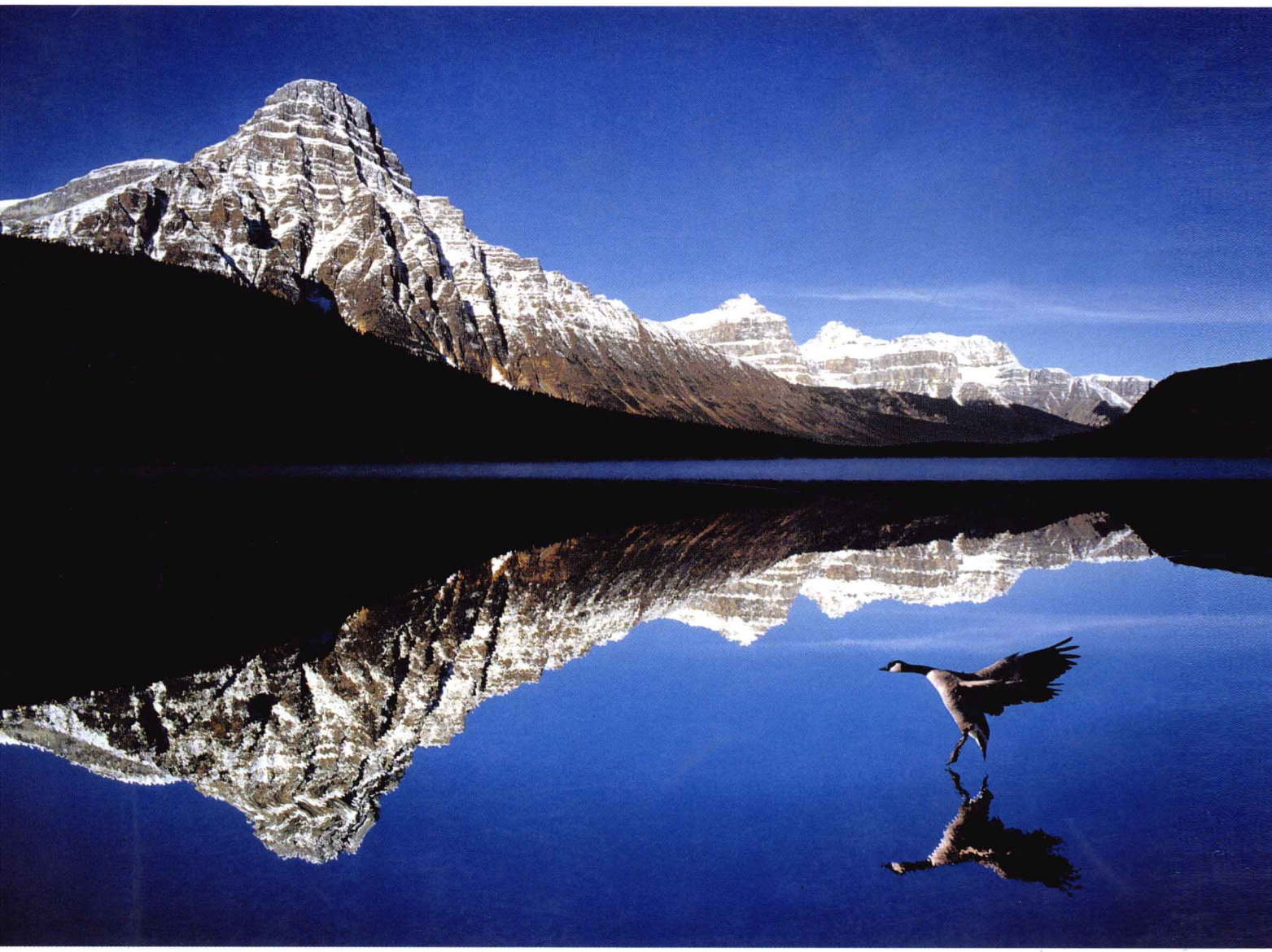
ENVIRONMENTAL SCIENCE

Earth As a Living Planet



Daniel Botkin • Edward Keller

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Earth As a Living Planet

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ENVIRONMENTAL SCIENCE

For Erene
who gave and cared so much

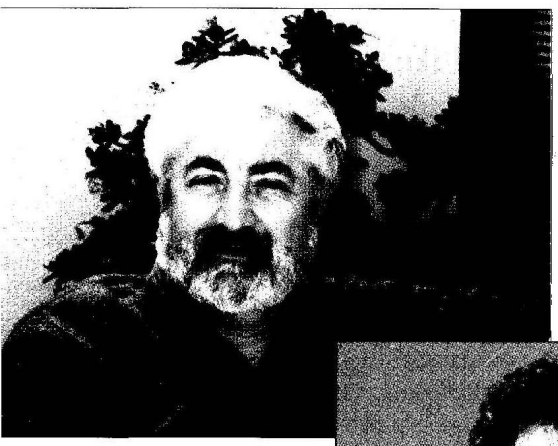
About the Authors

Daniel B. Botkin is President, The Center for the Study of the Environment and Director of the Program on Global Change, George Mason University. From 1978 to 1993, he was Professor of Biology and Environmental Studies at the University of California, Santa Barbara, serving as Chairman of the Environmental Studies Program from 1978 to 1985. For more than two decades, Professor Botkin has been active in the application of ecological science to environmental management. He is the winner of the Mitchell International Prize for Sustainable Development.

Trained in physics and biology, Professor Botkin is a leader in the application of advanced technology to the study of the environment. Other emphases of his research have been the characteristics of natural wilderness areas and the study of the biosphere and attempts to deal with global environmental problems. In recent years, Professor Botkin has advised the World Bank about tropical forests, biological diversity, and sustainability; the Rockefeller Foundation about global environmental issues; the government of Taiwan about approaches to solving environmental problems; and the state of California on the environmental effects of water diversion on Mono Lake. He served as the primary advisor to the National Geographic Society for their centennial edition map on "The Endangered Earth." He is currently directing a study for the states of Oregon and California concerning salmon and their forested habitats.

He has published more than 100 articles and books about environmental issues. His latest books are *Discordant Harmonies: A New Ecology for the 21st Century* (Oxford University Press) and *Forest Dynamics: An Ecological Model* (Oxford University Press).

Prior to joining the faculty at the University of California in 1978, he was on the faculty of the Yale School of Forestry and Environmental Studies (1968–1974) and a member of the staff of the Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA (1975–1977). He received a B.A. from the University of Rochester, an M.A. from the University of Wisconsin, and a Ph.D. from Rutgers University.

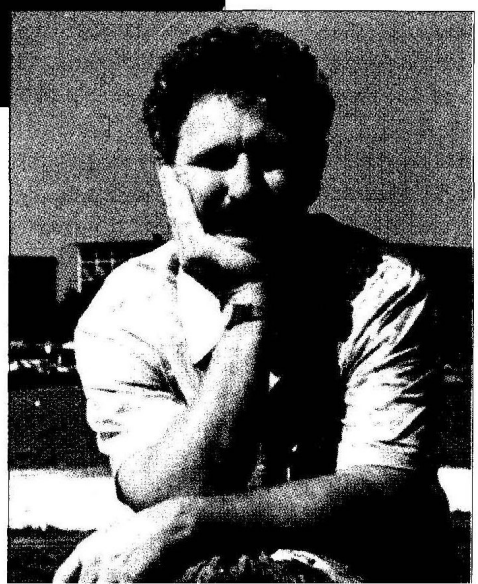


Daniel Botkin

Edward A. Keller is currently chair of the Environmental Studies Department and Professor of Geological Sciences at the University of California, Santa Barbara. Prior to joining the faculty at Santa Barbara, he taught geomorphology, environmental studies, and earth science at the University of North Carolina, Charlotte. He was the 1982–1983 Hartley Visiting Professor at the University of Southampton, England.

Professor Keller has focused his research efforts into three areas: studies of Quaternary stratigraphy and tectonics as they relate to earthquakes, active folding and mountain building processes; hydrologic process and wildfire in the chaparral environment of southern California; and role of fluid pressure in the earthquake cycle of active fold-and-thrust belts. He is the recipient of numerous water resources research grants to study fluvial processes and U.S. Geological Survey grants to study earthquake hazards.

Holding several degrees in geology, he has published over 100 papers and abstracts. The author of the textbook, *Environmental Geology*, he has also written several geological field guides. He holds bachelors degrees in both geology and mathematics from California State University, Fresno; and M.S. in geology from the University of California; and a Ph.D. in geology from Purdue University.



Edward Keller

Preface

Study of our environment has undergone tremendous change during the past three decades. In the 1960s and 1970s a grass roots movement to protect the environment began with the recognition of potential and real adverse effects of modern civilization on our environment. Views then were even more polarized than they are today. Some environmentalists argued that everything about the environment was good and should be protected without change—that is, all development of natural resources was bad. Some environmentalists believed that the world would be destroyed if we did not change our approach to the environment. To these people, economic and social development meant destruction of the environment and ultimately, perhaps, the end of civilization as well as the extinction of many species, perhaps even leading to the extinction of human beings. Some of these environmentalists saw science as part of the problem.

Opponents argued that these extreme "environmentalists" were opposed to progress and possibly to everything they thought good stemming from civilization and technology. Some of these people even believed that concern for the environment was bad. Nevertheless, during this period progress was made in dealing with environmental issues. Enthusiasm for the environment remained high. A number of nations, including the United States, enacted their first environmental laws. Agencies were established to deal with important environmental problems such as pollution abatement and conservation of endangered species.

Environmentalism in the 1980s was characterized by a conscious shift from enthusiastic rhetoric to development of alternative ways to solve environmental problems associated with local, regional, and global issues, such as human population, hazardous waste, acid precipitation, global warming, and stratospheric ozone depletion. People and institutions began putting more energy and resources into solving environmental problems and learning more about how the Earth works as a system. During this period there was also considerable confrontation and emotionalism surrounding the environment, and some activists put Earth first by taking nonyielding positions when it came to environmental protection. These approaches to the environment in the 1960s, 1970s and 1980s saw many advances as well as many failures. We believe many failures resulted from a basic lack of understanding about the environment and how natural ecological systems function.

A study of the environment in the 1990s is an exciting endeavor as we attempt to move from confrontation to cooperative problem-solving and place the study of the environment on a sound scientific basis. The enthusiasts of the 1960s have matured into today's environmental professionals: executives in alternative energy corporations, applied scientists who work on international projects to spread appropriate technologies to our inner cities and to developing nations, economists who calculate cost and benefits of pollution controls, environmental lawyers who mediate problems and help write laws to promote wise use of our resources, and other experts in many related fields.

In recent years our understanding of many aspects of the environment has increased greatly. This has ranged from our understanding of the transport and fate of pollutants and toxins in the air and water, appreciation of what is really necessary to save endangered species, to understanding how the Earth as a system operates.

BASIC PHILOSOPHY

The purpose of *Environmental Science* is to provide an up-to-date introduction to the most important concepts in the study of the environment. Information is presented from an analytical and interdisciplinary perspective from which we must view environmental issues in order to deal successfully with them.

Critical Thinking

We must do more than simply identify and discuss environmental problems and solutions. We must think critically about them. Critical thinking is so important that we have made it the focus of its own chapter, Chapter 2. With this in mind we have also developed *Environmental Science* to present the material in a factual, unbiased format. Our goal is to help you think through the issues, not tell you what to think. To this purpose, at the end of each chapter critical thinking exercises, called *Environmental Issues*, are provided.

Interdisciplinary Approach

The approach of *Environmental Science* is interdisciplinary in nature. Environmental science integrates

many disciplines and includes some of the most important topics of modern civilization as well as some of the oldest philosophical concerns of human beings—that of the nature of our relationship with our environment. Applied and basic aspects of environmental sciences require a solid foundation in the natural sciences, in addition to fields such as anthropology, economics, history, sociology, and philosophy of the environment. Not only do we need the best ideas and information to deal successfully with our environmental problems, but we also must be aware of the cultural and historical context in which we make decisions about the environment and understand ways in which choices are made and implemented. Thus, the field of environmental science integrates the natural sciences with environmental ethics, environmental economics, environmental law, environmental impact, and environmental planning. As a result, *Environmental Science* provides an introduction to the entire spectrum of relationships between people and the environment.

THEMES

Environmental Science is based on the philosophy that several threads of inquiry are of particular importance to environmental science. The book is organized around these key themes.

A Global Perspective

Until recently we generally believed that human activity caused only local, or at most, regional environmental change. We now know that effects of human activity on Earth are of such an extent that we are involved in a series of unplanned planetary experiments. The main goal of the emerging science known as *Earth System Science* is to obtain basic understanding of how our planet as a system works. This understanding can then be applied to help solve global environmental problems. The emergence of Earth System Science has opened up a new area of inquiry for faculty and students. Understanding of relationships between biological and physical sciences requires interdisciplinary cooperation and education.

Human Population

Underlying nearly all environmental problems is the rapidly increasing human population. Ultimately, we cannot expect to solve these other problems unless we can limit the total number of people on Earth to an amount the environment can sustain. We believe that education is important to the population problem. As people become more educated, and as the rate of literacy increases, population growth tends to decrease.

Sustainability

Sustainability is a term that has gained much popularity recently. Speaking generally, it means that a resource is used in such a way that it continues to be available. However, the term is used vaguely and it is something we are struggling to clarify. Some would define it as insuring that future generations have equal opportunities to the resources that our planet offers. Others would argue that sustainability refers to types of developments that are economically viable, do not harm the environment, and are socially just. We all agree that we must learn how to sustain our environmental resources so they continue to provide benefits for people and other living things on our planet.

The Urban World

An ever-growing number of people are living in urban areas. Unfortunately our urban centers have long been neglected and the quality of urban environment has suffered. It is here we experience air pollution, waste disposal problems, social unrest, and other stresses of the environment. In the past we have centered our studies on the environment more on wilderness than the urban environment. In the future we must place greater focus on towns and cities as livable environments.

Values, Knowledge, and Social Justice

Finding solutions to environmental problems involves more than simply gathering facts and understanding scientific issues of a particular problem. It also has much to do with our systems of values and issues of social justice. To solve our environmental problems, we must understand what are our values, and which potential solutions are socially just. Then, we can apply scientific knowledge about specific problems and find acceptable solutions.

These five key themes or threads of inquiry are discussed in more detail in Chapter 1. These icons are provided throughout the text to highlight where these issues are discussed.

ORGANIZATION

The text is divided into eight parts. *Part I* provides a broad overview of the key themes in *Environmental*

Science, the scientific method, and thinking critically about the environment. *Part II* presents the study of the Earth as a system, emphasizing how systems work and the basic biochemical cycles of our planet. *Part III* focuses on life and the environment and includes subjects such as human population, ecosystems, biological diversity, biological productivity and energy flow, and restoration and recovery of ecosystems in response to disturbance. *Part IV* has the objective of sustainable conservation and management of living resources. Topics covered include world food supply, agricultural effects on environment, plentiful and endangered species, forest ecology, conserving and managing life in the oceans, and environmental health and toxicology. *Part V* introduces and discusses a wide variety of topics related to energy, including the basic concepts about energy necessary for understanding fossil fuels and environment, alternative energy, and nuclear energy. *Part VI* presents the water environment on Earth in terms of water supply, use and management, and water pollution and treatment. *Part VII* concerns air pollution, from global issues such as climate, global warming, stratospheric ozone depletion, to regional issues such as acid rain, to local issues including urban air pollution and indoor air pollution. *Part VIII* is concerned with relationships between environment and society. Topics include environmental economics, the urban environment, integrated waste management, minerals and environment, environmental impact and planning, and integrating values and knowledge.

We believe a strength of *Environmental Science* is the systematic and in-depth coverage of the many subjects that comprise the field of environmental science. An important objective is to integrate physical and biological processes within a social framework. We recognize that environmental education is a lifelong process, and that any one course may not be able to cover in depth all of the subjects presented in *Environmental Science*. The book is designed so that chapters can be selected to allow instructors and students to focus on environmental issues of particular concern to them. The goal is to provide an instrument of learning useful to educators and students today so that future generations of students will be more informed and able to make judgments concerning the environment based upon sound scientific knowledge. We believe that understanding of, and critical thinking about, environmental problems is much more important than mere presentation of facts and information.

SPECIAL FEATURES

In writing *Environmental Science* we have designed a text that incorporates a number of special features that we believe will aid in the educational process. These include:

- Each chapter presents a list of **Chapter Concepts** so that students will be more aware of the understanding they should achieve after reading and studying the chapter.
- A **Case Study** begins each chapter to interest the reader in the subject—whether it be understanding biological diversity, the human population problem, or stratospheric ozone depletion.
- Inclusion of two kinds of learning modules. **A Closer Look** provides more detailed examples to help students work out important concepts. For example, Chapter 5 includes A Closer Look at growth of human population, Chapter 9 provides A Closer Look at reforestation of Mount Saint Helens volcano following the 1980 eruption, Chapter 15 provides A Closer Look at energy units, Chapter 18 provides A Closer Look at radiation, Chapter 21 provides A Closer Look at Earth System Science and global change, Chapter 25 provides A Closer Look of risk and benefit analysis of DDT, and Chapter 29 provides A Closer Look at natural hazards.
- Understanding of *Environmental Science* also requires working with graphs and numbers. As a result, **Working It Out** exercises are provided, as for example, in Chapter 8 on Ecosystems Equalities, equations for production, biomass and energy flow, and examples of energy flow calculations. These exercises are boxed off from the text so they can be omitted if an instructor does not wish to include quantitative analysis.
- Each chapter ends with discussion of an important **Environmental Issue** relative to that chapter. The purpose is to encourage critical thinking about particular issues and help students understand ways that these issues might be studied and evaluated. For example, Chapter 19 presents the Environmental Issue of how wet is a wetland? Chapter 8 presents the Environmental Issue—should we eat lower on the food chain? Chapter 13 raises the Environmental Issue—how does fragmentation of tropical forest contribute to habitat destruction? and Chapter 16 evaluates the Environmental Issue—should the gasoline tax be raised?
- **Key Terms** are presented with each chapter to provide a list of the important topics and also to serve as an aid for review.
- We present **Summary** and **Study Questions** for review of the material presented in each

chapter. We have attempted to develop questions that will utilize critical thinking skills.

- At the end of each chapter we also list publications to be considered for **Further Reading**.

SUPPLEMENTS

A variety of supplements for both students and instructors is available for *Environmental Science:*

- **Study Guide,** prepared by Nicholas Pinter of University of California, Santa Barbara, and Susann Pinter of University of Vermont. The Study Guide contains concise chapter summaries, chapter concepts, vocabulary reviews, and chapter review questions with detailed answers and explanations. In addition, it contains a sample final examination at the end of the book.
- **Instructor's Manual,** prepared by Ann S. Causey, of Auburn University. The Manual contains teaching suggestions for all instructors, both the experienced as well as the first-time lecturer; lecture and outline notes; a list of suggested supplemental readings, films, videos, and software; and lead-ins and critical thinking activities to give instructors ideas on how to begin and finish lectures. In addition, most chapters contain a list of five to ten ways individuals can minimize their impact on Earth's available resources.
- **Test Bank,** prepared by Nicholas Pinter of University of California, Santa Barbara, and Susann Pinter of University of Vermont. This Test Bank contains approximately 1,700 multiple-choice, short-answer, and essay questions. It is also available in **Computerized Test Bank** format.
- **Transparency Acetates** of figures from the text with large bold-faced labels to aid in classroom presentations.

A SPECIAL NOTE TO STUDENTS

We have written this book with the belief that students really want to be challenged to think about the important environmental problems that face the world today. We are attempting to bring the environment to the forefront of education. This is in response to tremendous public concern about the environment. Public opinion polls confirm that environment is an important social and political issue. We also believe that scientific literacy and critical thinking are very important. As a result, we have chosen to discuss important environmental issues, some of which are multifaceted, difficult and challenging. We all need to recognize that solutions to many environmental problems facing us today are not easy to find. There are differing opinions on which problems we should address and what solutions should be attempted. This is something we cannot teach you. We can present information and arguments, but ultimately you must think for yourself and develop solutions based on your value system and understanding. If this appears as a vague concept—it is! You are responsible for future generations just as are your instructors. Making informed decisions requires a lot of study as well as a commitment to be responsible in helping to insure that our planet maintains a healthy and productive environment. We believe that if our book, *Environmental Science,* helps you in that endeavor, then it has been successful.

Daniel B. Botkin
Edward A. Keller

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Completion of this book was only possible due to the cooperation and work of many people. To all those who so freely offered their advice and encouragement in this endeavor, we offer our most sincere appreciation. We are indebted to our colleagues who made contributions: Dorothy B. Rosenthal for writing Chapter 2 and the environmental issues at the end of each chapter; Mel S. Manalis for assistance in developing the energy chapters, global warming, and stratospheric ozone depletion; Marc J. McGinnis for assistance in helping develop discussions concerning environmental law; Harold Ward for writing parts of Chapter 29, particularly relating to environmental legislation and review; Joan Melcher for her excellent editing of the manuscript; and Nicholas Pinter who helped in many ways including review of the manuscript, suggested text revisions, development of suggested readings for students, and writing of the students' study guide. Finally, we would like to thank Harold Morowitz for helpful suggestions on how to introduce the basic energy concepts.

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Brief Contents

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