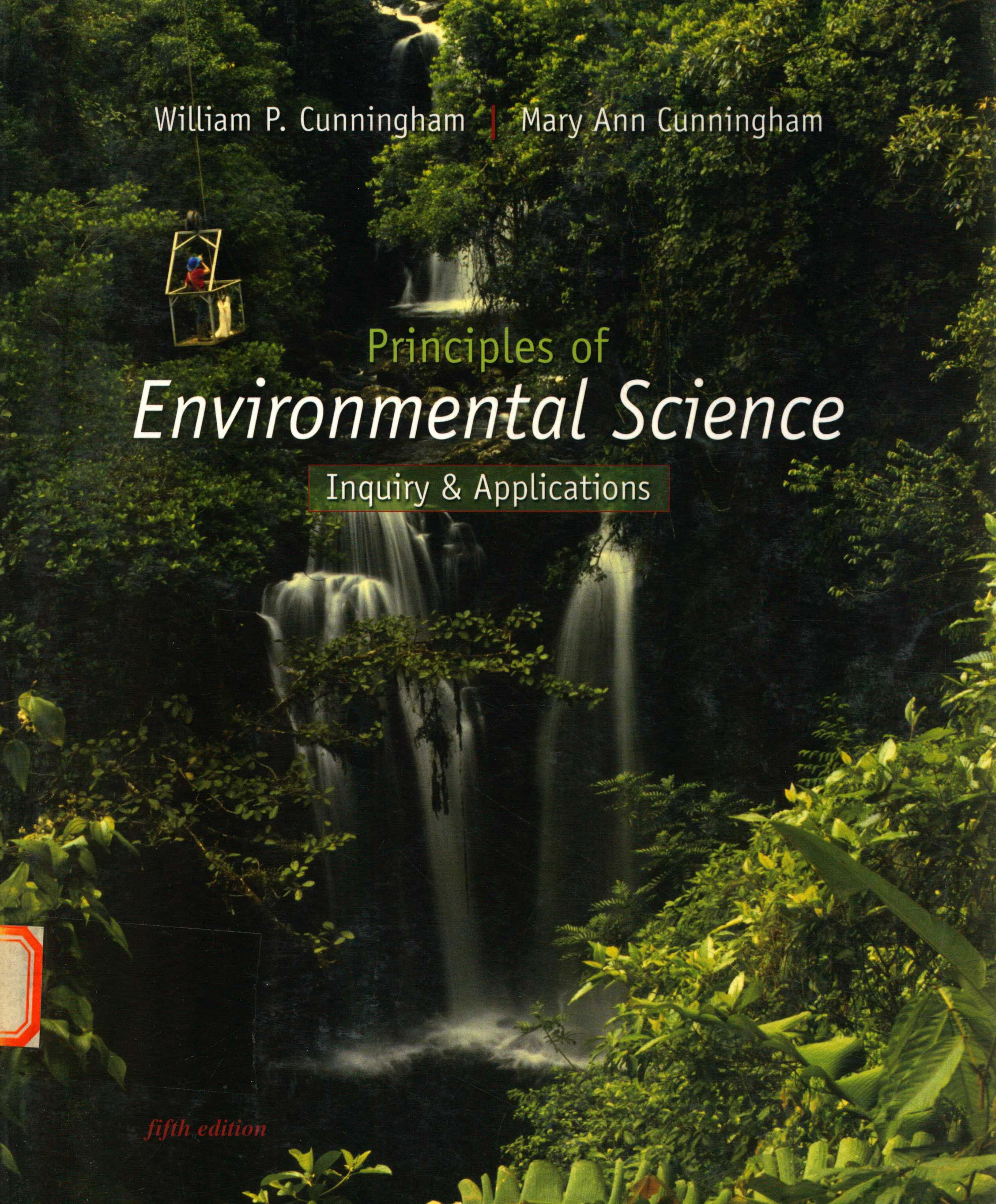
William P. Cunningham | Mary Ann Cunningham

Principles of Environmental Science

Inquiry & Applications

fifth edition



Principles of Environmental Science
Inquiry & Applications

FIFTH EDITION

William P. Cunningham
University of Minnesota

Mary Ann Cunningham
Vassar College

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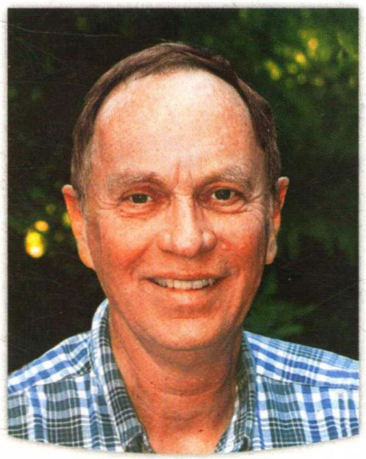
About the Authors



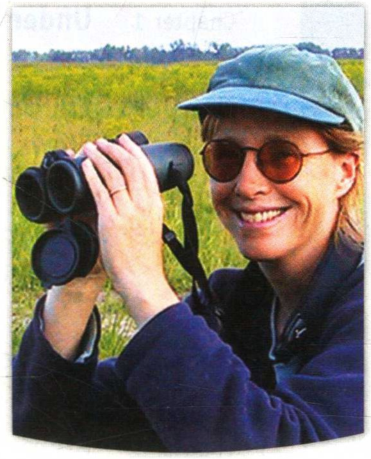
William P. Cunningham

William P. Cunningham is an emeritus professor at the University of Minnesota. In his 38-year career at the university, he taught a variety of biology courses, including Environmental Science, Conservation Biology, Environmental Health, Environmental Ethics, Plant Physiology, General Biology, and Cell Biology. He is a member of the Academy of Distinguished Teachers, the highest teaching award granted at the University of Minnesota. He was a member of a number of interdisciplinary programs for international students, teachers, and nontraditional students. He also carried out research or taught in Sweden, Norway, Brazil, New Zealand, China, and Indonesia.

Professor Cunningham has participated in a number of governmental and nongovernmental organizations over the past 40 years. He was chair of the Minnesota chapter of the Sierra Club, a member of the Sierra Club national committee on energy policy, vice president of the Friends of the Boundary Waters Canoe Area, chair of the Minnesota governor's task force on energy policy, and a citizen member of the Minnesota Legislative Commission on Energy.

In addition to environmental science textbooks, Cunningham edited three editions of an *Environmental Encyclopedia* published by Thompson-Gale Press. He has also authored or co-authored about 50 scientific articles, mostly in the fields of cell biology and conservation biology as well as several invited chapters or reports in the areas of energy policy and environmental health. His Ph.D. from the University of Texas was in botany.

His hobbies include backpacking, canoe and kayak building (and paddling), birding, hiking, gardening, and traveling. He lives in St. Paul, Minnesota with his wife, Mary. He has three children (one of whom is co-author of this book) and seven grandchildren.



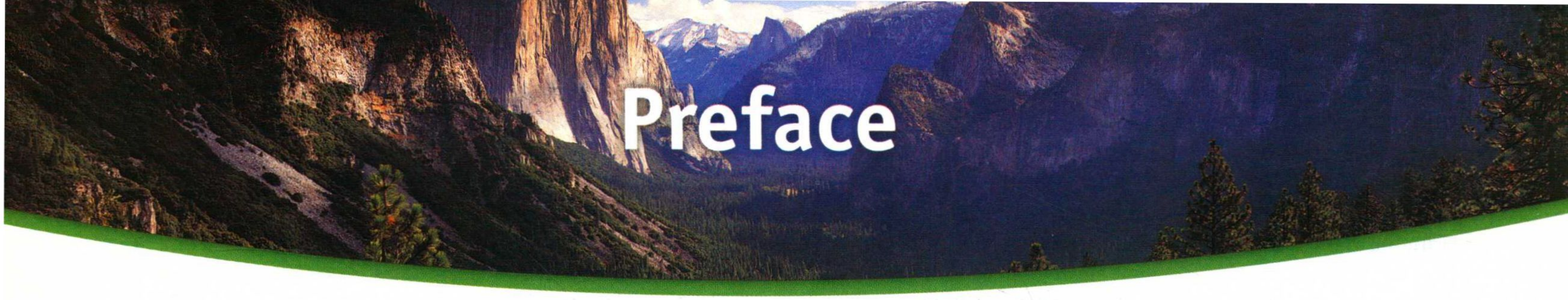
Mary Ann Cunningham

Mary Ann Cunningham is an associate professor of geography at Vassar College, in New York's Hudson Valley. A biogeographer with interests in landscape ecology, geographic information systems (GIS), and remote sensing, she teaches environmental science, natural resource conservation, and land-use planning, as well as GIS and remote sensing. Field research methods, statistical methods, and scientific methods in data analysis are regular components of her teaching. As a scientist and educator, Mary Ann enjoys teaching and conducting research with both science students and non-science liberal arts students. As a geographer, she likes to engage students with the ways their physical surroundings and social context shape their world experience. In addition to teaching at a liberal arts college, she has taught at community colleges and research universities.

Mary Ann has been writing in environmental science for over a decade, and she has been co-author of this book since its first edition. She is also co-author of *Environmental Science* (now in its tenth edition), and an editor of the *Environmental Encyclopedia* (third edition, Thompson-Gale Press). She has published work on pedagogy in cartography, as well as instructional and testing materials in environmental science. With colleagues at Vassar, she has published a GIS lab manual, *Exploring Environmental Science with GIS,* designed to provide students with an easy, inexpensive introduction to spatial and environmental analysis with GIS.

In addition to environmental science, Mary Ann's primary research activities focus on land-cover change, habitat fragmentation, and distributions of bird populations. This work allows her to conduct field studies in the grasslands of the Great Plains as well as in the woodlands of the Hudson Valley. In her spare time she loves to travel, hike, and watch birds.

Mary Ann holds a bachelor's degree from Carleton College, a master's degree from the University of Oregon, and a Ph.D. from the University of Minnesota.



Preface

Renewed Passion for Environmental Science

A new energy is invigorating the environmental movement. Analysts once said that environmentalism is dead, but now a diverse, savvy, and passionate movement is taking shape. The need for environmental science education has never been greater as the mounting evidence of environmental threats has become impossible to ignore. Meanwhile, scientists are finding better ways to interpret and explain research results, activists are discovering new approaches for shaping public policy, and the general public is awaking to the importance of clean water and clear air. In the United States, hundreds of colleges, communities, and local governments are working to reduce carbon emissions and to use energy efficiently. More than 400 bills have been passed in 40 states to require renewable energy or to otherwise combat climate change.

Environmental science is truly a global concern. Even people in developing countries are demanding better protection of environmental quality. The Chinese government, for example, responding to thousands of citizen protests, has promised new policies that will promote renewable energy, clean surface waters, and improve air quality. It remains to be seen how well these ambitions will be met, but the dramatic changes in rhetoric, technology, and creativity are remarkable. Most importantly, environmental concern is not just a fringe movement involving efforts to protect and improve our common environment: it is business leaders finding ways to reduce costs by reducing waste, insurance companies concerned about rising sea levels, and inner-city communities trying to lower asthma rates in children. Major changes are occurring across the globe in the quest to save the critical resources that provide life and health to the environment. It's a wonderful time to be studying these issues and to prepare to play a role either as a practitioner or an informed citizen.

What Sets This Book Apart?

A Positive, Balanced Viewpoint

If students are to take the ideas of environmental science to heart, they need positive messages about ways all of us can contribute to a more sustainable world. This book presents the positive developments through introductory **case studies** at the beginning of each chapter, illustrating an important current issue to demonstrate how it relates to practical environmental concerns. Most of these case studies present optimistic examples in which people are working to find solutions to environmental problems. These stories also help to demystify scientific investigation and help students understand how scientists study complex issues. In addition to these introductory stories, case studies and examples of how scientists investigate our environment appear periodically throughout the book to reiterate the practical importance of these issues.

Integrated Approach Emphasizing Sustainability

Environmental problems and their solutions occur at the intersection of natural systems and the human systems that manipulate the natural world. In this book we present an **integrated approach** to physical sciences—biology, ecology, geology, air and water resources—and to human systems that affect nature—food and agriculture, population growth, urbanization, environmental health, resource economics, and policy. Although it is tempting to emphasize purely natural systems, we feel that students can never understand why coral reefs are threatened or why tropical forests are being cut down if they don't know something about the cultural, economic, and political forces that shape our decisions.

Current and Accurate Data

Throughout this book, we present up-to-date tables and graphs with the most current available data. We hope this data will give students an appreciation of the kinds of information available in environmental science. Among the sources we have called upon here are geographic information systems (GIS) data and maps, current census and population data, international news and data sources, and federal data collection agencies. Every chapter in this book has numerous updates that reflect recent events in energy, food, climate, population trends, and other important issues.

Active Learning and Critical Thinking

Learning how scientists approach problems can help students develop habits of independent, orderly, and objective thought. But it takes active involvement to master these skills. *Principles of Environmental Science* integrates numerous learning aids that will encourage students to think for themselves. Data and interpretations aren't presented as immutable truths, but rather as evidence to be examined and tested.

- **Exploring Science** essays promote scientific literacy by demonstrating the methodology scientists use to explore complex environmental questions.
- **What Can You Do?** boxes encourage students to "make a difference" by assuming personal responsibility for environmentally friendly decisions. The text offers many examples of how scientists and citizens have worked to resolve environmental questions, both basic and applied.
- **Data Analysis** exercises conclude each chapter to give students further opportunities to apply skills and put into practice the knowledge they've gained. We pay special attention to graphing techniques in these boxes because data display is such an important part of scientific information delivery. We don't limit this discussion to simple pie charts and line plots, we use this space to demonstrate a variety of ways to display and analyze data.
- **Critical Thinking and Discussion**, a challenging, open-ended set of questions at the end of each chapter, encourages students to think more deeply and independently about issues and principles presented in the chapter. These questions make excellent starting points for discussion sections. They also could be used to practice for essay exams, or might even serve as an essay exam themselves.

What's New in This Edition?

Google Earth™ Placemarks

Throughout this book we've identified interesting and important geographical places that help in understanding environmental issues. Icons in the text identify these places and direct the reader to placemarkers on our web page that take you directly to those places in Google Earth™. You can zoom in for a close view or up to a higher altitude to gain an overall perspective. We believe the exercises we've created around these placemarkers on our website will help students gain a global perspective and will be useful for concept review, class discussion, and lecture enrichment.

Active Learning Exercises

Active Learning exercises encourage students to practice critical thinking skills and apply their understanding of chapter concepts to propose solutions.

Learning Outcomes

Each chapter opens with a list of learning outcomes that will help students organize study priorities. Rather than being imperative requirements, these outcomes have been changed to more friendly questions that lead rather than command.

End-of-Chapter Study Tools

For this edition, we've changed the review questions to practice quizzes to help students prepare for exams. This edition also has a number of new Data Analysis exercises, critical thinking and discussion questions, and conclusions that draw together key ideas in each chapter.

New Chapter Content

- Chapter 1 has been reorganized to engage students more quickly with a major emphasis on environmental problems and progress. A revised presentation of environmental history puts issues in context while a strengthened discussion of critical thinking and sound science helps students analyze information.
- Chapter 2 has improved presentations on systems, nutrients, isotopes, and ecosystems. A new Data Analysis box invites students to explore nutrient flow in a wetland.
- Chapter 3 has a new Exploring Science box on evolution of cichlids in Lake Victoria and a new What Can You Do? box on working locally for ecological diversity. It also has a revised section on human-caused ecological disturbances. A new Data Analysis box on the classic species competition studies of G. F. Gause gives students some historical background and invites them to learn to read graphs.
- Chapter 4 opens with a new case study on successful family planning in Thailand. The chapter goes on to a new discussion of ecological footprints along with updated world population and demographic data. It ends with a new Data Analysis box on communicating with graphs.
- Chapter 5 includes a modified introduction to biodiversity, an updated discussion of the Endangered Species Act, and a new Active Learning box on climate graphs.
- Chapter 6 has a new case study on British Columbia's Great Bear Rainforest, a major new section on world parks and preserves, and a new Exploring Science box on rangeland conservation in New Mexico.
- Chapter 7 has been extensively revised to include a section that emphasizes dramatic changes in food production and hunger in the past 40 years, an individual's relationship to food production, a new discussion of cheap food policies in the U.S., a new section on locavores, and other sustainable activities. It also includes a new Data Analysis exercise and two new Active Learning exercises.
- Chapter 8 opens with a new case study on successful Guinea worm eradication. It has an added section on the role of environmental factors in global disease and a revised section on conservation medicine including recent disease outbreaks. New information about methicillin-resistant Staph A has been added together with a new section on hormesis and epigenetics.
- Chapter 9 is among the most completely updated in the book. It has a new case study on ocean stabilization (geoengineering) as well as a new discussion of data from ice cores in

correlation with historic climate shifts. It also includes a new Active Learning box on calculating carbon reductions, an updated section on clean air legislation, and a new Data Analysis exercise on graphing air pollution.

- Chapter 10 opens with a revised case study on saving the Chattahoochee. It also has a revised section on water availability correlating with the drought in the southern United States. A new box on China's South-to-North water diversion project has been added as well as an updated section on water privatization and the conflict over water resources. Also included is a new Exploring Science box on the Gulf "dead zone."
- Chapter 11 opens with a revised case study about the problems associated with coal-bed methane wells. This chapter also provides a brief overview of the flooding in June 2008 that occurred in the Midwest. It ends with a new Data Analysis box on exploring recent earthquakes and evaluating erosion on farmland.
- Chapter 12 has a new emphasis on personal energy use and costs, as well as a new Active Learning box on the costs of driving. It includes a new table on energy use and an expanded discussion of Hubbert's peak and peak oil. The energy-efficient building and design section has been expanded and a new section on biomass fuels has been added to reflect changes in policy and technology.
- Chapter 13 has a new section on landfill methane and an expanded discussion on the export of e-waste to poor countries. This chapter also includes a new section on disposal problems for the 300 billion bottles of water consumed annually worldwide.
- Chapter 14 has a revised introduction to urban environments and economics. It also has a new Active Learning box on microlending.
- Chapter 15 opens with a new case study on greening in China. It contains a new section on the emerging grassroots movement to find solutions to global warming and a new section on sustainability that is tied to the opening story on economic development in China.

Acknowledgements

We express our gratitude to the entire McGraw-Hill book team for their wonderful work in putting together this edition. A special thanks to Janice Roerig-Blong (publisher), Marge Kemp (executive editor), Rose Koos (developmental editor), and Ashley Zellmer (editorial coordinator) who oversaw the developmental stages and made many creative contributions to this book. Cathy Conroy has done a superb job of copy editing, correcting errors, and improving our prose. Lori Hancock and LouAnn Wilson found excellent photos for us. Peggy Selle managed the project through production. Tami Petsche (marketing manager) has supported this project with her enthusiasm and creative ideas.

This text has had the benefit of input from more than 400 researchers, professionals, and instructors who have reviewed this book or our larger text, *Environmental Science: A Global Concern*. These reviewers have helped us keep the text current and focused. We deeply appreciate their many helpful suggestions and comments. Space does not permit inclusion of all the excellent ideas that were provided, but we will continue to do our best to incorporate the ideas that reviewers have given us. In addition, 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.

The following individuals provided reviews for this book. We thank them for their suggestions.

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Guided Tour

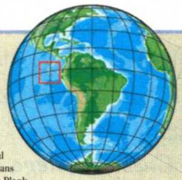
Application-based learning contributes to engaged scientific investigation

Case Studies

All chapters open with a real-world case study to help students appreciate and understand how environmental science impacts lives and how scientists study complex issues.

CASE STUDY

Ocean Fertilization



"Give me a half a tanker of iron and I'll give you an Ice Age." When oceanographer, John Martin, made that remark 25 years ago, most of his audience treated it as a joke, but now some people are taking his idea more seriously. Martin had carried out experiments showing that primary productivity in much of the ocean is limited by nutrient deficiencies. When he added iron to water collected a few hundred kilometers off the Antarctic coast, he found that chlorophyll levels increased by a factor of 10,000. Some subsequent experiments have produced even greater biomass growth (fig. 9.1).

The reason people are so interested in ocean fertilization is that it might offer a way to remove large amounts of carbon dioxide (CO_2) from the air. As we'll discuss in this chapter, a vast majority of climate scientists believe that our emissions of CO_2 and other heat-absorbing gases are now warming the atmosphere and changing our global climate. If these pollutants continue to accumulate at current rates, there could be truly disastrous consequences. Global climate change may well be the most serious threat—outside of nuclear war—that we currently face. We need urgently to reduce our discharges and to find ways to remove these gases from the air.

You'll learn in this chapter that numerous approaches for emissions reductions and carbon sequestration have been suggested. Many steps can be taken using existing technology and would actually save money. Some, like ocean enrichment, have uncertain benefits and potential complications. Critics worry that we might cause new problems in our attempt to solve old ones.

Will algal cells, stimulated by adding extra nutrients to the ocean, eventually die and sink to the bottom, or will they simply decay and release the CO_2 they've absorbed back into the atmosphere? It's possible that growing more algae in the ocean could help restore fish populations depleted by overharvesting. On the other hand, large-scale eutrophication often creates oxygen-depleted "dead zones" in which almost nothing can survive. Sometimes excess nutrients result in blooms of highly toxic algae and dinoflagellates. Many scientists worry that sensitive ecosystems, such as coral reefs, which already are being stressed by climate change and human intrusions, might be fatally damaged by efforts to change ocean chemistry.

However, at least two commercial companies have already announced plans for large-scale ocean fertilization. The Planktos Corporation of Foster City, California, expects to spread 50 to 100 tons of pulverized iron ore in a 50 to 100 km diameter area of the Pacific about 300 km west of the Galápagos Islands. And the Ocean Nourishment Corporation from New South Wales, Australia, already has approval to dump 500 tons of urea (as a nitrogen source) in the Sula Sea between the Philippines and Borneo. Ocean Nourishment also has plans for similar fertilization projects in Malaysia, Chile, and the United Arab Emirates. Both these companies hope to sell lucrative carbon offset credits on the global climate exchange as a result of their ocean nutrient enhancement.

In 2007, the International Maritime Organization, the international body that administers the Law of the Sea, declared that all ocean fertilization projects fall under their jurisdiction. They didn't ban these activities outright, but they expressed concern about unintended consequences and unknown ecological effects. Many environmental groups cheered this intervention, but others warn that we need to do everything in our power to combat global warming. What do you think? Is the risk of geoengineering worth its possible benefits? If you were a delegate to the Law of the Sea Convention, what monitoring steps and ecological safeguards would you impose on companies wanting to exploit this technology?

A major part of this chapter will be devoted to air pollutants and global climate change and what we might do about them. First, however, in order to understand our climate system better, we'll look at the factors that normally shape our weather and climate.

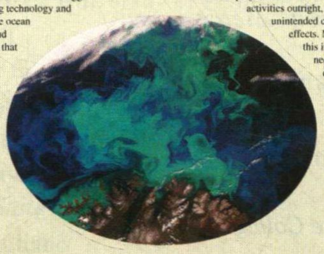


Figure 9.1 A massive plankton bloom fills the ocean off the coast of Norway.
Photo courtesy of NASA.

9.1 The Atmosphere Is a Complex System

We live at the bottom of a virtual ocean of air that extends upward about 500 km (300 mi). In the layer closest to the earth's surface, known as the troposphere, the air moves ceaselessly, flowing, swirling, and continually redistributing heat and moisture from one part of the globe to another. The composition and behavior of the troposphere and other layers control our **weather** (daily temperature and moisture conditions in a place) and our **climate** (long-term weather patterns).

The earth's earliest atmosphere probably consisted mainly of hydrogen and helium. Over billions of years, most of that hydrogen and helium diffused into space. Volcanic emissions added carbon, nitrogen, oxygen, sulfur, and other elements to the atmosphere.

200 Principles of Environmental Science http://www.mhhe.com/cunningham5e

New! Google Earth™ Placemarks

Google Earth™ interactive satellite imagery gives students a geographic context for global places and topics discussed in the text. Google Earth™ icons indicate when to visit the text's website, where students will find links to locations mentioned in the text, and corresponding exercises that will help them understand environmental topics. Placemark links can be found at www.mhhe.com/cunningham5e.

Data Analysis

At the end of each chapter, these exercises give students further opportunities to apply skills and analyze data.

Data Analysis: Graphing Multiple Variables

Is it possible to show relationships between two dependent variables on the same graph? Sometimes that's desirable when you want to make comparisons between them. The graph on page 198 does just that. It's a description of how people perceive different risks. We judge the severity of risks based on how familiar they are and how much control we have over our exposure.

- Take a look at the different risks in Figure 1. Make a list of about 5 that you consider most dangerous. Then list about 5 that you think are least dangerous.
- Do most of your most dangerous activities/items fall into one quadrant? What are the axes of the graph? Do the ideas on the axes help explain why you consider some activities more dangerous than others?

New! Active Learning

Students will be encouraged to practice critical thinking skills and apply their understanding of newly-learned concepts and to propose possible solutions.

Active Learning

Calculating Probabilities

You can calculate the statistical danger of a risky activity by multiplying the probability of danger by the frequency of the activity. For example, in the United States, 1 person in 3 will be injured in a car accident in their lifetime (so the probability of injury is 1 per 3 persons, or 1/3). In a population of 30 car-riding people, the cumulative risk of injury is 30 people × (1 injury/3 people) = 10 injuries over 30 lifetimes.

1. If the average person takes 50,000 trips in a lifetime and the accident risk is 1/3 per lifetime, what is the probability of an accident per trip?
2. If you have been riding safely for 20 years, what is the probability of an accident during your next trip?

swers: 1. Probability of injury per trip = (1 injury/3 lifetimes) × lifetime/50,000 trips) = 1 injury/150,000 trips. 2. 1 in 150,000. atistically, you have the same chance each time.

What Do You Think?

This feature provides challenging environmental studies that offer an opportunity for students to consider contradictory data, special interest and conflicting interpretations within a real scenario.

WHAT DO YOU THINK?

Cultural Choices and the Rate of Population Growth

The good news is that the human population on earth may never double again. The bad news is that it may take a century to stabilize. Meanwhile, the choices we make individually, and collectively through our political, economic, and cultural actions, will determine whether it will be a pleasant, or not so pleasant, hundred years. The choices are already being made in India, where two different states are taking two very different approaches to population growth.

In 1999, having added more than 180 million people in just a decade, India reached a population of 1 billion humans. If current growth rates persist, India will have at least 1.63 billion residents in 2050 and will surpass China as the world's most populous country. How will this country, where more than a quarter of its inhabitants live in abject poverty, feed, house, educate, and employ all those being added each year? A fierce debate is taking place about how to control India's population, with ramifications for the rest of the world as well.

On one side of this issue are those who believe that the best way to reduce the number of children born is poverty eradication and progress for women. Drawing on social justice principles established at the 1994 UN Conference on Population and Development in Cairo, some argue that responsible economic development, a broad-based social welfare system, education and empowerment of women, and high-quality health care—including family planning services—are essential components of population control. Without progress in these areas, they believe, efforts to provide contraceptives or encourage sterilization are futile.

On the other side of this debate are those who contend that, while social progress is an admirable goal, India doesn't have the time or

Its annual growth rate of 1.7 percent suggests that India's population could double in 41 years, becoming the world's most populous country by 2050. Indian states have taken different approaches to slow population growth. Despite its poverty, Kerala has a total fertility rate lower than the United States.

Exploring Science

Current environmental issues exemplify the principles of scientific observation and data-gathering techniques to promote scientific literacy.

Exploring SCIENCE: Studying the Gulf Dead Zone

In the 1980s shrimp boat crews noticed that certain locations off the Gulf Coast of Louisiana were emptied of all aquatic life. Since the region supports shrimp, fish, and oyster fisheries worth $250 to $450 million per year, these "dead zones" were important to the economy as well as to the Gulf's ecological systems. In 1985, Nancy Rabelais, a scientist working with Louisiana Universities Marine Consortium, began mapping areas of low oxygen concentrations in the Gulf waters. Her results, published in 1991, showed that vast areas, just above the floor of the Gulf, had oxygen concentration less than 2 parts per million (ppm), a level that eliminated all animal life except primitive worms. Healthy aquatic systems usually have about 10 ppm dissolved oxygen. What caused this hypoxic (oxygen-starved) area to develop?

Rabelais and her team tracked the phenomenon for several years, and it became clear that the dead zone was growing larger over time, that poor shrimp harvests coincided with years when the zone was large, and that the size of the dead zone, which ranges from 5,000 to 20,000 km² (about the size of New Jersey), depended on rainfall and runoff rates from the Mississippi River. Excessive nutrients, mainly nitrogen, from farms and cities far upstream on the Mississippi River, were the suspected culprit.

How did Rabelais and her team know that nutrients were the problem? They noticed that each year, 7–10 days after large spring rains in the agricultural parts of the upper Mississippi watershed, oxygen concentrations in the Gulf drop from 5 ppm to below 2 ppm. These rains are known to wash soil, organic debris, and last year's nitrogen-rich fertilizers from farm fields. The scientists also knew that saltwater ecosystems normally have little available nitrogen, a key nutrient for algae and plant growth. Pulses of agricultural runoff were followed by a profuse growth of algae and phytoplankton (tiny floating plants). Such a burst of biological activity produces an excess of dead plant cells and fecal matter that drifts to the seafloor. Shrimp, clams, oysters, and other filter feeders normally consume this debris, but they can't keep up with the sudden flood of material. Instead, decomposing bacteria in the sediment break down the debris, and they consume most of the available dissolved oxygen as well. Putrefying sediments also produce hydrogen sulfide, which further poisons the water near the seafloor.

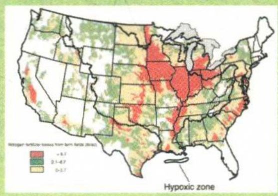
In well-mixed water bodies, as in the open ocean, oxygen from upper layers of water is frequently mixed into lower water layers. Warm, protected water bodies are often stratified, however, as abundant sunlight keeps the upper layers warmer, and less dense, than lower layers. Denser lower layers cannot mix with upper layers unless strong currents or winds stir the water.

Many enclosed coastal waters, including Chesapeake Bay, Long Island Sound, the Mediterranean Sea, and the Black Sea, tend to be stratified and suffer hypoxic conditions that destroy bottom and near-bottom communities. There are about 200 dead zones around the world, and the number has doubled each decade since dead zones were first observed in the 1970s. The Gulf of Mexico is second in size behind a 100,000 km² dead zone in the Baltic Sea.

Can dead zones recover? Yes. Water is a forgiving medium, and organisms use nitrogen quickly. In 1996 in the Black Sea region, farmers in collapsing communist economies cut their nitrogen applications by half out of economic necessity; the Black Sea dead zone disappeared, while farmers saw no drop in their crop yields. In the Mississippi watershed, farmers can afford abundant fertilizer, and they fear they can't afford to risk underfertilizing. Because of the great geographic distance between the farm states and the Gulf, Midwestern states have been slow to develop an interest in the dead zone. At the same time, concentrated feedlot production of beef and pork is rapidly increasing, and feedlot runoff is the fastest growing, and least regulated, source of nutrient enrichment in rivers.

In 2001, federal, state, and tribal governments forged an agreement to cut nitrogen inputs by 30 percent and reduce the size of the dead zone to 5,000 km². This agreement represented astonishingly quick research and political response to scientific results, but it doesn't appear to be enough. Computer models suggest that it would take a 40–45 percent reduction in nitrogen to achieve the 5,000 km² goal.

Human activities have increased the flow of nitrogen reaching U.S. coastal waters by four to eight times since the 1950s. Phosphorus, another key nutrient, has tripled. This case study shows how water pollution can connect far-distant places, such as Midwestern farmers and Louisiana shrimpers.



The Mississippi River drains 40 percent of the coterminous United States, including the most heavily farmed states. Nitrogen fertilizer produces a summer "dead zone" in the Gulf of Mexico.

What Can You Do?

Practical ideas that students can employ to make a positive difference in our environment.

What Can You Do?

Reducing Individual CO_2 Emissions

Each of us can take steps to reduce global warming. While individually each change may have only a small impact, collectively they add up. Furthermore, most will save money in the long run and have other environmental and health benefits by reducing air pollution and resource consumption. The savings vary depending on where and how you live, but the following are averages for the United States.

	CO_2 Reduction (Pounds per Year)	Approximate Yearly Savings (U.S. $)
1. Keep your car tires at full pressure, avoid quick starts and stops, and drive within the speed limit.	1,100	$130
2. Carpool, walk, or take the bus once per week.	800	$100
3. Turn off the lights when you leave a room.	300	$10
4. Replace all your incandescent light bulbs with compact fluorescent bulbs.	100 each	$5 each
5. Raise your air conditioning 2°.	400	$20
6. Lower your furnace thermostat 2°.	550	$50
7. When heating or cooling, close doors and windows.	500	$20
8. When heating or cooling aren't needed, open doors and windows.	500	$20
9. Unplug TVs, DVD players, computers, and other instant-on electronics.	250	$20
10. Eat local, seasonal food.	250	variable
11. Take only five-minute showers.	250	$25
12. Take the train instead of flying 500 miles.	300	$100
13. Air dry your clothes.	700	$100
14. Replace your old car, truck, or SUV with one that gets at least 50 mpg.	6,000	$750
15. Defrost your refrigerator and keep coils and door seals clean.	700	$100

Source: Interfaith Power and Light, 2007.

Pedagogical features facilitate student understanding of environmental science

Learning Outcomes

After studying this chapter, you should be able to answer the following questions:

- Why are we concerned about human population growth?
- Will the world's population double again as it did between 1965 and 2000?
- What is the relationship between population growth and environmental impact?
- Why has the human population grown so rapidly since 1800?
- How is human population growth changing in different parts of the world?
- How does population growth change as a society develops?
- What factors slow down or speed up human population growth?

New! Learning Outcomes

Questions at the beginning of each chapter challenge students to find their own answers.

Practice Quiz

1. About how many years of human existence passed before the world population reached its first billion? What factors restricted population before that time, and what factors contributed to growth after that point?
2. Describe the pattern of human population growth over the past 200 years. What is the shape of the growth curve (recall chapter 3)?
3. Define *ecological footprint*. Why is it helpful, but why might it also be inaccurate?
4. Why do some economists consider human resources more important than natural resources in determining a country's future?

Conclusion

The conclusion summarizes the chapter by highlighting key ideas and relating them to one another.

Practice Quiz

Short-answer questions allow students to check their knowledge of chapter concepts.

Conclusion

A few decades ago, we were warned that a human population explosion was about to engulf the world. Exponential population growth was seen as a cause or corollary to nearly every important environmental problem. Some people still warn that the total number of humans might grow to 30 or 40 billion by the end of this century. Birth rates have fallen, however, almost everywhere, and most demographers now believe that we will reach an equilibrium around 9 billion people in about 2050. Some claim that if we promote equality, democracy, human development, and modern family planning techniques, population might even decline to below its current level of 6.7 billion in the next 50 years. How we should carry out family planning and birth control remains a controversial issue. Should we focus on political and economic reforms, and hope that a demographic transition will naturally follow; or should we take more direct action (or any action) to reduce births?

Whether our planet can support 9 billion—or even 6 billion—people on a long-term basis remains a vital question. If all those people try to live at a level of material comfort and affluence now enjoyed by residents of the wealthiest nations, using the old, polluting, inefficient technology that we now employ, the answer is almost certain that even 6 billion people is too many in the long run. If we find more sustainable ways to live, however, it may be that 9 billion people could live happy, comfortable, productive lives. If we don't find new ways to live, we probably face a crisis no matter what happens to our population size. We'll discuss pollution problems, energy sources, and sustainability in subsequent chapters of this book.

Critical Thinking and Discussion Questions

Brief scenarios of everyday occurrences or ideas challenge students to apply what they have learned to their lives.

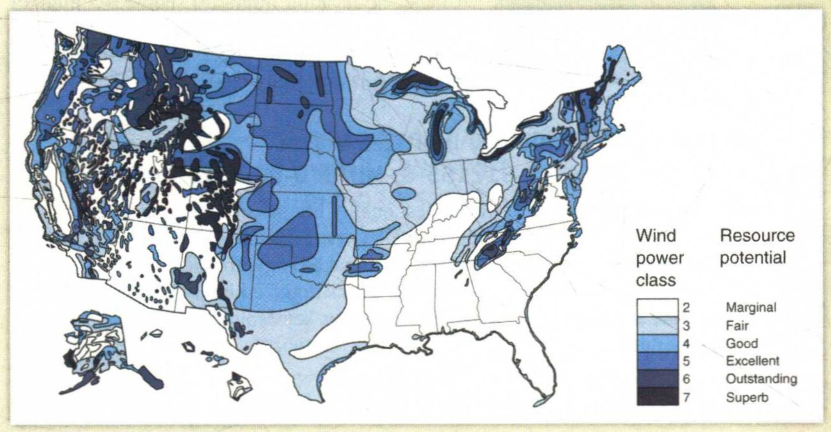
Critical Thinking and Discussion Questions

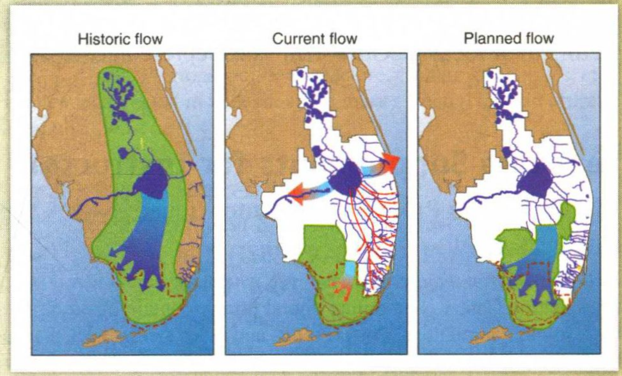
Apply the principles you have learned in this chapter to discuss these questions with other students.

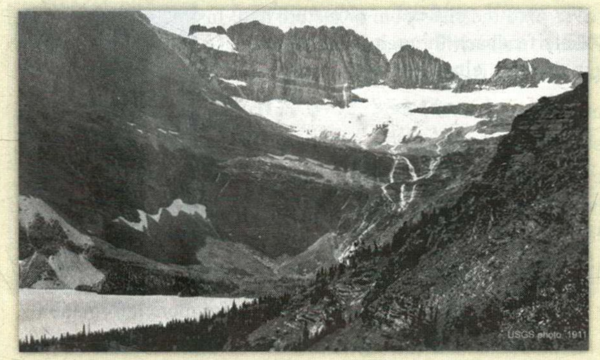
1. Suppose that you were head of a family planning agency in India. How would you design a scientific study to determine the effectiveness of different approaches to population stabilization? How would you account for factors such as culture, religion, education, and economics?
2. Why do you suppose that the United Nations gives high, medium, and low projections for future population growth? Why not give a single estimate? What factors would you consider in making these projections?
3. Some demographers claim that the total world population has already begun to slow, while others dispute this claim. How would you recognize a true demographic transition, as opposed to mere random fluctuations in birth and death rates?
4. Why do we usually express crude birth and death rates per thousand people? Why not give the numbers per person or for the entire population?

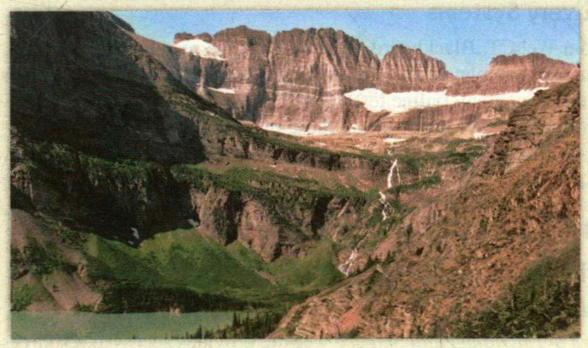
Relevant photos and instructional art support learning

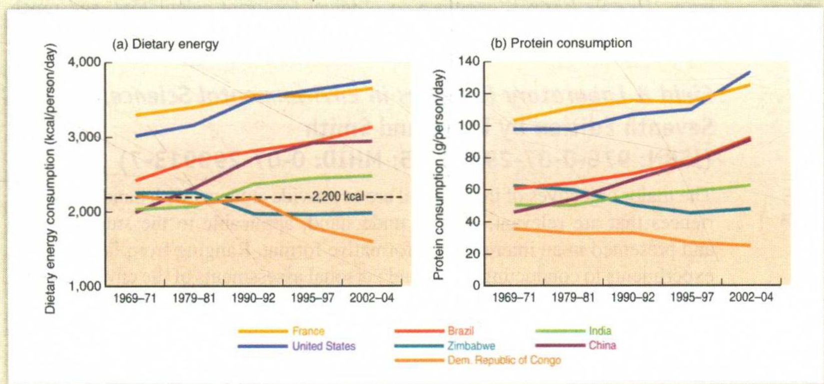
Numerous high quality photos and realistic illustrations display detailed diagrams, graphs, and real-life situations.











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- **Tables** Every table that appears in the text is provided in electronic format.
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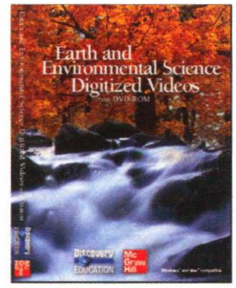

Earth and Environmental Science DVD by Discovery Channel Education (ISBN: 978-0-07-352541-9; MHID: 0-07-352541-3)

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Text-specific Website (http://www.mhhe.com/cunningham5e)

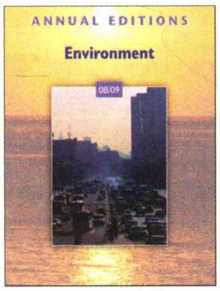
The *Principles of Environmental Science* website provides access to resources including quizzes for each chapter, additional case studies, interactive base maps, Google Earth™ exercises, ecological footprint calculators, and much more.

Field & Laboratory Exercises in Environmental Science, Seventh Edition by Enger and Smith (ISBN: 978-0-07-290913-5; MHID: 0-07-290913-7)

The major objectives of this manual are to provide students with hands-on experiences that are relevant, easy to understand, applicable to the student's life, and 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.

Exploring Environmental Science with GIS **by Stewart, Cunningham, Schneiderman, and Gold (ISBN: 978-0-07-297564-2; MHID: 0-07-297564-4)**

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.



Annual Editions: Environment **08/09 by Sharp (ISBN: 978-0-07-351548-9; MHID: 0-07-351548-5)**

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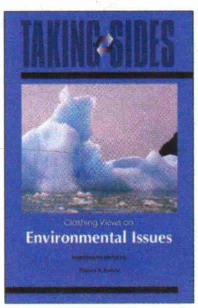

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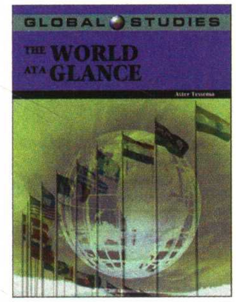
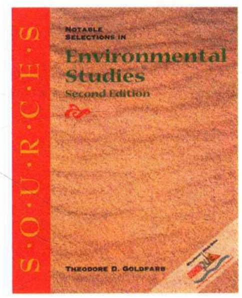


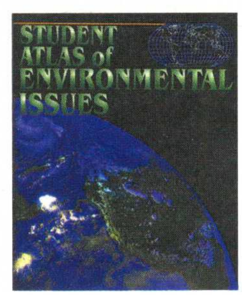
Global Studies: The World at a Glance, **Second Edition by Tessema (ISBN: 978-0-07-340408-0; MHID: 0-07-340408-X)**

This book features a compilation of up-to-date data and accurate information on some of the important facts about the world we live in. While it is close to impossible to be an expert in all areas, such as a nation's capital, type of government, currency, major languages, population, religions, political structure, climate, economics, etc., this book is intended to assist in understanding these essential facts in order to make useful applications.



Sources: Notable Selections in Environmental Studies, **Third Edition by Goldfarb (ISBN: 978-0-07-352758-1; MHID: 0-07-352758-0)**

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 from 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 (ISBN: 978-0-69-736520-0; MHID: 0-69-736520-4)**

This atlas 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 that help students understand the dimensions of the world's environmental problems and the geographical basis of these problems.

Brief Contents

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