Ecology in Action

Taking a fresh approach to integrating key concepts and research processes, this undergraduate textbook encourages students to develop an understanding of how ecologists raise and answer real-world questions. Four unique chapters describe the development and evolution of different research programs in each of ecology's core areas, showing students that research is undertaken by real people who are profoundly influenced by their social and political environments.

Beginning with a case study to capture student interest, each chapter emphasizes the linkage between observations, ideas, questions, hypotheses, predictions, results, and conclusions. Discussion questions, integrated within the text, encourage active participation and a range of end-of-chapter questions reinforce knowledge and encourage application of analytical and critical thinking skills to real ecological questions. Students are asked to analyse and interpret real data, with support from online tutorials that show them how to use the R programming language for statistical analysis.

FRED D. SINGER is Professor Emeritus of Biology at Radford University, where he began teaching in 1989. A committed teacher, he developed research programs on the behavioral and community ecology of spiders, dragonflies, and zebrafish, while also collaborating with several colleagues to promote active learning as part of an ongoing research program on new approaches to teaching. In 2000, in recognition of his dual research programs, he was awarded the Radford Foundation Award for Creative Scholarship. He has taught approximately 20 different courses, including general ecology, field ecology, and climate change ecology, using the philosophy that the best learning occurs when students deal with real experiments and real data.

"In contrast to most other science textbooks, Singer's book. . . emphasizes the roles of curiosity and careful observation in discovering hypotheses that are worth testing. This will be an ideal ecology text for anyone who would like to help students appreciate the excitement of scientific creativity."

Robert Askins, Connecticut College, USA

". . . an excellent resource for students and young professionals. . . Singer provides a detailed overview of the foundations of ecology while he seamlessly incorporates an illuminating insight into how ecology is done. This is a welcome perspective in an ecological textbook since many contemporary titles heavily focus on abstract ecological concepts."

Joris van der Ham, George Mason University, USA

". . . written in a very student-friendly manner. . . Case studies incorporated into the text provide a much needed basis for the comprehension of difficult ecological concepts."

Troy Ladine, East Texas Baptist University, USA

"It is very refreshing to read a new textbook, rather than a new edition of an old textbook. . . The case studies bring the chapters to life, which contributes to making this a very interesting read."

Judith Lock, University of Southampton, UK

". . . I'm excited by this book. It is refreshing and interesting with unique examples and clean artwork. . . The inclusion of an assortment of end of chapter questions. . . that run the gamut from application to data analysis will give students practice and insight into both critical thinking and quantitative skills that most books do not."

Lynn Mahaffy, University of Delaware, USA

"This book is a breath of fresh air. Singer has provided a clear and compelling text that will engage students at every level of knowledge."

Holly Porter-Morgan, City University of New York, USA

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To Cindy for true love and grace, to Jed and Alison who kept the questions coming
when they were young and have metamorphosed into awesome adults, and to my canine companions,
Maia, Sheik, and Cheyanne, who somehow knew when my face needed a good licking.

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PREFACE

I taught at a university where teaching is a professor's major action. Coming from a research background, I was somewhat surprised at this emphasis, but after immersing myself in teaching for 25 years, I decided that it was time to share my ideas. Over those years, I learned that students (and people in general) learn best when they are actively doing things. One of my goals in writing this text is to get students actively involved in what ecologists do, to learn where knowledge comes from, to learn how to ask questions, how to approach answering these questions, and to expect that the answer will be somewhat unsatisfactory and will generate a new series of stimulating questions. *Ecology in Action* is the title of this book but it is also a philosophy of learning, and a statement of hope for future times when scientifically sound ecological action will be essential.

Humans are natural ecologists. We are great observers of phenomena of all types, we develop expectations of what will happen under a set of conditions, and we recognize patterns. We also love to do experiments. Unfortunately, some of the experiments we are conducting today are very risky. We are increasing atmospheric carbon dioxide levels and collecting data on the effects of climate change. We have doubled the amount of fixed nitrogen in global systems and are collecting data on ecosystem response. We are breaking up large continuous habitat into small fragments and observing how populations of endangered species respond to their diminished habitat. The good news is that we are collecting at least some of the relevant data. My hope for the future is that everyone who reads this book will be able to interpret these data effectively, so they can take appropriate action as scientists or as private citizens.

MY GOALS FOR THE READER

I wrote this book for biology majors who have a year of introductory biology and at least one semester of general chemistry. Ecology is a young and growing science, and the informational content is increasing explosively.

After reading this book, students should be able to:

- understand the key concepts in ecology.
- learn how to learn, how to identify what is important, and how to go about finding answers to questions.
- understand how everything we know about ecology started as an idea and metamorphosed into knowledge; in other words, each reader will learn about ecological process. The approach throughout the book is to integrate content and process in a manner that promotes a much deeper understanding of core areas of ecology.
- appreciate how research can be an extension or reflection of an ecologist's personality, values, or social situation. The history of an idea is presented, so that students can follow the logical development of an ecological concept through time. Students learn how ecologists think of their questions, and students then become empowered to think of their own questions.
- recognize that the natural world is awesome and fascinating. Examples are carefully chosen to engage students, and introduce the reader to novel species from parts of the world that they may have never heard of. At the same time students learn that humans are influencing natural systems in many profound ways. Numerous explicit connections between ecological concepts and ecological applications are made, enabling students to use their knowledge to treat the world in a sustainable manner.

ORGANIZATION AND STRUCTURE OF THE BOOK

Ecology in Action has 24 chapters, beginning with an introductory part that presents major ecological questions and a discussion of the physical environment. Tony Sinclair's research in the Serengeti is highlighted in the first chapter, as the questions that he asks span the entire biological hierarchy, from molecules to global ecology. The remainder of the text is divided into four primary parts: organismal and evolutionary ecology, population ecology, community ecology, and ecosystem and global ecology. Each part has two major components. The bulk of each part (four or five major concepts chapters) presents students with the major concepts of each topic, and the supporting experimentation/observations related to each major concept. The final chapter of each part immerses the students in a research program of one individual or group of individuals that made important contributions to the field.

Major concepts chapters

Each major concepts chapter begins with an introduction that describes one element of a case study that will be discussed in some detail in the chapter. In addition, the introduction provides a roadmap of the major concepts that will be explored and concludes with a list of 3–5 key questions that will be addressed as the chapter's major focus. I gave preference to case studies that highlighted fascinating natural history, that taught an important ecological concept, that demonstrated important aspects of ecological process, and that showed how ideas changed over time. The main body of each chapter answers the initial 3–5 questions in the context of research studies, which were chosen based on three criteria: (1) Do they clearly demonstrate an important concept? (2) Are they classics that show where ideas or new methods originated? (3) Are they recent or ongoing? Recent research is emphasized to convey the message that ecological knowledge is always evolving, that though we have just made a new discovery, there is now a new pressing question that needs to be addressed. At the end of each chapter is a *Revisit* section, which returns to the initial case study and address some of the issues it raises in light of what students have learned in the chapter.

All chapters have a strong emphasis on data analysis and interpretation. In my experience, the greatest challenge for many students is drawing reasonable conclusions from an experiment or observation. All chapters contain questions that prompt students to analyse data. These questions require certain analytic skills that students usually learn in an introductory statistics course, or in their science laboratories. To make sure all students can solve these problems, the text provides several opportunities to learn or review all of the necessary analytic approaches.

Research program chapters

One distinguishing feature of this text is the chapters that introduce students to research programs. Because we tend to do labs in 3 hour blocks of time, students gain a mistaken impression about how science is actually done. My goal with these research program chapters is to allow students to gain a deeper understanding of answers to the following questions:

1. How does a research program differ from a research project or question?
2. How do ecologists think of their questions?
3. How do ecologists and the scientific community decide what is important, and what is trivial?
4. How are research findings evaluated?
5. What factors determine a successful research program?
6. How is ecological research an extension or reflection of a scientist's personality?
7. How do ecologists work at different levels of the ecological hierarchy, and how do they collaborate with other ecologists and other scientists from different fields?

I present the research programs of four different ecologists or groups of ecologists who are major contributors to the discipline. Diversity of approach is important, so the following researchers are featured, in part because they used philosophically different approaches to ask and answer questions: organismal and evolutionary ecology – Bernd Heinrich; population ecology – Jane Goodall/Anne Pusey; community ecology – Dan Janzen/Winnie Hallwachs; ecosystem and global ecology – Jane Lubchenco. In addition to reading many of their papers and books, I conducted lengthy in-person interviews with each researcher, and also traveled with Anne Pusey to Tanzania to meet the famous chimpanzees of Gombe. On a personal level, it was awesome to meet these people (and chimpanzees) and to gain an understanding of why they are so successful.

PEDAGOGICAL FEATURES

Emphasis on ecological processes

Having read all of the books on the market (numerous times), I am quite confident that none explores ecological process as much as *Ecology in Action*. The four research program chapters have a heavy emphasis on ecological process, and this is carried on throughout the major concepts chapters to show students where ideas come from and how they develop over time. Through repeated exposure, students understand the relationship between a hypothesis and a prediction, how to analyse data, and how to draw logical conclusions.

Strong evolutionary foundation

Evolution is introduced early – initially in Chapter 1, and extensively in Chapter 3. Students learn skills that are rarely taught in ecology texts, for example, how to make and interpret an evolutionary tree and how to use molecular data to make evolutionary inferences. Having established a strong evolutionary foundation, students can then understand more advanced topics that are presented in almost every other chapter.

Historical perspective

People are natural storytellers and story listeners. The historical perspective used in the book immerses students in the history of an idea, so that they understand not only where an idea originated, but also how it changed over time and how it is related to other ideas that exist today. In the process, they also learn how to ask scientific questions and get considerable experience with how ecologists come up with their answers. Students learn that many answers are tentative, or only apply under restricted conditions.

Case studies

Engaging case studies begin each major concepts chapter and are revisited at the end of the chapter in light of the issues raised in the main text.

Key questions

Key questions are listed at the beginning of each chapter and provide a roadmap to help students prepare for and structure their learning. Summaries at the end of each chapter recap the key points.

Artwork

Illustrations are carefully designed to allow students to easily take away the key information they need and photographs help bring the subject to life.

Key terms

Key terms are highlighted in bold so that students can easily identify them. Definitions are provided in a comprehensive glossary at the end of the book.

Thinking ecologically questions

Each chapter has about three or four *Thinking ecologically* questions embedded in the text, allowing students to think about a problem while reading about it, rather than coming back to it at a later time. When I teach, I often require students to work on a *Thinking ecologically* question in class as soon as I finish the topic as a way of reinforcing the concept. These questions are usually open-ended; they develop a student's critical thinking skills and they can be easily read around without disrupting the flow of the narrative, which allows instructors to choose which questions to assign.

End-of-chapter questions

Review questions

About five or six review questions require students to review and summarize the major concepts, helping them retain what they have learned.

Synthesis and application questions

About 5–10 questions require students to use higher order thinking skills to apply what they've learned in the chapter. Students may be asked to design an experiment or a series of systematic observations to test a particular hypothesis, and to articulate predictions generated by the hypothesis. Alternatively, students may be asked to develop an analogy between what they just learned and a concept that they learned in a previous chapter; or students may be asked to apply a concept that they learned in the chapter to a different context.

Analyse the data

These end-of-chapter questions present students with real data sets (or occasionally graphs) and ask them to answer a question based on these data. In some cases the data were already presented in the text in a different context, while in other cases students are provided with new data sets to work from. Students are usually asked to interpret their findings in the context of a concept that was introduced in the chapter.

Dealing with data

To help students deal with data analysis a special embedded box feature, *Dealing with data*, is included primarily in the early chapters. *Dealing with data* boxes present analytic concepts such as extrapolation, error reduction, and data transformation, and applied statistical techniques beginning with calculating means and standard errors, branching into t-tests, one-way ANOVA, simple correlation and regression analysis, chi-square, and several other commonly used statistical approaches. There are also discipline-specific *Dealing with data* boxes that teach students how particular methodologies, such as molecular biology databases, geographic information systems, and stable isotope analyses, are used by ecologists to answer important questions.

Further reading

Each chapter concludes with 4–6 suggested readings that are a suitable basis for further discussion. These readings are mostly recent publications that present novel findings, but a few classics are also included to give students a sense of ecological history.

ONLINE RESOURCES

Supporting online resources for the book can be found at www.cambridge.org/ecologyinaction

For students and instructors

- All of the figures in jpeg (and PowerPoint) format
- Online glossary
- Statistics tutorial: an introduction to R.

One feature that distinguishes this text from some others is the *Analyse the data* feature that asks students to analyse real data sets and draw conclusions based on their analysis. To do so requires using elementary statistical analyses, so the website has a tutorial that, in conjunction with the *Dealing with data* feature, uses data sets in the text to teach the basics of statistics using the R programming language and software environment. R is free, and its use is expanding tremendously within the ecological community. Being able to use R will be a major boon to any ecology student moving forward. Much thanks to Dr Edd Hammill for developing a superb tutorial that integrates seamlessly with *Ecology in Action*.

For instructors only

- Solutions to questions.

The website provides answers to the *Analyse the data* questions.

Thinking ecologically and *Synthesis and application* questions are, for the most part, open-ended. As such, it is impossible to give an answer key, but some suggested approaches to dealing with each question are provided. I am also hoping to hear interesting ideas from students and instructors, for suggestions on the book and additional online resources that might be useful for teaching and learning.

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I'd like to thank ecologists around the world for doing the research that I've discussed, for doing so much more research that I could not discuss, and for persistently pushing the frontiers of our understanding of the natural world. Jane Goodall, Winnie Hallwachs, Bernd Heinrich, Dan Janzen, Jane Lubchenco, Anne Pusey and Tony Sinclair gave me large chunks of their time, so that I could hear their story and share it with you. I am very grateful to them.

My wife, Cindy Miller, carefully read the first draft and identified numerous mistakes, contradictions, omissions, and general cases of fuzziness before I passed the first draft to my development editor, Mary Catherine Hager. Mary Catherine further refined the first and second drafts, helping to me to write with a more consistent voice and coercing me to use a more linear approach in my writing. The folks at Cambridge University Press were awesome at every stage of the process. Dom Lewis adopted the project and has steadfastly encouraged me at every step. Claire Eudall coordinated my writing and research, and mostly kept me on schedule. Claire and Natasha Lewis sourced images and permissions, Charlie Howell co-ordinated the illustrations, text design and cover, and Jess Murphy and Rachel Cox managed the book through production with support from Megan Waddington.

Approaches to teaching don't develop within a vacuum; instead they are nurtured by experiences with students, colleagues, and even administrators. Edd Hamill of Utah State University wrote a spectacular tutorial that guides students through the R programming language and software environment. At Radford University, Joel Hagen, Chuck Kugler, and later Donna Boyd, Rich Murphy, Bob Sheehy, and about 5000 students taught me many things about teaching. One of those 5000 students, Daniel Metz, wrote out answers to many of the *Thinking ecologically* and *End-of-chapter questions*. Bud Bennett chased down hundreds of obscure articles and books through interlibrary loans. Matt Lee provided iconic help with some design issues. Lastly, Sam Minner, Orion Rogers, and Joe Scartelli provided financial support during sabbaticals and some summers.

When I was concerned about a particular chapter, I turned it over to other readers for help. These informal reviewers were David Blockstein, Judy Guinan, Joel Hagen, Chuck Kugler, and Mac Post. When I was puzzled about a study, I asked the study's lead author for help, and these researchers were almost universally delighted to provide clarification. Particularly helpful were Stanton Braude, Tim Brodribb, Jim Clark, William Cooper, Charlie Crisafulli, Jim Elser, Marc Fourrier, Jim Galloway, Philip Groom, Elizabeth Howard, Scott Kraus, William Laurance, Kim Mouritsem, Vojtech Novotny, Karen Oberhauser, Susan Riechert, Bill Ripple, W. H. Schlessinger, Rich Kliman, Paul Sherman, and Martin Wikelski.

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