

A dramatic photograph of a person standing on a dark, mossy rock in the foreground, looking up at a colossal, thundering waterfall that fills the background. The water is white and turbulent, creating a sense of immense scale and power. The overall tone is dark and awe-inspiring.

William P. Cunningham
Mary Ann Cunningham
Barbara Saigo

RAW-HILL NOT FOR RESALE
NATION ONLY 14AS107

EIGHTH EDITION

Environmental Science

A GLOBAL CONCERN

EIGHTH EDITION



Environmental Science

A GLOBAL CONCERN

William P. Cunningham

University of Minnesota

MaryAnn Cunningham

Vassar College

Barbara Woodworth Saigo

St. Cloud State University

Sarwood Biology Resources

Sarwood Publications



Higher Education

Boston Burr Ridge, IL Dubuque, IA Madison, WI New York San Francisco St. Louis
Bangkok Bogotá Caracas Kuala Lumpur Lisbon London Madrid Mexico City
Milan Montreal New Delhi Santiago Seoul Singapore Sydney Taipei Toronto



Higher Education

ENVIRONMENTAL SCIENCE: A GLOBAL CONCERN EIGHTH EDITION

Published by McGraw-Hill, an business unit of The McGraw-Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY, 10020. Copyright © 2005, 2003, 2001, 1999, 1997 by The McGraw-Hill Companies, Inc. All rights reserved. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of The McGraw-Hill Companies, Inc., including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.



This book is printed on recycled, acid-free paper containing 10% postconsumer waste.

1 2 3 4 5 6 7 8 9 0 / 0 9 8 7 6 5 4 3

ISBN 0-07-243956-4

Publisher: *Margaret J. Kemp*
Senior developmental editor: *Kathleen R. Loewenberg*
Executive marketing manager: *Lisa L. Gottschalk*
Lead project manager: *Joyce M. Berendes*
Lead production supervisor: *Sandy Ludovissy*
Lead media project manager: *Judi David*
Senior media technology producer: *Jeffry Schmitt*
Senior coordinator of freelance design: *Mickelle D. Whitaker*
Cover/interior designer: *Jamie E. O'Neal*
Cover image: "Tiny Figure" by *Dettifoss/Bryan & Cherry Alexander Photography*
Senior photo research coordinator: *Lori Hancock*
Photo research: *Connie Mueller*
Supplement producer: *Brenda A. Ernzen*
Compositor: *Precision Graphics*
Typeface: *10/12 Times Roman*
Printer: *Quebecor World Versailles Inc.*

Interior design image credits:

Title Page: *Digital Vision, PhotoDisc*; Preface Header: *PhotoDisc, Digital Vision, Artville*; Brief Contents Header: *Corbis, Artville*; Contents Header: *Corbis, Digital Vision*; Glossary/Credits/Index Headers: *Corbis, Digital Vision*; What Do You Think? Icon: *Getty Images*; Exploring Science Icon: *Getty Images, Corbis*; Case Study Icon: *Artville*; What Can You Do? Icon: *Getty Images*; Tables: *Corbis*; Key Concepts: *Corbis*

Library of Congress Cataloging-in-Publication Data

Cunningham, William P.

Environmental science : a global concern. — 8th ed. / William P. Cunningham, Mary Ann Cunningham, Barbara Woodworth Saigo.

p. cm.

Includes index.

ISBN 0-07-243956-4

I. Environmental sciences. I. Cunningham, Mary Ann. II. Saigo, Barbara Woodworth. III. Title.

GE105.C86 2005

363.7—dc22

2003025301

CIP



PREFACE

We face a rising epidemic of global environmental problems: global warming, diminishing biodiversity, growing shortages in freshwater supplies, long range transport of air pollutants and accumulation of persistent organic compounds in food webs, to mention just a few. To combat these problems and to find ways to prevent others from occurring, we need an environmentally-informed citizenry. The purpose of this book is to provide an interesting, accessible introduction to environmental science for students from a variety of backgrounds. Combining a broad, interdisciplinary approach that includes both natural sciences and human dimensions of environmental issues, this book integrates information from many different areas in a way that is accessible and useful to students from any field of study.

AUDIENCE

This book is intended for use in a one- or two-semester course in environmental science, human ecology, or environmental studies at the college or advanced placement high school level. Because most students who will use this book are freshmen or sophomore non-science majors, we have tried to make the text readable and accessible without technical jargon or a presumption of prior science background. At the same time, enough data and depth are presented to make this book suitable for many upper-division classes and a valuable resource for students who will keep it in their personal libraries after their formal studies are completed.

SUSTAINABILITY

An overarching theme in this book is sustainability: can we find ways to meet our present needs without compromising the ability of future generations to meet their own needs. Can we live on renewable energy sources and the surplus produced by biogeochemical cycles without damaging the productive capacity of our environment? The concepts of inherent values, ethical rights, stewardship, and equity between generations and between people living under different conditions now all play important roles in our

consideration of how natural resources should be managed. Consequently, ethics, philosophy and environmental worldviews are among the first topics we discuss in this book.

"This text is excellent as it provides a balanced view of renewable energy sources, taking into account both the advantages and disadvantages of the available technologies."

Lawrence Roberge
Goodwin College

CRITICAL THINKING

Critical thinking is another central theme in this book. Environmental science is a complex field, one in which a large number of special interests, contradictory data, and conflicting interpretations battle for our attention. How can we decide what to believe when apparently equally eminent experts hold diametrically opposed opinions on controversial topics? Perhaps the most valuable skill any student can gain from the study of environmental science is the ability to think purposively, analytically, and clearly about evidence. To understand the complexity and conflicting interpretations of environmental problems, students need a number of skills. They need to be able to identify and evaluate biases, recognize and assess assumptions, and understand conceptual frameworks. They must also learn to acknowledge and clarify uncertainties, equivocations, and contradictions in arguments. Reaching satisfactory conclusions about environmental dilemmas isn't just a matter of logic and rationality; we also need open-mindedness, skepticism, independence, and an ability to empathize with others. We discuss these skills in the introductory chapter of this book and then model their application in boxed readings, case studies, and questions at the ends of each chapter.

"Objectivity, readability, and visual presentations all combine to make this text stand out from all of the others out there. The authors' thoroughness and objective treatment of the topics are genuine strengths of this textbook."

Ned Knight
Linfield College

BALANCED VIEW

In every edition of this textbook, we have tried to pull together and summarize the most important current environmental information, and to explain the context and significance of scientific evidence. There's a temptation, in discussing environmental conditions to focus on extremes. While acknowledging problems, we also are careful to describe good news, progress towards sustainability, and the many ways individuals can make positive contributions toward environmental protection. Because science is always conditional, and there can be many ways to interpret data, we also present a balanced view that recognizes uncertainties and conflicting interpretations. At the same time, we stress that scientific consensus does emerge on major issues. We feel it is essential that students understand the need for differing interpretations of evidence and also recognize the value of general agreement among scholars.

"The voice of the Cunningham text is more optimistic than the book we are currently using."

Susan Brydon Golz
Rockland Community College

We hope you will find this book a valuable source of information about our global environment, as well as an inspiration for solutions to the dilemmas we face. Everyone has a role to play in this endeavor. Whether as students, educators, researchers, activists, or consumers, each of us can find ways to contribute in solving our common problems.

GLOBAL CONCERN

We live in an increasingly interconnected world. An awareness of international events, population trends, health conditions, and environmental quality are essential for educated citizens. The coal burned in China, the nuclear waste dumped in the ocean by Russia, or the pesticides used on farms in Central America affects all of us. This text has set the standard in the market for incorporating a worldview of environmental issues into each chapter with discussions in the text, photos, examples used, boxed readings, and data.

"Seldom have I seen such a good, succinct explanation of historical trends in world temperature means and why Milankovitch cycles occur."

David A. Francko
Miami University (Ohio)

UNIQUE "HOW TO STUDY" CHAPTER

Our first chapter provides information that most students need but that is rarely discussed in introductory texts: how to study, how to prepare for tests, critical thinking, concept maps, and why environmental science is exciting and important. These topics are presented in the beginning of the book so students can begin to use

them immediately. This is the kind of information that most of us cover in the first lecture of a class. No other textbook goes into the depth on the fundamentals of critical thinking theory and application found here.

"What a novel idea! Many of our students come into the course with a circumscribed background in science, and this section answers many questions that are foremost in their minds. I believe that this chapter does a wonderful job of opening the idea of active self-learners to them and importantly describes the techniques needed to make this transition."

Glenn Wehner
Truman State University

NEW TO THIS EDITION

The eighth edition has undergone a major revision and reorganization reflecting both the wealth of new information available and valuable suggestions for improvement by a large number of reviewers who have been kind enough to read the text carefully and give us their detailed comments. Among these changes are:

- Updated art program with 129 new photographs and over 100 new or revised pieces of line art, including 50 new, realistic, 3D drawings.

"The photographs are good and generally have short and to-the-point captions. There are a number of very good illustrations of which I have not seen this type of before in any other text."

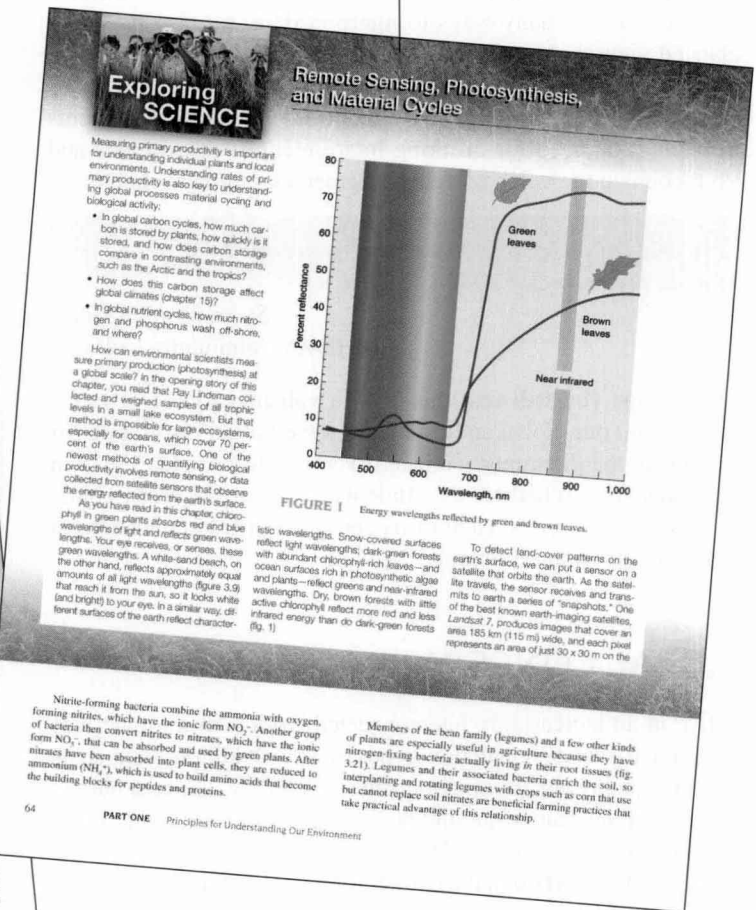
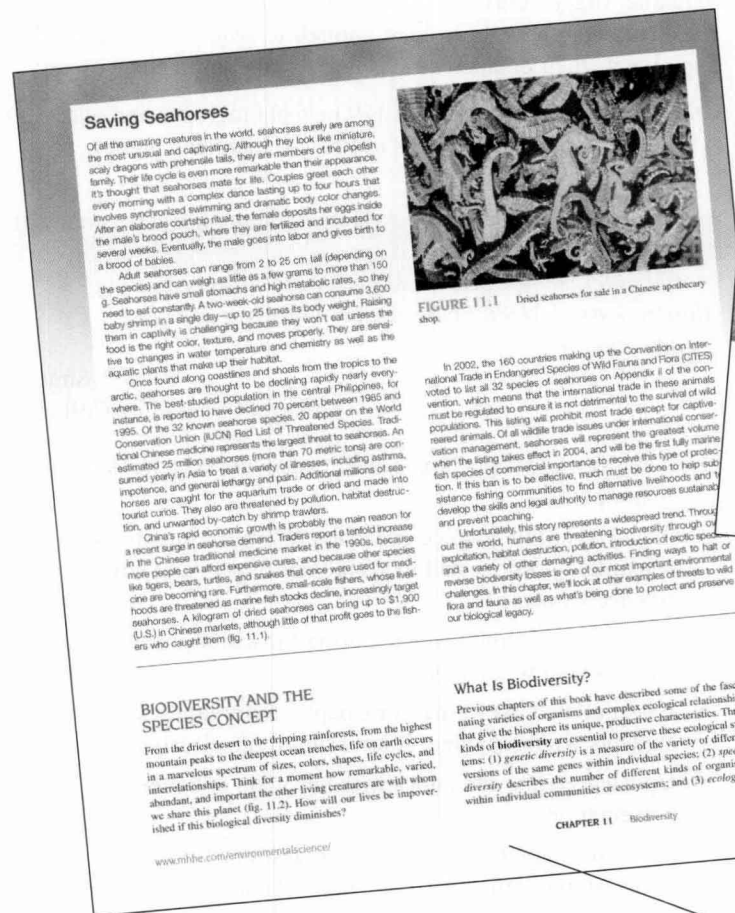
Patricia Smith
Valencia Community College

- New Key Concepts boxes to help students keep track of major points.
- New Exploring Science boxes to emphasize important scientific questions and help students understand how science works.
- New large fold-out piece featuring full-color physiographic and political world maps.
- New bulleted list format for Chapter Summaries so that students will recognize major issues more clearly.
- Updated graphs and tables with new data or better presentations.
- Revised Chapter Objectives and Questions for Review and Discussion to reflect new and revised material. To help students study effectively, all these elements follow the chapter organization more closely than before.
- New brief list of Selected Readings in each chapter to suggest some especially valuable sources for further study. We also have a much more extensive reading list on the Online Learning Center with roughly 100 citations from recent literature per chapter.

- Visit www.mhhe.com/environmentalscience and click on this text's title to access a detailed list of changes for each chapter.

This text is designed to be useful as a self-education tool for students. To facilitate studying and encourage higher-level thinking, each chapter begins with a set of **Objectives** based on major concepts that students should master. The **Learning Online** section lists important chapter topics for which there are hyperlinks available on the accompanying website.

New “**Exploring Science**” boxes focus on the science behind the story. **Case Studies**, “**What Do You Think?**” essays, many with “**Ethical Considerations**” attached, also give students real-life examples to evaluate. All of these boxed readings are carefully planned to build upon chapter content and encourage students to practice critical thinking skills and formulate reasoned opinions.



A short **Opening Story**, taken from recent news events, sets the subject in context and illuminates the importance of the material to be discussed. **Key Terms**, indicated by boldface type, are defined in the context where they are first used, and are also defined in the **Glossary** for quick reference.

The “What Can You Do?” listings help students to learn that small, individual steps can make a real difference in affecting our environment.

What can you do?

Lowering Our Forest Impacts

Americans throw away 30 million trees' worth of newspaper every year. Your habits and purchases affect the health of world forests. Here are some ways you can make a difference.

- Reuse and recycle paper. Make double-sided copies. Save office paper and use the back for scratch paper. Buy recycled paper.
- Use e-mail. Store information in digital form, and only print messages you really need to keep.
- If you build, conserve wood. Use water board, particle board, laminated beams or other composites rather than plywood and timbers made from old-growth trees.
- Buy products made from “good wood” or other certified sustainably harvested wood.
- Don’t patronize fast-food restaurants that purchase beef from cattle grazing on deforested rainforest land. Don’t buy coffee, bananas, pineapples or other cash crops if their production contributes to forest destruction.
- Do buy Brazil nuts, castews, mushrooms, rattan furniture, and other non-timber forest products harvested sustainably by local people from intact forests. Remember that tropical rainforest is not the only biome under attack. Contact the Taiga Rescue Network (www.stl.ttn/tgarecue) for information about boreal forests.
- Stay informed about resource and land-use policies, and let your elected representatives know what you think.

Opponents of forest thinning also worry that it is another disguise for below-cost timber sales. A recent Forest Service study found that the cost of thinning the 1.6 million acres of forest in the Klamath Mountains of southeastern Oregon would be \$2.7 billion, more than \$1,685 per acre, and more than the entire fire-fighting budget for 2004.

Sustainable Forestry and Non-Timber Forest Products

Creative solutions to forest management problems are available. In both temperate and tropical regions, scores of certification programs are being developed to identify sustainably produced wood products. One organization that is currently active in 40 countries is the Forest Stewardship Council (FSC). The FSC works to set standards for certification. SmartWood, a program of the Rainforest Alliance, is the most extensive certification program. This organization works with both tropical and temperate forest products companies. One of the promising movements in North American forestry is the development of cooperatives and networks among private landowners. In the United States alone, there are more than 9 million owners of small (less than 100 acres) forest lands. Groups such as the Community Forestry Resource Center are sharing information and resources to assist in sustainable management of small working forests like these.

FIGURE 12.20 Non-timber forest products, such as natural rubber, can provide an income without destroying forests.



New **Three-Dimensional Art** has transformed this eighth edition and raised it to a new standard, providing students with images that are more realistic and identifiable. For example, life-like images of wolves, hares, Inuit people, and other organisms involved in the arctic food web allow the students to more accurately visualize the connections between these various components.

“These are great illustrations, much improved over the common diagrammatic-flow representations used in most texts.”

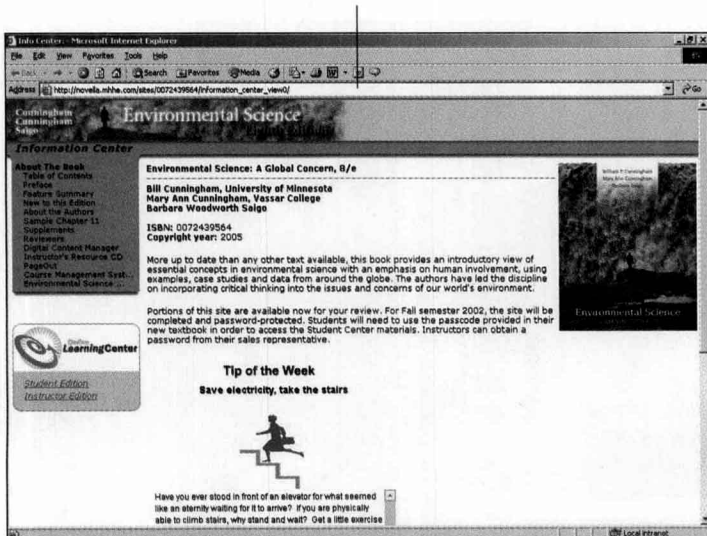
David I. Johnson
Michigan State University



At the end of each chapter, a bulleted **Summary** and a set of **Questions for Review** provide an opportunity for students to test their understanding of the material just covered, while **Questions for Critical Thinking** are designed to stimulate creative, analytical thinking and to serve as a springboard for class discussions. **Web Exercises** make use of current data on the Internet and ask students to perform activities such as graphing data, comparing maps, and using live GIS sources to learn about environmental issues and information sources.

USEFUL SUPPLEMENTS

- **Digital Content Manager (DCM) CD-ROM.** This multimedia collection of visual resources allows instructors to utilize artwork from the text in multiple formats to create customized classroom presentations, visually based tests and/or quizzes, dynamic course website content, or attractive printed support materials (see fold-out piece for more information).
- **Instructor's Testing and Resource CD-ROM.** This cross-platform CD-ROM provides a computerized test bank utilizing Brownstone Diploma® testing software to quickly create customized exams. The user-friendly program allows instructors to search for questions by topic, format, or difficulty level; edit existing questions or add new ones; and scramble questions and answer keys for multiple versions of the same test.
- **Transparencies.** A set of 100 transparencies is available to users of the text. These acetates include key figures from the text, including new art from this edition.
- **Online Learning Center**
(www.mhhe.com/environmentalscience/).
This comprehensive website offers numerous resources for both students and instructors.



Questions For Critical Thinking

1. One reviewer said that this chapter is the most biased in this book. Do you agree? How much moral outrage is appropriate in an issue such as this? Does emotion interfere with rational analysis or effective communication? What is the proper balance between emotion and objectivity in a subject such as this?
2. Many ecologists would like to move away from protecting individual endangered species to concentrating on protecting whole communities or ecosystems. Others fear that the public will only respond to and support glamorous "flagship" species such as gorillas, tigers, or otters. If you were designing a conservation strategy, where would you put your emphasis?
3. Put yourself in the place of a fishing industry worker. If you continue to catch many species they will quickly become economically extinct if not completely exterminated. On the other hand, there are few jobs in your village and welfare will barely keep you alive. What would you do?
4. Only a few hundred grizzly bears remain in the contiguous United States, but populations are healthy in Canada and Alaska. Should we spend millions of dollars for grizzly recovery and management programs in Yellowstone National Park and adjacent wilderness areas?
5. How could people have believed a century ago that nature is so vast and fertile that human actions could never have a lasting impact on wildlife populations? Are there similar examples of denial or misjudgment occurring now?
6. Suppose you're having dinner with a friend who orders swordfish. What would you say? What are the ethical and biological arguments for or against eating endangered species?
7. In the past, mass extinction has allowed for new growth, including the evolution of our own species. Should we assume that another mass extinction would be a bad thing? Could it possibly be beneficial to us? To the world?
8. Some captive breeding programs in zoos are so successful that they often produce surplus animals that cannot be released into the wild because no native habitat remains. Plans to euthanize

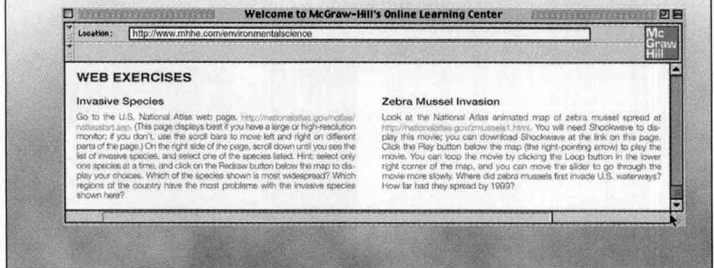
surplus animals raise storms of protests from animal lovers. What would you do if you were in charge of the zoo?

Key Terms

biodiversity 000	habitat conservation plans (HCP) 000
biodiversity hot spots 000	HIPPO 000
endangered species 000	invasive species 000
existence value 000	overharvesting 000
extinction 000	threatened species 000
gap analysis 000	vulnerable species 000

Further Readings

- Baskin, Yvonne. 2003. *A Plague of Rats and Rabbits: The Growing Threat of Species Invasions*. Island Press.
- Ellis, Richard. 2003. *The Empty Ocean: Plundering the World's Marine Life*. Island Press.
- Gibbs, W. Wayt. 2001. On the termination of species. *Scientific American* 285(5):40-49.
- Lehman, Clarence L., and David Tilman. 2000. Biodiversity, stability, and productivity in competitive communities. *The American Naturalist* 156:534-53.
- MacArthur, R. H., and E. O. Wilson. 1963. An equilibrium theory of insular zoogeography. *Evolution* 17:373-87.
- May, Robert M. 1972. Will a large complex system be stable? *Nature* 238:413-14.
- Myers, N., et al. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403:853.
- Poani, K., B. D. Richter, M. G. Anderson, and H. E. Richter. 2002. Biodiversity conservation at multiple scales: Functional sites, landscapes, and networks. *Bioscience* 50(2):133-46.

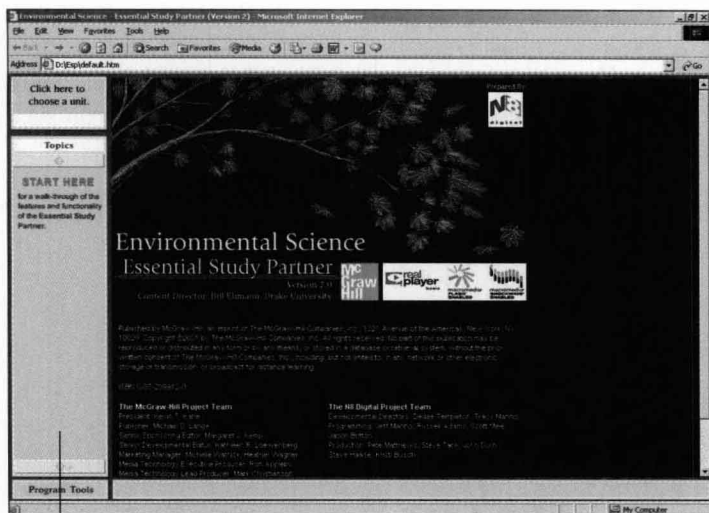


Student Resources—Everything you need in one place:

- Practice quizzing
- How to study tips
- Hyperlinks on chapter topics
- Web exercises
- Guide to electronic research
- Regional Perspectives (case studies)
- Environmental issues world map
- Key-term flashcards
- How to Contact Your Elected Officials
- Further readings
- Metric equivalents and conversion tables
- Career information
- PowerWeb's hundreds of current articles and daily news items have been integrated into each chapter on the OLC
- Access Science offers the advantage of an online, interactive encyclopedia

Instructor Resources—In addition to all of the above, you'll receive:

- Supplements resource chart for each chapter
- Questions for eInstruction
- Answers to web exercises
- Additional case studies
- Answers to critical thinking questions
- PageOut (create your own course website)



- **Environmental Science Essential Study Partner CD-ROM.** A complete, interactive student study tool, this CD features animations, videos, and learning activities. From quizzes to interactive diagrams, you'll find that there has never been a better study partner to ensure the mastery of core concepts. Best of all, it's available FREE with a new textbook purchase in an optional package.

PACKAGING OPPORTUNITIES AND RELATED TITLES

McGraw-Hill offers many different packaging opportunities that not only provide your students with valuable environmental-related material, but also a substantial cost savings. Ask your McGraw-Hill sales representative for information on discounts and special ISBNs for ordering a package that contains one or more of the following:

Annual Edition: Environment 04/05

This 23rd edition is a compilation of current articles from the best of the public press. The selections explore the global environment, the world's population, energy, the biosphere, natural resources, and pollution.

Interactive World Issues CD-ROM

This CD explores environmental issues that affect various geographic regions. For example, you'll visit Oregon and investigate water rights of the Columbia River. Listen to Native Americans whose living depends on salmon fishing and then to the farmers who need water to irrigate their crops. Additional case studies discuss migration in Mexico, apartheid in South Africa, population issues in China, and farming in urban Chicago.

New!! Exploring Environmental Science with GIS

This short book provides exercises for students and instructors who are new to GIS, but are familiar with the Windows operating system. The exercises focus on improving analytical skills, understanding spatial relationships, and understanding the nature and structure of environmental data. Because the software used is distributed free of charge, this text is appropriate for courses and schools that are not yet ready to commit to the expense and time involved in acquiring other GIS packages.

Student Interactive CD-ROM

This CD is packaged complimentary with every new copy of Cunningham et al: *Environmental Science*, 8th edition. The CD-ROM features chapter-based quizzes, chapter-based text web exercises, student tutorial, animations and PowerPoints of all the images found in the textbook.

Taking Sides: Clashing Views on Controversial Environmental Issues, Revised 10th Edition

This represents the arguments of leading environmentalists, scientists, and policymakers. The issues reflect a variety of viewpoints and are staged as "pro" and "con" debates. Issues are organized around four core areas: general philosophical and political issues, the environment and technology, disposing of wastes, and the environment and the future.

Field and Laboratory Activities for Environmental Science, 7th Edition by Enger and Smith

The major objectives of this manual are to provide students with hands on experiences that are relevant, easy-to-understand and applicable to the student's life, presented in an interesting, informative format. Ranging from field and lab experiments to conducting social and personal assessments of the environmental impact of human activities, the manual presents something for everyone, regardless of the budget or facilities of each class. These labs are grouped by categories that can be used in conjunction with any introductory environmental textbook.

Sources: Notable Selections in Environmental Studies, 2nd Edition

This volume brings together primary source selections of enduring intellectual value—classic articles, book excerpts, and research studies—that have shaped environmental studies and our contemporary understanding of it. The book includes carefully edited selections for the works of the most distinguished environmental observers, past and present. Selections are organized topically

around the following major areas of study: energy, environmental degradation, population issues and the environment, human health and the environment, and environment and society.

***Student Atlas of Environmental Issues* by Allen**

The Student Atlas of Environmental Issues is an invaluable pedagogical tool for exploring the human impact on the air, waters, biosphere, and land in every major world region. This informative resource provides a unique combination of maps and data helping students understand the dimensions of the world's environmental problems and the geographical basis of these problems.

***You Can Make a Difference: Be Environmentally Responsible*, 2nd Edition by Getis**

This book is organized around the three parts of the biosphere: land, water, and air. Each section contains descriptions of the environmental problems associated with that part of the biosphere. Immediately following each problem or "challenge" are suggested ways that individuals can help solve or alleviate them. This book has been written to provide the reader with some easy and practical ways to protect the Earth and to help understand why the task is so important.

ACKNOWLEDGMENTS

We're indebted to all the students and teachers who have sent helpful suggestions, corrections, and recommendations for improving this book. Unfortunately, space doesn't permit inclusion of all the excellent ideas that were provided. All have been saved, however, and will be helpful in future editions. We hope that those who read this edition will offer their advice and insights as well. Little of the vast range of material in this book represents our own personal research. All of us owe a great debt to the many scholars whose work forms the basis of our understanding of environmental science. We stand on the shoulders of giants. If errors persist in spite of our best efforts to root them out, we accept responsibility and ask for your indulgence.

We want to express our appreciation to the entire McGraw-Hill book team for their wonderful work in putting together this edition. Kathy Loewenberg oversaw the developmental stages and has made many creative contributions to the book. Joyce Berendes, as production project manager, kept everything running smoothly and has been extremely tolerant and accommodating even when some of us have missed deadlines. Cathy Conroy did an excellent job of copyediting and spotting errors/inconsistencies. Connie Mueller and Lori Hancock found superb photographs. The folks at Precision Graphics did an excellent job of composition and page layout. Marge Kemp has continued to support this project over the years with enthusiasm and creative ideas.

We especially want to thank our distinguished panel of advisors who helped select this edition's cover, and more importantly, guided the amazing new art program through development. We're very grateful for their thoughtful and timely comments on such critical illustrations.

Board of Advisors

Dawn Ford, *University of Tennessee*
Dan Gleason, *Georgia Southern University*
Peggy Green, *Broward Community College*
David Johnson, *Michigan State University (East Lansing)*
Lissa Leege, *Georgia Southern University*
Stacy Smith, *Lexington Community College*
Ed Standora, *Buffalo State College*

We also gratefully acknowledge the constructive criticism of the many colleagues who provided reviews of this, and the previous, edition of the book. They include:

Reviewers for the Eighth Edition

C. Marjorie Aelion
University of South Carolina
James R. Albanese
State University of New York at Oneonta
M. Elizabeth Allyn
Penn State York
Robb A. Bajema
Aquinas College
Christine Baumann Feurt
University of New England
Jerry Beilby
Northwestern College
Brian L. Bingham
Western Washington University
Richard J. Bryant
Southwestern Oklahoma State University
Susan Brydon Golz
Rockland Community College
Dan Buresh
Sitting Bull College
Ray D. Burkett
Southwest Tennessee Community College
Lawrence D. Cahoon
University of North Carolina at Wilmington
William A. Calder
University of Arizona
Winifred Caponigri
Holy Cross College
Raymond A. Catalano
California University of Pennsylvania

Amy B. Chan Hilton <i>Florida A & M University</i>	Frank Huang <i>New Mexico Tech</i>
Mingteh Chang <i>Stephen F. Austin State University</i>	John C. Inman <i>Presbyterian College</i>
David T. Corey <i>Midlands Technical College</i>	Dan F. Ippolito <i>Anderson University</i>
Anne M. Cummings <i>Pikes Peak Community College</i>	Marlo G. Johansen <i>Gavilan College</i>
Randi Darling <i>Westfield State College</i>	Kristen A. Keteles <i>University of Central Arkansas</i>
James N. DeVries <i>Lancaster Bible College</i>	Vishnu R. Khade <i>Eastern Connecticut State University</i>
Ronald E. D'Orazio <i>Ellsworth Community College</i>	Carol A. Kimmons <i>University of Tennessee at Chattanooga</i>
Leslie E. Dorworth <i>Illinois-Indiana Sea Grant College</i>	Eric C. Kindahl <i>Hood College</i>
L. Donald Duke <i>University of California - Los Angeles</i>	Mark E. Knauss <i>Shorter College</i>
David S. Duncan <i>University of South Florida</i>	Ned J. Knight <i>Linfield College</i>
David J. Eisenhour <i>Morehead State University</i>	Mark Kozubowski <i>Bethany College</i>
David L. Evans <i>Pennsylvania State University</i>	Steve LaDochy <i>California State University-Los Angeles</i>
Edwin M. Everham III <i>Florida Gulf Coast University</i>	Robert W. Ling Jr. <i>Kankakee Community College</i>
Anne M. Falke <i>Worcester State College</i>	Chris Lobban <i>University of Guam</i>
Qinguo Fan <i>University of Massachusetts Dartmouth</i>	Peter Lortz <i>North Seattle Community College</i>
David G. Fisher <i>Maharishi University of Management</i>	Judy Ann Lowman <i>Chaffey College</i>
Malcolm Fitz Patrick <i>Worcester Polytechnic Institute</i>	Dorothy May <i>Park University</i>
Catherine Folio <i>Brookdale Community College</i>	Emmanuel K. Mbobi <i>Kent State University Stark Campus</i>
Carl F. Frieze <i>University of Dayton</i>	Kathy McCann Evans <i>Reading Area Community College</i>
Allan A. Gahr <i>Gordon College</i>	Alan McInTosh <i>University of Vermont</i>
Lesley Garner <i>University of West Alabama</i>	Michael J. McLeod <i>Belmont Abbey College</i>
Rodney G. Handy <i>Western Kentucky University</i>	Sheila G. Miracle <i>Southeast Community College</i>
Gregory S. Holden <i>Colorado School of Mines</i>	Dusan Miskovic <i>Northwood University</i>
Robert E. Holtz <i>Concordia University</i>	Thomas E. Murray <i>Elizabethtown College</i>

James L. Nation
University of Florida

Victor I. Okereke
State University of New York – Morrisville

Carl S. Oplinger
Muhlenberg College

Mark A. Ouimette
Hardin-Simmons University

Jon K. Piper
Bethel College

Richard Puetz
Illinois Valley Community College

Kathleen L. Purvis
The Claremont Colleges

Jodie Ramsay
Northern State University

Lakshmi N. Reddi
Kansas State University

Samuel K. Riffell
Michigan State University–East Lansing

Lawrence F. Roberge
Lesley University

Lynette Rushton
South Puget Sound Community College

May Linda Samuel
Benedict College

Bradley A. Sarchet
Colby-Sawyer College

Rick Schmude
College of Lake County

R.P. Sinha
Elizabeth City State University

Jerry M. Skinner
Keystone College

Edwin J. Skoch
John Carroll University

William A. Smith
Charleston Southern University

Patricia L. Smith
Valencia Community College–Orlando

Ravi Srinivas
University of St. Thomas–Houston

Richard T. Stevens
Cleveland State Community College

Thomas M. Tharp
Purdue University

Teresa A. Thomas
Southwestern College at Chula Vista

Anne Todd Bockarie
Philadelphia University

John C. Tucker
University of Tennessee at Chattanooga

Robert F. Volp
Murray State University

Carl Waltz
Gwynedd Mercy College

Thomas Waring
Montana Tech

Phillip L. Watson
Ferris State University

Harold J. Webster
Penn State DuBois

Glenn R. Wehner
Truman State University

Richard Wilke
University of Wisconsin–Stevens Point

Danielle M. Wirth
Des Moines Area Community College

David R. Yesner
University of Alaska–Anchorage

Reviewers for the Seventh Edition:

Ghulam Sediq Aasef
Kaskaskia College

David Arieti
Waubensee College

Lisa R. Arnold
South Georgia College

David Bass
University of Central Oklahoma

Sharmistha Basu-Dutt
State University of West Georgia

R. P. Benard
American International College

Bruce Bennett
Community College of Rhode Island

David Bixler
Chaffey College

Del Blackburn
Clark College

Dorothy F. Boorse
Gordon College

Fred J. Brenner
Grove City College

Joel G. Burken
University of Missouri-Rolla

William A. Calder <i>University of Arizona</i>	Gina Johnston <i>California State University, Chico</i>
Catherine W. Carter <i>Georgia Perimeter College</i>	J. Timothy Kimmel <i>Barton County Community College</i>
Richard Clements <i>Chattanooga State Technical Community College</i>	John C. Kinworthy <i>Concordia University</i>
Terence H. Cooper <i>University of Minnesota</i>	Peter Kish <i>Southwestern Oklahoma State University</i>
William C. Culver <i>St. Petersburg Junior College</i>	Penelope M. Koines <i>University of Maryland, College Park</i>
Roy G. Darville <i>East Texas Baptist University</i>	John Koscelny <i>Coffeyville Community College</i>
Linda M. Desmarteau <i>University of Washington, Tacoma</i>	Bennett D. Kottler <i>Southern Connecticut State University</i>
Jean W. Dupon <i>Menlo College</i>	Thomas A. Kreiling <i>William Rainey Harper College</i>
David A. Easterla <i>Northwest Missouri State University</i>	John F. Logue <i>University of South Carolina Sumter</i>
Kathy McCann Evans <i>Reading Area Community College</i>	David A. Lovejoy <i>Westfield State College</i>
David G. Fisher <i>Maharishi University of Management</i>	Paul E. Lutz <i>Lenoir-Rhyne College</i>
Chris Fox <i>Community College of Baltimore County-Catonsville</i>	Michael J. Manetas <i>Humboldt State University</i>
Heather Gallacher <i>Cleveland State University</i>	Heidi Marcum <i>Baylor University</i>
Jianbang Gan <i>Tuskegee University</i>	Bernard A. Marcus <i>Genesee Community College</i>
Sandi Gardner <i>Triton College</i>	Dorothy G. May <i>Park University</i>
J. Phil Gibson <i>Agnes Scott College</i>	Dave Mense <i>Pitt Community College</i>
Joseph W. Goy <i>Harding University</i>	Gary L. Miller <i>University of North Carolina-Asheville</i>
W. David Hacker <i>New Mexico Highlands University</i>	David M. Myton <i>Lake Superior State University</i>
Gregory J. Haenel <i>Elon College</i>	Muthena Naseri <i>Moorpark College</i>
Mark F. Hammer <i>Wayne State College</i>	Melvin L. Northup <i>Grand Valley State University</i>
Stephen Herr <i>Oral Roberts University</i>	Chuks A. Ogbonnaya <i>Mountain Empire College</i>
Graham C. Hickman <i>Texas A&M University-Corpus Christi</i>	Joyce H. Ownbey <i>Sacramento City College</i>
Robert E. Hoitz <i>Concordia University</i>	Jeff Port <i>Ottawa University</i>
Jean R. Hushagen <i>Bismarck State College</i>	Brian C. Reeder <i>Morehead State University</i>

Charles Rhyne
Jackson State University

Gwynne Stoner Rife
University of Findlay

Carlton Lee Rockett
Bowling Green State University

John M. Rybczyk
California University of Pennsylvania

Robert Sanford
University of Southern Maine

Timothy Savisky
University of Pittsburgh at Greensburg

P. D. Scarlatos
Florida Atlantic University

Neil B. Schanker
College of the Siskiyous

Fred Schindler
Indian Hills Community College

James L. Seago, Jr.
State University of New York at Oswego

Robert Shamansky
Simpson College

Brian R. Shmaefsky
Kingwood College

Alan Stam
Capital University

Lori Stevens
University of Vermont

Max R. Terman
Tabor College

S. Kant Vajpayee
University of Southern Mississippi

G. Peter van Walsum
Baylor University

Warren Viessman, Jr.
University of Florida

John A. Wiggins
New Jersey Institute of Technology

Richard J. Wright
Valencia Community College

Yan Xiang
University of Wisconsin-Green Bay

Len Yannielli
Naugatuck Valley Community Technical College



CONTENTS IN BRIEF

PART ONE

PRINCIPLES FOR UNDERSTANDING OUR ENVIRONMENT

- Chapter 1 Understanding Our Environment 15
- Chapter 2 Environmental Philosophy, Ethics, and Science 33
- Chapter 3 Matter, Energy, and Life 48
- Chapter 4 Biological Communities and
Species Interactions 71
- Chapter 5 Biomes: Global Patterns of Life 93
- Chapter 6 Population Biology 110

PART TWO

PEOPLE IN THE ENVIRONMENT

- Chapter 7 Human Populations 124
- Chapter 8 Environmental Health and Toxicology 146
- Chapter 9 Food and Agriculture 169
- Chapter 10 Pest Control 195

PART THREE

UNDERSTANDING AND MANAGING LIVING SYSTEMS

- Chapter 11 Biodiversity 216
- Chapter 12 Land Use: Forests and Grasslands 238
- Chapter 13 Preserving and Restoring Nature 263

PART FOUR

PHYSICAL RESOURCES AND ENVIRONMENTAL SYSTEMS

- Chapter 14 Geology and Earth Resources 288
- Chapter 15 Air, Weather, and Climate 306
- Chapter 16 Air Pollution 328
- Chapter 17 Water Use and Management 353
- Chapter 18 Water Pollution 377

PART FIVE

ISSUES AND POLICY

- Chapter 19 Conventional Energy 405
- Chapter 20 Sustainable Energy 428
- Chapter 21 Solid, Toxic, and Hazardous Waste 455
- Chapter 22 Urbanization and Sustainable Cities 477
- Chapter 23 Ecological Economics 497
- Chapter 24 Environmental Policy, Law, and Planning 520
- Chapter 25 What Then Shall We Do? 543

CONTENTS

Preface XIV

Introduction Learning to Learn 1

Objectives 1

Learning Online 1

Why Study Environmental Science? 2

How Can I Get an A in this Class? 3

Develop Good Study Habits 3

Recognize and Hone Your Learning Styles 4

Use This Textbook Effectively 5

Will This Be on the Test? 6

Thinking About Thinking 7

Approaches to Truth and Knowledge 8

What Do I Need to Think Critically? 8

Applying Critical Thinking 9

Some Clues for Unpacking an Argument 9

Avoiding Logical Errors and Fallacies 9

Using Critical Thinking in Environmental Science 10

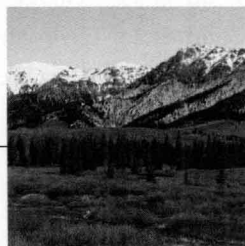
Concept Maps 10

How Do I Create a Concept Map? 10

What do you think?

Don't Believe Everything

You See on the Internet 11



PART ONE

PRINCIPLES FOR UNDERSTANDING OUR ENVIRONMENT

Chapter 1 Understanding Our Environment 15

Objectives 15

Learning Online 15

Measuring Sustainability and Ecological Footprints 16

What Is Environmental Science? 16

A Brief History of Conservation and Environmentalism 17

Historic Roots of Nature Protection 17

Pragmatic Resource Conservation 17

Moral and Aesthetic Nature Preservation 18

Modern Environmentalism 19

Global Concerns 20

Current Conditions 20

A Marvelous Planet 20

Environmental Dilemmas 21

Exploring Science What's Happening to Frogs? 22

Signs of Hope 23

Rich/Poor: A Divided World 24

Human Development 25

A Fair Share of Resources? 26

Economic Progress 27

Sustainable Development 27

Can Development Be Truly Sustainable? 28

The 20:20 Compact for Human Development 29

Indigenous People 29

Chapter 2 Environmental Philosophy, Ethics, and Science 33

Learning Online 33

Objectives 33

Sharkless Seas? 34

Environmental Ethics and Philosophy 34

Are There Universal Ethical Principles? 35

Values, Rights, and Obligations 35

Religious and Cultural Perspectives 37

Buddhism, Shamanism and Nature-Based Religions 37

Christianity, Judaism, and Islam 38

Ecofeminism 38

Environmental Justice 39

Environmental Racism 40

Dumping Across Borders 40

Science as a Way of Knowing 40

Cooperation and Insight in Science 41

Scientific Design 41

Deductive and Inductive Reasoning 42

Hypotheses and Theories 43

Modeling and Natural Experiments 43

Statistics and Probability 44

Intuition and Inspiration 44

Paradigms and Scientific Consensus 45

Pseudoscience and Baloney Detection 45

Chapter 3 Matter, Energy, and Life 48

Objectives 48

Learning Online 48

Measuring Energy Flows in Cedar Bog Lake 49

Elements of Life 49

Matter, Atoms, Molecules, and Compounds 50

Chemical Bonds 50

Ions, Acids, and Bases 51

Organic Compounds 51

Case Study A "Water Planet" 52

Cells: The Fundamental Units of Life 53

Energy 54

Energy Types and Qualities 54

Thermodynamics and Energy Transfers 54

Energy for Life 55

Solar Energy: Warmth and Light 55

How Does Photosynthesis Capture Energy? 56

From Species to Ecosystems 57

Populations, Communities, and Ecosystems 57

Food Chains, Food Webs, and Trophic Levels 58

Ecological Pyramids 59

Material Cycles and Life Processes 60

The Hydrologic Cycle 61

The Carbon Cycle 62

The Nitrogen Cycle 63

Exploring Science Remote Sensing, Photosynthesis, and Material Cycles 64

The Phosphorus Cycle 66

The Sulfur Cycle 67

Chapter 4 Biological Communities and Species Interactions 71

Objectives 71

Learning Online 71

Why Trees Need Salmon 72

Who Lives Where, and Why? 72

Critical Factors and Tolerance Limits 72

Natural Selection, Adaptation, and Evolution 74

The Ecological Niche 75

Species Interactions 77

Exploitation Predation and Parasitism 77

Keystone Species 78

Competition 79

Symbiosis 79

What do you think? Understanding Competition 80

Defensive Mechanisms 81

Community Properties 82

Productivity 82

Abundance and Diversity 83

Complexity and Connectedness 84

Resilience and Stability 84

Edges and Boundaries 84

Communities in Transition 86

Ecological Succession 86

Case Study Where Have All the Songbirds Gone? 87

Introduced Species and Community Change 89

What can you do? Working Locally for Ecological Diversity 89

Chapter 5 Biomes: Global Patterns of Life 93

Objectives 93

Learning Online 93

Integrity, Stability, and Beauty of the Land 94

Terrestrial Biomes 94

Deserts 95

Grasslands: Prairies and Savannas 95

Tundra 95

Conifer Forests 97

Broad-Leaved Deciduous Forests 98

Mediterranean/Chaparral/Thorn Scrub 99

Tropical Moist Forests 99

Tropical Seasonal Forests 100

Marine Ecosystems 100

The Open Ocean 101

Shallow Coasts: Coral Reefs and Mangroves 101

Tidal Environments and Barrier Islands 102

Freshwater Ecosystems 103

Lakes 103

Wetlands 104

Human Disturbance 105

Chapter 6 Population Biology 110

Objectives 110

Learning Online 110

How Many Fish in the Sea? 111

Dynamics of Population Growth 111

Exponential Growth and Doubling Times 112

Biotic Potential and Carry Capacity 112

Population Oscillations and Irruptive Growth 112

What do you think? Too Many Deer? 113

Growth to a Stable Population 114

Strategies of Population Growth 114

Factors That Increase or Decrease Populations 115

Natality, Fecundity, and Fertility 116

Immigration 116

Mortality and Survivorship 116

Emigration 117

Factors That Regulate Population Growth 117

Density-Independent Factors 118

Density-Dependent Factors 118

Conservation Biology 120

Island Biogeography 120

Conservation Genetics 120

Population Viability Analysis 121

Metapopulations 121