" called "primer" that should be downloaded from the R site. This package, as with all R packages, provides tools that offer greater functionality and convenience for users. It also is necessary to run some of the available code. The primer package also includes data sets that readers can use along with the text. The code I tried worked after some work, including changing my working directory and installing other required packages. The success of the code can be attributed to the author's use of Sweave, which allows one to imbed code into the LaTeX files and use R on-the-fly to generate figures. Therefore, the code must be correct when it goes to print.

The book is not without some editorial challenges, from a variety of typos to more subtle issues. One example involves the definition of zero net growth isoclines in the Lotka-Volterra predator-prey model that "tell us when populations tend to decrease or increase." Instead, more technically, these indicate when populations do not change. In this example we are saved by the math which shows us that the isoclines emerge when the growth rates are set equal to zero. In another example, the text introduces projection matrix multiplication and the worked

example has a non-zero element in the main diagonal that is ignored. Nonetheless, we see the error is later corrected. This reviewer, however, is not greatly troubled by these oversights and, instead, sees these issues as learning opportunities for my students. Such challenges, however, may interfere with learning by those new to both the models and R. The author's website includes a list of known problems in the book (<http://www.cas.muohio.edu/~stevenmh/primer/>).

I find the writing to be casual and fresh. My students will get the sense that the author is a real person and that ecological models can be fun, interesting, and understood by readers. We see descriptions of model output as "cool" and that we can use projection matrices to "calculate all kinds of fun and useful stuff..." which makes the reading pleasurable.

The text is built upon the premise of learning by example and, as a result, is replete with worked examples. Readers should read the book with R running on a nearby computer. I must stress that this book is different from many others where the models are passively explained. This is a book to really work with. And the software that it is based on is freely available. To help facilitate code entry, the author provides all of the code on the accompanying website. The vast majority of the code I tried worked and provided output exactly as it appeared in the text. The examples in the book, however, can be completed without use of the website.

In conclusion, I found the text to be an excellent foray into ecological models using R. I plan to use this book in my upcoming modeling course for upper-level undergraduates, a course cross-listed in the math and biology departments. The models will present some challenges for my students but I think the pace of the text will work for them. In addition, many of my students will be new to R, and to programming, but the text does a great job of integrating an introduction to R with the models. I can see this book being valuable to graduate students and research ecologists wishing to work with these foundational models in R. It is now time to jump into R!

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