Preface

This book builds the foundation for, and constructs upon it, a theory of ecology designed to explain a lot from a little. By "little" I mean only inferential logic derived from information theory. And by "a lot" I mean the ecological phenomena that are the focus of macroecology: patterns in the partitioning of space and energy by individual organisms and by species in ecosystems.

Parts I–III are foundational. Part I is epistemological, describing the roles and types of theory in ecology and setting forth the concept of the logic of inference. I give special attention here to varying views concerning the role of mechanism in science. Part II is a self-contained primer on macroecology. I provide an extensive review of the field, covering the questions asked, the metrics used, the patterns observed to prevail, applications in conservation biology, and the broad categories and examples of theories advanced to explain those patterns. In Part III, I teach the maximum entropy (MaxEnt) method of inference from information theory, clarify the connection between information entropy and thermodynamic entropy, and discuss previous applications of the maximum entropy method in fields other than ecology.

In Part IV, I construct the MaxEnt Theory of Ecology (METE),[1] derive its predictions, and compare them to empirical patterns. In Part V, I draw connections between MaxEnt and other prominent ecological theories such as metabolic theory and the neutral theory of ecology. I also review other approaches to applying MaxEnt in ecology and potential applications of METE to problems in conservation biology. In the last chapter of Part V, I describe "loose ends" and possible ways to tie them up. METE is a static theory in which patterns in the abundance, distribution, and energetics of species in an ecosystem at any given moment in time derive from the instantaneous values of a small set of quantities, called state variables. As a possible extension of METE, I propose a way to construct a dynamic version, in which the time dependence of state variables can be predicted. Other unresolved issues are described and a set of research topics are suggested that I hope inspire some readers to engage in the effort to further advance the theory.

[1] Mete: (mēte) vt: to measure out appropriately, allocate.

My primary aim is a textbook that will provide readers with the concepts and practical tools required to understand (and contribute to) a rising area of science, generally, and macroecology in particular: the MaxEnt method. While the book's topical focus is a theory of macroecology based on the concept of maximum information entropy, I will evaluate the success of the book by the number of its readers who become empowered to use the methods described in it for any purpose whatsoever.

Exercises for the reader are provided at the end of each chapter. More difficult ones are noted with a * or a * *, with * * reserved for problems of term-paper magnitude or beyond. Some of the exercises involve just filling in steps in derivations or are qualitative discussion topic suggestions.

Used as a textbook for a one semester graduate seminar or lecture course covering topics in theoretical ecology, macroecology, and maximum entropy methods, instructors might find it reasonable to have students read and discuss Part I for the first week of the course. Because Part II introduces many quantitative concepts and methods that may be unfamiliar to students, it will probably require four weeks for adequate coverage of the material, two weeks for each of Chapters 3 and 4. Part III can be covered in two more weeks—one week to deal with the concepts in Chapter 5 and one to go over examples of MaxEnt calculations as described in Chapter 6. Three weeks on Part IV should be sufficient, with most of that time devoted to Chapter 7. Part V could be covered in as little as two weeks, assuming the material in Chapter 11 is not used to launch student research projects. If the class chooses to conduct term projects based on the suggestions in Chapter 11, an additional two or three weeks could be set aside for that, adding up to a 14 or 15 week course.

By way of warning, the subject matter herein contains material of a mathematical nature. To allow the reader to exercise discretion, truly f(x)-rated material, such as difficult derivations, is set aside in boxes and Appendices for the mathematically prurient. Their ecological content is explained in the main text, so that reading and understanding them is not essential to understanding concepts, or to being able to use the theory. To assist users, I explain, and provide explicit directions for using, a variety of computational tools to work out and compare with data the predictions of theory.

Two sources of funding, the US National Science Foundation and the Miller Foundation, provided me with the opportunity to develop many of the ideas herein. Much of the material is based upon work supported by the National Science Foundation under Grant No. 0516161.

I am indebted to numerous people for inspiration, technical advice, and occasional harsh criticism (without which I would have included material here that I would surely come to regret). First, I thank my current and former graduate students who have worked with me in the development and testing of ecological theory; they include Danielle Christiansen, Erin Conlisk, Jennifer Dunne, Jessica Green, Ann Kinzig, Justin Kitzes, Neo Martinez, Erica Newman, Annette Ostling, and Adam Smith. Two postdocs made invaluable contributions as well: Uthara Srinivasan and

Tommaso Zillio. Others, whose insights have hugely enriched my understanding of macroecology or maximum entropy, include Drew Allen, Jayanth Banavar, Luis-Borda de Agua, Jim Brown, Rick Condit, John Conlisk, Fred Cummings, Roderick Dewar, Brian Enquist, Jim Gillooly, Patty Gowaty, Ken Harte, Fangliang He, Stephen Hubbell, R. Krishnamani, Bill Kunin, Amos Maritan, Pablo Marquet, Brian McGill, Shahid Naeem, Jeff Nekola, Graham Pyke, Mark Ritchie, Michael Rosenzweig, Jalel Sager, Ida Sognnaes, David Storch, Geoffrey West, and Ethan White. Many people associated with Oxford University Press have been critical to the production of this book. Ian Sherman, Jennifer Dunne, Helen Eaton, Muhammed Ridwaan, Abhirami Ravikumar and Jeannie Labno deserve special thanks for their vision, effort, and skill.

While I cannot thank them all, there are thousands of professional ecologists, indigenous people, and volunteers who have over the years made this work possible. They are the census-takers, the counters of plants and animals who have laboriously set up gridded landscapes or walked transects, scoured the ground or the tree tops, watched and listened, pored through taxonomic keys, and entered data that I have used to test theory. I am quite sure that the rewards they obtained from close encounters with the living treasures of our planet more than make up for the absence of anything but a generic thanks from me.

Both my daughter, Julia, and my wife, Mel, have been patient and critically responsive to my Ancient-Mariner-like efforts over the past few years to explain maximum entropy to them, thereby allowing me to understand it better. The love and support my family has provided is immeasurable.

Finally, while I never had the honor to meet Edwin Jaynes, he probably deserves the most thanks of all. His papers developing the concept of maximum information entropy are brilliant; during the course of writing this book there were many times I found myself wishing I could talk to him in person.