William P. Cunningham

Mary Ann Cunningham

PRINCIPLES OF Environmental Science

Inquiry & Applications

SEVENTH EDITION

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Environmental Science

Inquiry & Application

Seventh Edition

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University of Minnesota

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About the Authors

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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 eleventh 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.

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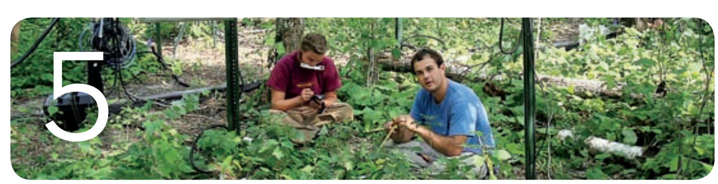
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Preface

THINKING TOWARD THE FUTURE

Environmental science is a study of how we use, abuse, and steward the ecological systems that support us. What are these systems, how do they function, and can they be used sustainably? Is it possible to live sustainably on this earth? Critical thinking and careful evaluation of evidence are essential for exploring these complex questions, in the face of often-contradictory evidence. Above all, students today are challenged to rethink old paradigms, assumptions, and limits, as we work to invent a new, more sustainable future for generations that follow us.

One classic parable for the possibility of sustainable living is the "ecocide" of Easter Island. This remote Pacific island, also called Rapa Nui, represents an oft-repeated morality tale of environmental destruction. The classic story is that early Polynesian colonists cleared the forest, eroded the soil, overpopulated the island, depleted the land through greed and ignorance, and finally dwindled to a war-torn, impoverished remnant of their former society. This narrative has informed environmental thought for a generation or more, but it may no longer be enough to guide us to a sustainable future.

An alternative narrative that better fits recent data is that early colonists prospered for centuries, inventing ways to farm the land sustainably, to replenish soil and conserve water, and restrain population growth. Although they felled the forests and cleared fields over the centuries, people still adapted and thrived—until the arrival of European diseases and slave traders, both of which decimated the population and reduced them to dwindling and impoverished numbers.[1]

These two narratives have contrasting morals: Do humans inevitably destroy their own homes? Or do we have the potential to invent strategies for sustaining our resources? Are the main drivers of environmental destruction overpopulation, habitat destruction, greed, injustice among societies, or some combination of these? To find better answers, today's students may need to move beyond the traditional story and embrace the idea that cooperation and creativity can lead to a sustainable future, if we put our hearts into the project.

Crises and opportunities abound

Understanding the nature of environmental destruction is necessary, but so is a commitment to progress and cooperation. We face challenges like never before—burgeoning cities, warming climates, looming water crises. We also have unprecedented opportunity to make a difference—we are seeing global expansion in access to education, healthcare, information, even political participation and human rights. Birthrates are falling almost everywhere, as women's rights gradually improve. Creative individuals are inventing new ideas for alternative energy and transportation systems that were undreamed of a generation ago. We are rethinking our assumptions about cities, food production, water use, and air quality. Local action is rewriting our expectations, and even economic and political powers feel increasingly compelled to show cooperation in improving environmental quality.

Students are leading the way in reimagining our possible futures. Student movements have led innovation in technology and science, in environmental governance, and in environmental justice around the world. The organization 350.org, highlighted in chapter 16, was started by a small group of students to address climate change. That movement has energized local communities to join the public debate on how to seek a sustainable future.

Sustainability, a central idea in this book, has grown from a fringe notion two decades ago to a widely shared framework for daily actions (recycling, reducing consumption) and civic planning (building energy-efficient buildings, investing in public transit and bicycle routes). Sustainability isn't just about the environment anymore. Increasingly we know that sustainability is also smart economics and that it is essential for social equity. Energy efficiency saves money. Alternative energy reduces our reliance on fuel sources in politically unstable regions. Healthier food options reduce medical costs. Smaller families can be happier and more secure. Accounting for the public costs and burdens of pollution and waste disposal helps us rethink the ways we dispose of our garbage and protect public health.

All of these are ideas this book explores. Our aim is to help students understand the ways in which methods and principles of environmental science apply to pressing issues around us. We also hope that this book can help each student find the ways that his or her passions can be engaged—whether they are in biology, math, journalism, politics, artistic expression, psychology, chemistry, or other subjects—in working for a smarter, more stable future.

WHAT SETS THIS BOOK APART?

Solid science: This book reflects decades of experience in the field and in the classroom, which make it up-to-date in approach, in data, and in applications of critical thinking. Emerging ideas and issues are introduced, such as ecosystem services, cooperative ecological relationships, and epigenetics, and the economics of air pollution control, in addition to basic principles such as population biology, the nature of systems, and climate processes.

[1]*See* Hunt, T.L., Lipo, C.P. 2009. Revisiting Rapa Nui (Easter Island) "ecocide." *Pacific Science* 63 (4): 601–616.

Demystifying science: We make science accessible by showing how and why data collection is done and by giving examples, practice, and exercises that demonstrate central principles. *Exploring Science* readings empower students by helping them understand how scientists do their work and by asking them to collect and analyze their own data. *Applications* exercises and *Data Analysis* exercises help students practice the ideas, rather than just reading about them.

Quantitative reasoning: Students need to become comfortable with graphs, data, and comparing numbers. We provide focused discussions on why scientists answer questions with numbers, the nature of statistics, of probability, and how to interpret the message in a graph. We give accessible details on population models, GIS (spatial analysis), remote sensing, and other quantitative techniques. In-text *Applications* and online, testable *Data Analysis* questions give students opportunities to gather and evaluate data on their own.

Critical thinking: We provide a focus on critical thinking, one of the most essential skills for citizens, as well as for students. We offer abundant opportunities for students to weigh contrasting evidence and evaluate assumptions and arguments, including *What Do You Think?* readings.

Synthesis: Students come to environmental science from a multitude of fields and interests. We emphasize that most of our pressing problems, from global hunger or climate change to conservation of biodiversity, draw on sciences and economics and policy. This synthesis shows students that they can be engaged in environmental science, no matter what their interests or career path.

A global perspective: Environmental science is a globally interconnected discipline. *Case studies*, data, and examples from around the world give opportunities to examine international questions. Eleven of 16 case studies examine international issues of global importance, such as forest conservation in Indonesia, soy production in Brazil, car-free cities in Germany. Half of all boxed readings and *Key Concepts* are also global. Moreover, *Google Earth* placemarks bring students virtually to locations where they can see and learn the context of the issues they read.

Key concepts: In each chapter this section draws together compelling illustrations and succinct text to create a summary "take-home" message. These key concepts draw together the major ideas, questions, and debates in the chapter but give students a central idea on which to focus. These can also serve as starting points for lectures, student projects, or discussions.

Positive perspective: All the ideas noted here can empower students to do more effective work for the issues they believe in. While we don't shy away from the bad news, we highlight positive ways in which groups and individuals are working to improve their environment. *What Can You Do?* boxes in every chapter offer practical examples of things everyone can do to make worthwhile progress towards sustainability

Thorough coverage: No other book on in the field addresses the multifaceted nature of environmental questions such as climate policy, on sustainability, or population change, with the thoroughness this book has. We cover not just climate change but also the nature of climate and weather systems that influence our climate. We explore both food shortages and the emerging causes of hunger—such as political conflict, biofuels, and global commodity trading—as well as the growing pandemic of obesity-related illness. In these and other examples, this book is a leader in in-depth coverage of key topics.

Active learning: 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. This book integrates a range of learning aids—active learning exercises, *Critical Thinking and Discussion Questions*, and *Data Analysis* exercises—that push students to think for themselves. Data and interpretations aren't presented as immutable truths, but rather as evidence to be examined and tested, as they should be in the real world.

WHAT'S NEW IN THIS EDITION?

- **Gorgeous new art:** This edition introduces an entirely new art program, with beautiful new drawings that bring key concepts to life. Creative paging also gives the book an accessible, compelling appearance. Dozens of new striking, thought-provoking photographs highlight crucial topics.
- **New chapter on climate change:** Global warming may well be the most difficult and important challenge the world will face in this century. In response to suggestions from reviewers, we have split coverage of climate change from discussion of air pollution. This gives climate change the attention and emphasis it deserves without diminishing important and current topics in air pollution.
- **Up-to-date information:** Throughout the text, we provide the most current available data, as well as recent innovations in meeting environmental challenges. We introduce students to current developments such as establishment of Marine Protected Areas, REDD (reducing emissions through deforestation and degradation), renewable energy development in China, fertility declines in the developing world, and the impact of global food trade on world hunger.
- **New Case Studies:** More than two-thirds of the opening case studies are new to this edition, giving readers current and exciting examples of environmental science in action. These case studies illustrate important principles and demonstrate the importance and interconnections of these issues. Because grim stories can stop students in their tracks, a majority of our case studies offer a positive view of progress towards sustainability and environmental protection. And while we updated the case studies for this edition, all case studies from previous editions can be found on Connect at www.mcgrawhillconnect.com.
- **New Exploring Science readings:** These boxed readings illustrate how science is actually done as well as presenting information about important topics in environmental science. Many of these readings, like the case studies, give encouraging examples of progress toward sustainability.

For example, we have a current example of how technology (including GIS mapping, using mobile devices, such as iPads and smartphones) is being used to protect habitat for endangered chimpanzee populations in Gombe National Park in Tanzania. We also have an inspiring story of how inexpensive water purification systems are being made available to poor, rural villages in India.

- **New What Do Think? readings:** This popular feature invites students to think critically and creatively about current environmental dilemmas. They also serve as a springboard for class or after-class discussions. We have added challenging new topics, including the future of nuclear power following the catastrophe in Japan, and Australia's current adaptations to unprecedented, widespread drought. These important topics encourage students to examine implications of environmental science in their own lives.
- **An exciting new online learning platform:** McGraw-Hill's ConnectPlus (www.mcgrawhillconnect.com)

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is a web-based assignment and assessment platform that gives students the means to better connect with their coursework, with their instructors, and with the important concepts that they will need to know for success now and in the future. Valuable assets such as LearnSmart (an adaptive learning system), an interactive ebook, Data Analysis exercises, the extensive case study library and Google Earth exercises are all available in Connect.

DETAILED CHANGES IN THIS EDITION

- **Chapter 1** has all new art throughout the chapter. It has a new discussion of ecosystem services, including a new fig. 1.8 to illustrate these relationships. Exploring Science boxes on "How do we know the state of population and poverty?" and "Why do scientists answer questions with a number?" have been updated and expanded. Throughout the chapter, the text has been updated and enhanced.
- **Chapter 2** has a new opening case study on ecological connections in the Chesapeake Bay. The new food web diagram in fig. 2.16 now clearly shows connections between organisms in different trophic levels. All drawings of elemental cycles have been revised to a uniform appearance that makes it easier to understand sources, flows, and sinks. Estimates of total stocks and exchanges for key compartments have been added. All art has been upgraded and enhanced.
- **Chapter 3** has a new opening case study on evolution that includes new data from studies of Galápagos finches. Among the new figures are comparisons between specialist niches and generalists (fig. 3.5), speciation, resource partitioning, isolation, taxonomy, and keystone species. The chapter has a new discussion of symbiotic relationships and coevolution, including Darwin's moth. It also has a new Data Analysis exercise on resource partitioning among Darwin's finches.
- **Chapter 4** has a new opening case study on impressive population stabilization in Brazil. Small drawings or photos are added to make graphs more interesting and understandable. Demographic data is updated throughout chapter. A new figure emphasizes the relationship between environmental impacts, population growth, affluence, and technology. A new map (fig. 4.18) shows fertility rates by country. A new Data Analysis box at the end of the chapter draws on superb demographic graphics from Gapminder.org.
- **Chapter 5** has a new opening case study on a ground-breaking field study that is helping to elucidate the effects of climate change on boreal forests. A new graph shows rates of family losses during major geologic episodes of mass extinction. A new Exploring Science box shows the effects of invasive earthworms in northern forests. New mini case studies of invasive species describe emerald ash borers and Asian carp species (species of major current concern in the U.S.)
- **Chapter 6** has a new opening case study on innovative forest protection agreements between Indonesia and Norway as part of the UN REDD program. The Active Learning box on forest area has been updated and corrected so students can calculate the amount of original forests lost. A new Exploring Science box describes the use of modern technology by native peoples in Amazonian forest protection programs. This theme continues in another new Exploring Science box on how the Jane Goodall Institute is empowering local communities around Gombe National Park in Tanzania to identify conservation priorities.
- **Chapter 7** has updated data and text throughout, including an enhanced opening case study on farming in Brazil. Our discussion of the role of global trade policy and biofuels on food supply has been refined. New data on food supply, hunger and obesity are presented. An improved discussion of global fisheries and policy options, as well as new presentation of agricultural inputs, including rising pesticide use and pesticide tolerance has been added. A new figure (7.28) shows the use of herbicide tolerant genes in genetically modified (GM) crops. And a new Data Analysis exercise on agricultural production statistics and patterns fills out the chapter.
- **Chapter 8** has a new opening case study on the dangers of Bisphenol A, a chemical found in a wide range of consumer products, including food and beverage containers. The coverage of conservation medicine now includes the dire epidemic of "white nose syndrome" that's killing millions of cave-dwelling bats in the eastern U.S. as well as Chytridiomycosis, which is wiping out thousands of amphibian species worldwide.
- **Chapter 9** has a new case study on Texas drought that illustrates the threats of weather extremes and their possible links to global climate change. New and updated figures include climate change data and greenhouse gas releases. The chapter also raises questions about why we debate

climate change, and offers options for responding to climate change, including personal actions in a practical "What Can You Do?" box.

- **Chapter 10** is an entirely new chapter that treats air pollution separately from climate and climate processes. The chapter opens with a new case study on the London Smog of 1952, which is followed by details on sulfur dioxide, nitrogen oxides, and other air pollutants. We have added extensive discussion of mercury pollution, including the question of whether cap and trade is the right approach for regulating this neurotoxin. We have also added extensive discussion of halogens and their impacts on climate as well as on stratospheric ozone. A new discussion on the economic impacts of the Clean Air Act shows students why pollution control is important for economic as well as health effects. A new Data Analysis box lets students examine EPA data on air pollution data in their own area.
- **Chapter 11** has a new section "Living in an age of thirst" to expand our discussion of major droughts and to clarify the threats to freshwater supplies posed by climate change. This section includes a new map of world water scarcity, stress, and vulnerability. This theme is continued in a sobering but somewhat optimistic What Do You Think? box explaining how Australia is responding to record drought. A brief description of the megadrought in the 13th century that led to abandonment of Anasazi pueblos in America's four corners area compliments this section. A new, optimistic, Exploring Science box describes the invention and implementation by Professor Ashok Gadgil of low-cost water purification systems for developing countries.
- **Chapter 12** has a new opening case study on the environmental and social destruction caused by mountaintop removal mining. The diagrams of geological subduction and uplift have been redrawn and improved. Photos of rare earth metals are included in a box on these strategic materials along with discussion of new rare earth mines and technological advances that require less of these materials in batteries and motors. New photos have been added of historic mine reclamation, the 2011 tsunami in Japan, the 2010 eruption of Mt. Merapi in Indonesia, and of 2010 floods in Pakistan that displaced 20 million people.
- **Chapter 13** has a new opening case study about Desertech, a massive program to link high-voltage direct-current transmission lines to solar thermal energy facilities in the deserts of North Africa with off-shore wind farms, hydroelectric dams, and other renewable energy sources to provide sustainable energy in Europe. The chapter also describes how dramatic changes in unconventional fossil fuel sources, such as tar sands, shale oil and natural gas formations, and deep-sea deposits are rapidly changing our estimates of potential fossil fuel supplies. We discuss these changes along with new developments in renewable energy systems and the changing fate of nuclear power following the tsunami in Japan. Calls for a supergrid in North America are compared to developments now taking place in Europe.
- **Chapter 14** has a new case study on alternative waste management and biogas use in Kristianstad, Sweden, one of many European cities taking a new approach to handling solid waste. New figures and data have been added throughout the chapter on waste production and waste management. It also has an updated discussion of Superfund cleanup progress and costs.
- **Chapter 15** examines urban blight and emptying out of rust-belt cities along with the environmental and social impacts of urban sprawl. It describes how some of these problems can be solved through urban renewal and a new emphasis on sustainability in urban planning. The economics section of this chapter has a new section on how market mechanisms can be used to achieve environmental and social goals. New photos have been added of a walking street in Vauban, Germany, a village market as example of classical economics, communal irrigation systems in Bali, and renewable energy as example of scarcity-led technical innovation.
- **Chapter 16** has a new opening case study about how students in 350.org are working to combat climate change. A new discussion has been added to the policy section on the precautionary principle. The analysis of national environmental organizations has been streamlined in favor of more coverage of student groups and the ways in which modern electronic communications and social media are changing the world. An added emphasis on sustainability serves as a capstone for this chapter bringing us back to principles that began chapter 1.

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ADDITIONAL MATERIALS IN ENVIRONMENTAL SCIENCE

Annual Editions: *Environment* by Richard Eathorne

ISBN: 9780073515698

Revised annually for more than 32 years, this text provides convenient inexpensive access to current articles selected from some of the most respected magazines, newspapers, and journals published today. Instructional features include: an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit for additional research, learning outcomes, and critical thinking questions. An Instructor Resource Guide with test materials is available for download as well as a practical guide for *Using Annual Editions in the Classroom*.

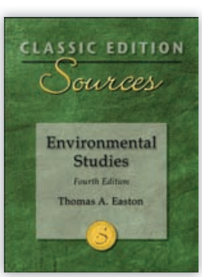
Taking Sides: *Clashing Views on Environmental Issues* by Tom Easton

ISBN: 9780073514512

Revised bi-annually for more than 30 years, this text is a debate-style reader designed to introduce students to controversies in environmental policy and science. The readings present arguments by leaders in the field and have been selected for their liveliness and substance. Instructional features include: an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, internet references by unit, learning outcomes, critical thinking questions, and "Is There Common Ground?" questions to guide further research. An Instructor Resource Guide with test materials is available for download as well as a practical guide for *Using Taking Sides in the Classroom*.

Classic Edition Sources: *Environmental Studies* by Tom Easton

ISBN: 9780073527642



This collection brings together more than 40 selections of enduring intellectual value—classic articles, reviews, book excerpts, and research studies—that help define the study of the environment and our current understanding of it. These readings represent almost 150 years of ecological thought and application with dates of publication ranging from 1864 to the present. Instructional features include: an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit to facilitate further research. An Instructor Resource Guide with test materials is available for download.

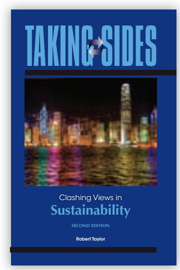
Annual Editions: *Sustainability* by Nicholas Smith-Sebasto

ISBN: 9780073528694

This new addition to the Annual Editions series provides carefully selected articles from the most respected magazines, newspapers, and journals published today. This volume contains interesting, well-illustrated readings by environmentalists, educators, researchers, scientists, and writers that provide perspective on the emerging field of sustainability. Instructional features include: an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit for additional research, learning outcomes, and critical thinking questions. An Instructor Resource Guide with test materials is available for download, as is the practical guide *Using Annual Editions in the Classroom*.

Taking Sides: *Sustainability* by Robert Taylor

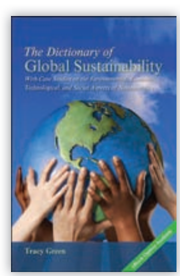
ISBN: 9780073514505



This new addition to the Taking Sides series introduces students to controversies in the emerging field of sustainability. The text presents arguments by policy analysts, scientists, economists, and environmentalists that have been selected for their liveliness and substance. Instructional features include: an annotated table of contents, a correlation guide to main textbooks, a topic guide for all articles, Internet references by unit, learning outcomes, critical thinking questions, and "Is There Common Ground?" questions to guide further research. An Instructor Resource Guide with test materials is available for download as well as a practical guide for *Using Taking Sides in the Classroom*.

The Dictionary of Global Sustainability by Tracy Green

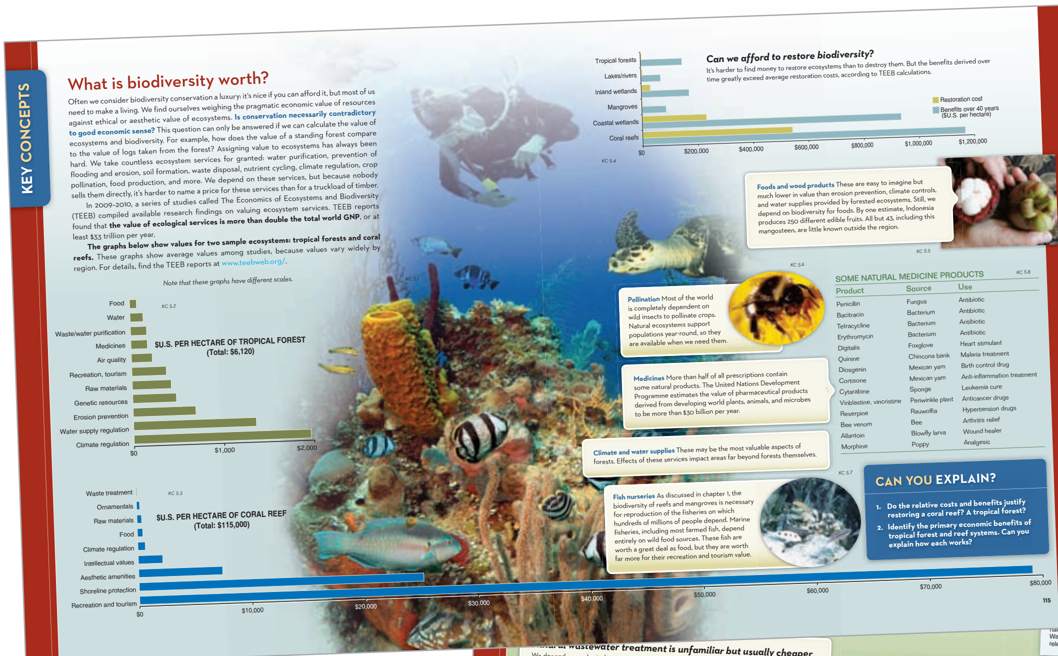
ISBN: 9780073514529

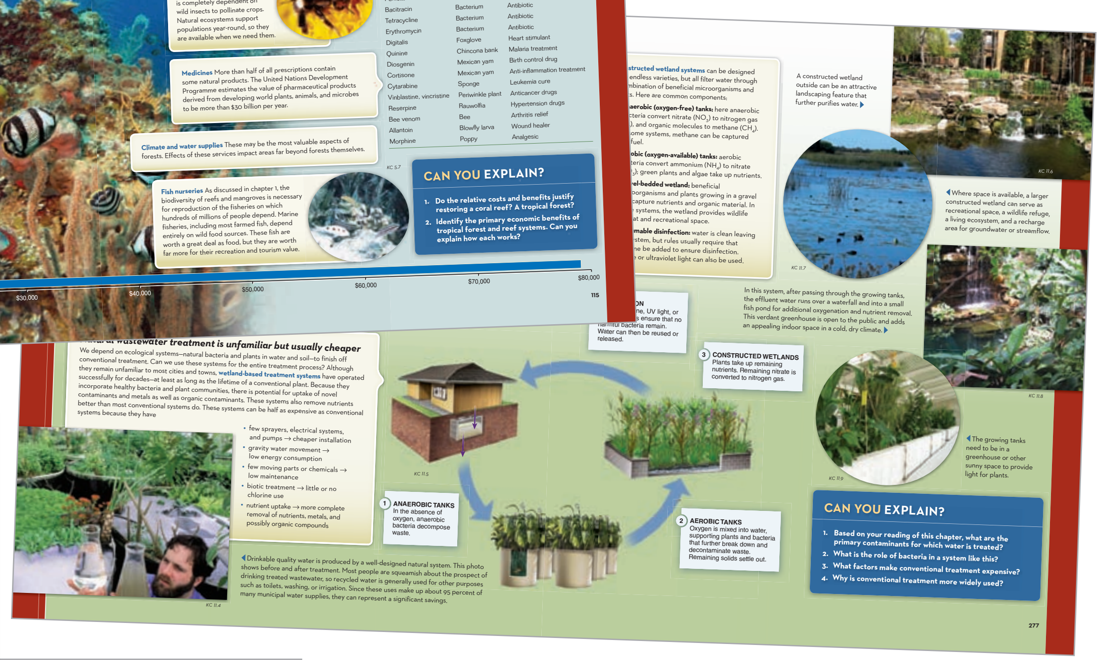


This textbook serves as a quick reference guide to students and professionals seeking a better understanding of sustainability concepts. The volume provides nearly 2800 key terms in this emerging field, as well as a listing of organizations and scholarly and trade journals—domestic and international—that will lead the reader to valuable research materials. It includes case studies that examine sustainability projects from around the world designed to illustrate the theory and practice of environmental, economic, technological, and social aspects of sustainability.

Guided Tour

Application-based learning contributes to engaged scientific investigation.



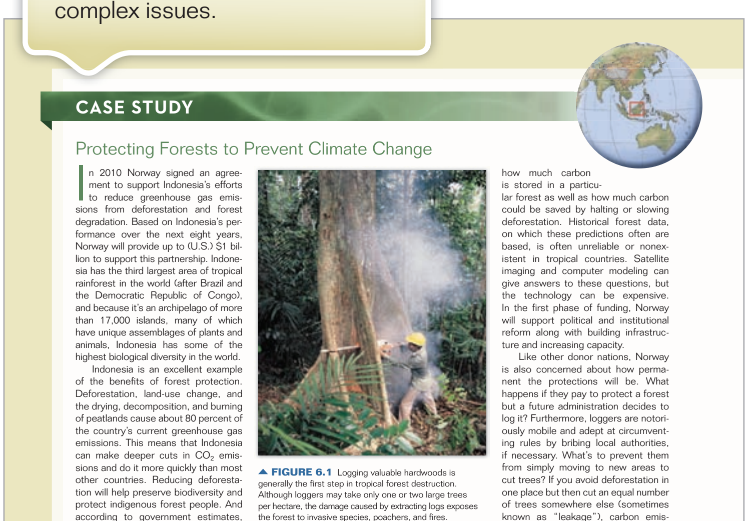


Key Concepts

Key concepts from each chapter are presented in a beautifully arranged layout to guide the student through the often complex network issues.

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

Protecting Forests to Prevent Climate Change

In 2010 Norway signed an agreement to support Indonesia's efforts to reduce greenhouse gas emissions from deforestation and forest degradation. Based on Indonesia's performance over the next eight years, Norway will provide up to (U.S.) $1 billion to support this partnership. Indonesia has the third largest area of tropical rainforest in the world (after Brazil and the Democratic Republic of Congo), and because it's an archipelago of more than 17,000 islands, many of which have unique assemblages of plants and animals, Indonesia has some of the highest biological diversity in the world.

Indonesia is an excellent example of the benefits of forest protection. Deforestation, land-use change, and the drying, decomposition, and burning of peatlands cause about 80 percent of the country's current greenhouse gas emissions. This means that Indonesia can make deeper cuts in CO_2 emissions and do it more quickly than most other countries. Reducing deforestation will help preserve biodiversity and protect indigenous forest people. And according to government estimates, up to 80 percent of Indonesia's logging

▲ **FIGURE 6.1** Logging valuable hardwoods is generally the first step in tropical forest destruction. Although loggers may take only one or two large trees per hectare, the damage caused by extracting logs exposes the forest to invasive species, poachers, and fires.

how much carbon is stored in a particular forest as well as how much carbon could be saved by halting or slowing deforestation. Historical forest data, on which these predictions often are based, is often unreliable or nonexistent in tropical countries. Satellite imaging and computer modeling can give answers to these questions, but the technology can be expensive. In the first phase of funding, Norway will support political and institutional reform along with building infrastructure and increasing capacity.

Like other donor nations, Norway is also concerned about how permanent the protections will be. What happens if they pay to protect a forest but a future administration decides to log it? Furthermore, loggers are notoriously mobile and adept at circumventing rules by bribing local authorities, if necessary. What's to prevent them from simply moving to new areas to cut trees? If you avoid deforestation in one place but then cut an equal number of trees somewhere else (sometimes known as "leakage"), carbon emissions won't have gone down at all.

Google Earth™ interactive satellite imagery gives students a geographic context for global places and topics discussed in the text. Google Earth™ icons indicate a corresponding exercise in Connect. In these exercises students will find links to locations mentioned in the text, and corresponding assessments that will help them understand environmental topics.

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

Examining Climate Graphs

Among the nine types of terrestrial biomes you've just read about, one of the important factors is the number of months when the average temperature is below freezing (0°C). This is because most plants photosynthesize most actively when daytime temperatures are well above freezing—and when water is fluid, not frozen (chapter 2). Among the biome examples shown, how many sites have fewer than three months when the average temperature is above 0°? How many sites have all months above freezing? Look at figure 5.3: Do all deserts have average yearly temperatures above freezing? Now look at figure 5.4: Which biome do you live in? Which biome do most Americans live in?

ANSWERS: Only the tundra site has less than three months above freezing. Three sites have all months above freezing. No. Answers will vary. Most Americans live in temperate coniferous or broadleaf forest biomes.

What Can YOU DO?

Working Locally for Ecological Diversity

You might think that diversity and complexity of ecological systems are too large or too abstract for you to have any influence. But you can contribute to a complex, resilient, and interesting ecosystem, whether you live in the inner city, a suburb, or a rural area.

- Take walks. The best way to learn about ecological systems in your area is to take walks and practice observing your environment. Go with friends and try to identify some of the species and trophic relationships in your area.
- Keep your cat indoors. Our lovable domestic cats are also very successful predators. Migratory birds, especially those nesting on the ground, have not evolved defenses against these predators.
- Plant a butterfly garden. Use native plants that support a diverse insect population. Native trees with berries or fruit also support birds. (Be sure to avoid non-native invasive species.) Allow structural diversity (open areas, shrubs, and trees) to support a range of species.
- Join a local environmental organization. Often, the best way to be effective is to concentrate your efforts close to home. City parks and neighborhoods support ecolo... communities, as do farming and rural areas. Join an organization

What Can You Do?

Students can employ these practical ideas to make a positive difference in our environment.

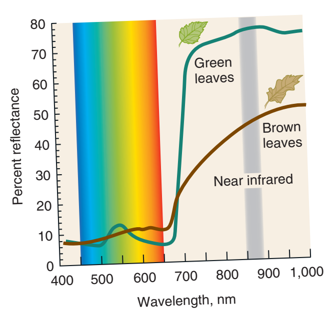
EXPLORING *Science* — *Remote Sensing, Photosynthesis, and Material Cycles*

Measuring primary productivity is important for understanding individual plants and local environments. Understanding the rates of primary productivity is also key to understanding global processes, such as material cycling, and biological activity:

- In global carbon cycles, how much carbon is stored by plants, how quickly is it stored, and how does carbon storage compare in contrasting environments, such as the Arctic and the tropics?
- How does this carbon storage affect global climates (chapter 9)?
- In global nutrient cycles, how much nitrogen and phosphorus wash offshore, and where?

How can environmental scientists measure primary production (photosynthesis) at a global scale? In a small, relatively closed ecosystem, such as a pond, ecologists can collect and analyze samples of all trophic levels. But that method is impossible for large ecosystems, especially for oceans, which cover 70 percent of the earth's surface. One of the newest methods of quantifying biological productivity involves remote sensing, or using data collected from satellite sensors that observe the energy reflected from the earth's surface.

As you have read in this chapter, chlorophyll in green plants *absorbs* red and blue



▲ **FIGURE 1** Energy wavelengths reflected by green and brown leaves.

Exploring Science

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

What Do YOU THINK?

Shade-Grown Coffee and Cocoa

Do your purchases of coffee and chocolate help to protect or destroy tropical forests? Coffee and cocoa are two of the many products grown exclusively in developing countries but consumed almost entirely in the wealthier, developed nations. Coffee grows in cool, mountain areas of the tropics, while cocoa is native to the warm, moist lowlands. What sets these two apart is that both come from small trees adapted to grow in low light, in the shady understory of a mature forest. **Shade-grown** coffee and cocoa (grown beneath an understory of taller trees) allow farmers to produce a crop at the same time as forest habitat remains for birds, butterflies, and other wild species.

Until a few decades ago, most of the world's coffee and cocoa were shade-grown. But new varieties of both crops have been developed that can be grown in full sun. Growing in full sun, trees can be crowded together more closely. With more sunshine, photosynthesis and yields increase.

◀ Cocoa pods grow directly on the trunk and large branches of cocoa trees.

coffee and cocoa plantations in these areas are converted to monocultures, an incalculable number of species will be lost.

The Brazilian state of Bahia demonstrates both the ecological importance of these crops and how they might help preserve forest species. At one time, Brazil produced much of the world's cocoa, but in the early 1900s, the crop was introduced into West Africa. Now Côte d'Ivoire alone grows more than 40 percent of the world total. Rapid increases in global supplies have made prices plummet, and the value of Brazil's harvest has dropped by 90 percent. Côte d'Ivoire is aided in this competition by a labor system that reportedly includes widespread child slavery. Even adult workers in Côte d'Ivoire get only about $165 (U.S.) per year (if they get paid at all), compared with a minimum wage of $850 (U.S.) per year in Brazil.

What Do You Think?

Students are presented with challenging environmental studies that offer an opportunity to consider contradictory data, special interest topics, and conflicting interpretations within a real scenario.

Pedagogical Features Facilitate Student Understanding of Environmental Science

CHAPTER 3

Evolution, Species Interactions, and Biological Communities

The Galápagos Islands have provided an accidental laboratory for examining biological diversity and species interactions.

LEARNING OUTCOMES

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

- How does species diversity arise?
- What do we mean by tolerance limits? Give examples.
- How do interactions both aid and hinder species?
- Why don't species always reproduce up to their biotic potential?
- What is the relationship between species diversity and community stability?
- What is disturbance, and how does it affect communities?
- Explain ecological succession and give examples of its stages.

Learning Outcomes

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

Practice Quiz

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

PRACTICE QUIZ

1. What are the two most important nutrients causing eutrophication in the Chesapeake Bay?
2. What are systems and how do feedback loops regulate them?
3. Your body contains vast numbers of carbon atoms. How is it possible that some of these carbons may have been part of the body of a prehistoric creature?
4. List six unique properties of water. Describe, briefly, how each of these properties makes water essential to life as we know it.
5. What is DNA, and why is it important?
6. The oceans store a vast amount of heat, but this huge reservoir of energy is of little use to humans. Explain the difference between high-quality and low-quality energy.
7. In the biosphere, matter follows circular pathways, while energy flows in a linear fashion. Explain
8. Which wavelengths do our eyes respond to, and why? (Refer to fig. 2.13.) About how long are short ultraviolet wavelengths compared to microwave lengths?
9. Where do extremophiles live? How do they get the energy they need for survival?
10. Ecosystems require energy to function. From where does most of this energy come? Where does it go?
11. How do green plants capture energy, and what do they do with it?
12. Define the terms *species*, *population*, and *biological community*.
13. Why are big, fierce animals rare?
14. Most ecosystems can be visualized as a pyramid with many organisms in the lowest trophic levels and only a few individuals at the top. Give an example of an inverted numbers pyramid

CRITICAL THINKING AND DISCUSSION

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

1. Ecosystems are often defined as a matter of convenience because we can't study everything at once. How would you describe the characteristics and boundaries of the ecosystem in which you live? In what respects is your ecosystem an open one?
2. Think of some practical examples of increasing entropy in everyday life. Is a messy room really evidence of thermodynamics at work, or merely personal preference?
3. Some chemical bonds are weak and have a very short half-life (fractions of a second, in some cases); others are strong and stable, lasting for years or even centuries. What would our world be like if all chemical bonds were either very weak or extremely strong?
4. If you had to design a research project to evaluate the relative biomass of producers and consumers in an ecosystem, what would you measure? (*Note:* This could be a natural system or a human-made one.)
5. Understanding storage compartments is essential to understanding material cycles, such as the carbon cycle. If you look around your backyard, how many carbon storage compartments are there? Which ones are the biggest? Which ones are the longest lasting?

Critical Thinking and Discussion Questions

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

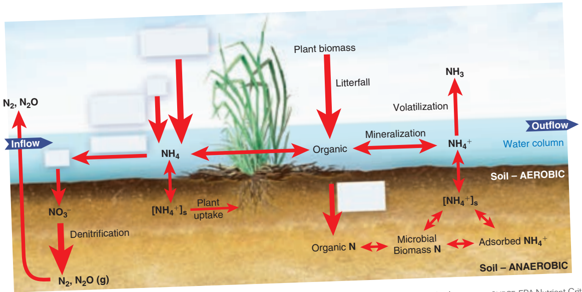
Data Analysis

At the end of each chapter, these exercises give students further opportunities to apply critical thinking skills and analyze data. These are assigned through Connect in an interactive online environment. Students are asked to analyze data in the form of documents, videos, and animations.

DATA ANALYSIS Examining Nutrients in a Wetland System

As you have read, movements of nitrogen and phosphorus are among the most important considerations in many wetland systems, because high levels of these nutrients can cause excessive algae and bacteria growth. This is a topic of great interest, and many studies have examined how nutrients move in a wetland, and in other ecosystems. Taking a little time to examine these nutrient cycles in detail will draw on your knowledge of atoms, compounds, systems, cycles, and other ideas in this chapter. Understanding nutrient cycling will also help you in later chapters of this book.

One excellent overview was produced by the Environmental Protection Agency. Go to Connect to find a description of the figure shown here, and to further explore the movement of our dominant nutrient, nitrogen, through environmental systems.



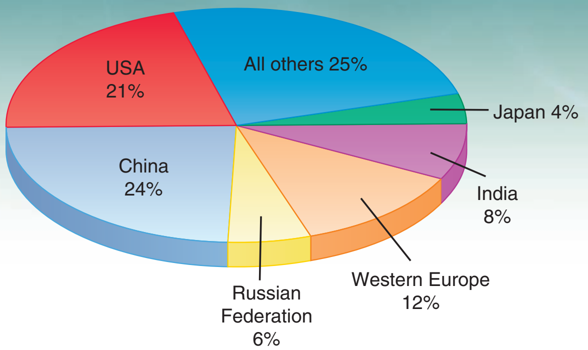
▲ **FIGURE 1** A detailed schematic diagram of the nitrogen cycle in a wetland. Study the online original to fill in the boxes. SOURCE: EPA Nutrient Criteria Technical Guidance Manual, www.epa.gov/waterscience/criteria/nutrient/guidance/.

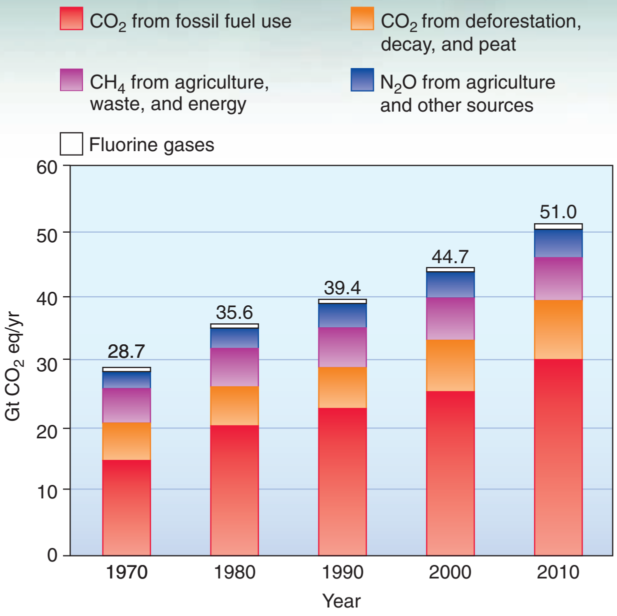
connect ENVIRONMENTAL SCIENCE

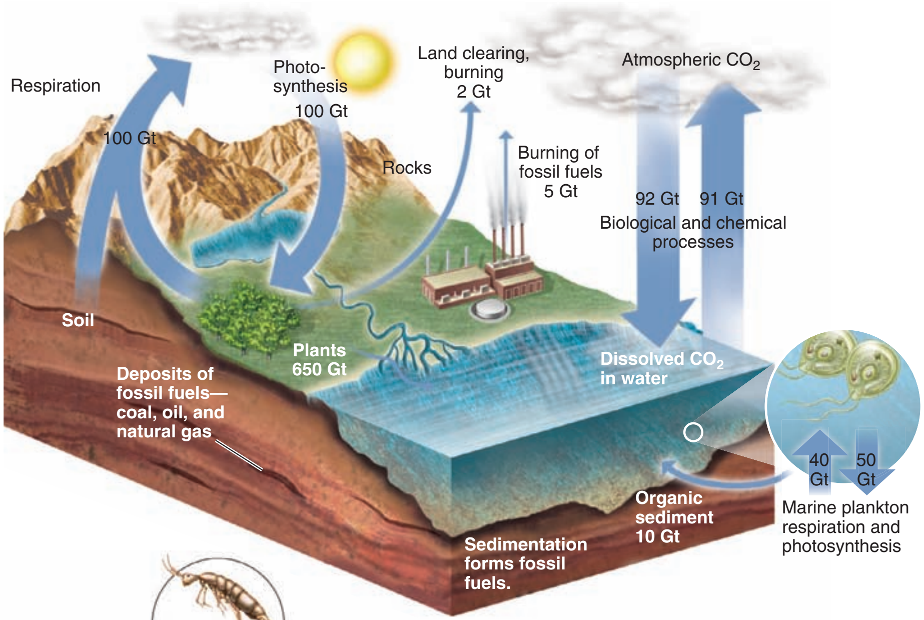
TO ACCESS ADDITIONAL RESOURCES FOR THIS CHAPTER, PLEASE VISIT CONNECT AT www.connect.mcgraw-hill.com.

You will find LearnSmart, an adaptive learning system, Google Earth™ exercises, additional Case Studies, Data Analysis exercises, and an interactive ebook.

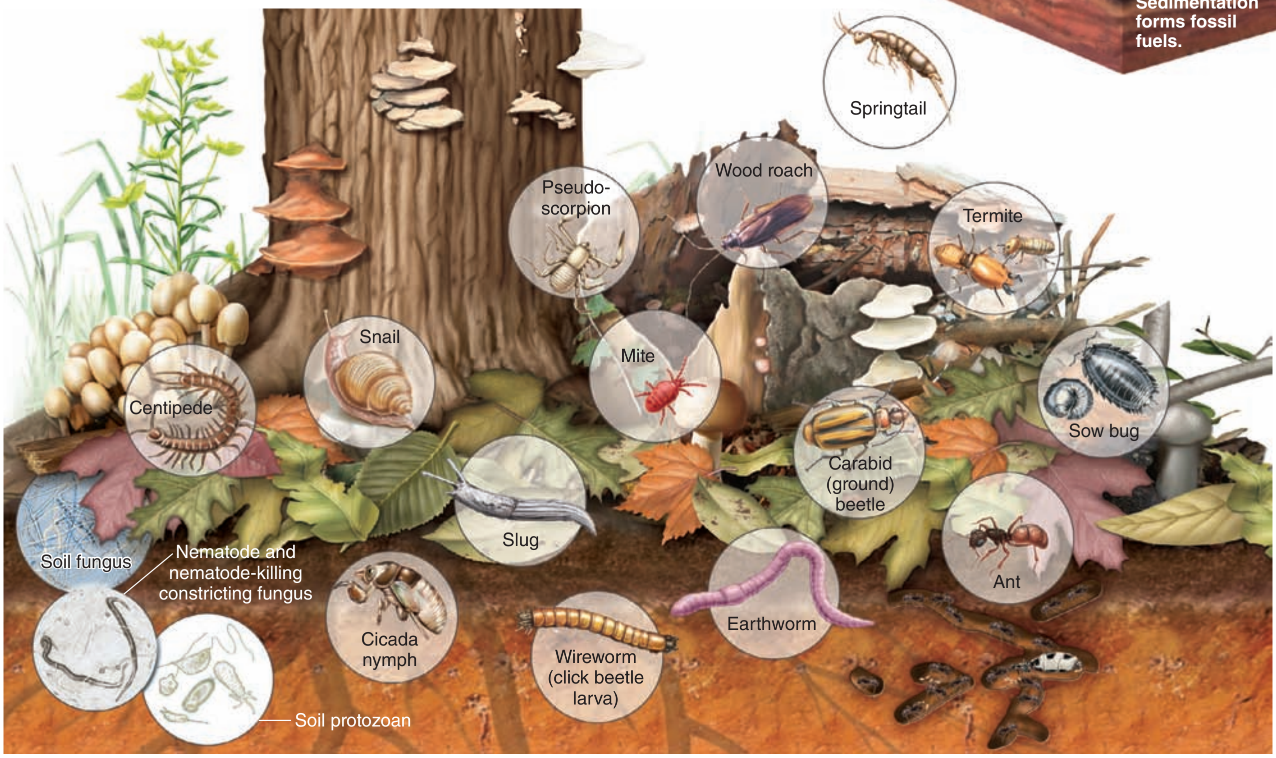
Relevant Photos and Instructional Art Support Learning







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



CHAPTER

1 Understanding Our Environment

Fish and the reefs that support them are essential to the livelihoods of people in the Philippines and most other tropical island nations.

LEARNING OUTCOMES

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

- Describe several important environmental problems facing the world.
- List several examples of progress in environmental quality.
- Explain the idea of sustainability and some of its aims.
- Why are scientists cautious about claiming absolute proof of particular theories?
- What is critical thinking, and why is it important in environmental science?
- Why do we use graphs and data to answer questions in science?
- Identify several people who helped shape our ideas of resource conservation and preservation—why did they promote these ideas when they did?

CASE STUDY

Saving the Reefs of Apo Island

As their outrigger canoes glide gracefully onto Apo Island's beach after an early morning fishing expedition, villagers call to each other to ask how the fishing was. "Tunay mabuti!" (very good!) is the cheerful reply. Nearly every canoe has a basketful of fish, enough to feed a family, with a surplus to send to the market. But life hasn't always been so good on the island. Forty years ago this island, like many others in the Philippines, was experiencing a catastrophic decline in fish stocks, the mainstay of the islanders' diet and livelihood. Rapid population growth coupled with destructive fishing methods had damaged critical habitat and exhausted fish stocks. Dynamite and cyanide were used to stun fish, making them easy to capture but destroying whole ecosystems at once. Fishing boats dragged heavy trawl nets across the sea floor, bulldozing the substrate on which fish depended. Fine-mesh nets were used to capture smaller and smaller fish. The island's fringe of coral reef, the breeding ground and nursery for nearly all the island's fish, was being steadily degraded and torn apart.

In 1979, scientists from Silliman University on nearby Negros Island visited Apo and proposed that residents could improve their livelihoods by managing their resources differently. Simply by protecting their coral reef, islanders could rebuild and preserve a sustainable fishery. The scientists showed villagers from Apo a no-take marine reserve at the uninhabited Sumilon Island, which was teeming with fish (fig. 1.1).

After much discussion, several families decided to establish a marine sanctuary along a short section of Apo Island's shoreline. The area still had high-quality coral, but there were few fish. Participating families took turns watching to make sure no one trespassed in the no-fishing zone. Within a few years, fish in the sanctuary became both dramatically larger and more numerous. Fishing improved outside the sanctuary, as increasingly abundant fish spread to surrounding areas. In 1985, Apo villagers voted to establish a 500 m (0.3 mi) wide marine sanctuary around the entire island.

Villagers now manage their preserve carefully. They allow fishing, but only with low-impact methods such as handheld lines, bamboo traps, large-mesh nets, spearfishing without scuba gear, and hand netting. Coral-destroying techniques, such as dynamite, cyanide, and trawling, are prohibited. By protecting the reef, villagers are guarding the nursery of an entire marine ecosystem. Young fish growing up in the shelter of the coral disperse to neighboring waters and yield abundant harvests. Fishermen report that they spend much less time traveling to distant fishing areas now that fish around the island are so much more abundant.

Apo's sanctuary has become the inspiration for more than 400 similar marine preserves in the Philippines and many others around the world.

The idea of marine protected areas (MPAs) has also spread to larger fisheries. Protecting just a small amount of critical reproductive area can ensure stability of populations and fisheries. Regional MPAs have now been established from California to New Zealand. The idea is a technologically simple and inexpensive approach to protecting the world's increasingly imperiled fisheries. The United Nations Environment Programme (UNEP) reports that 75 percent of the world's fisheries are at or beyond maximum supportable fishing levels; about a quarter have collapsed completely, with fish populations no longer able to produce enough young to support an economic fishery. MPAs are one of the best ways to reverse these declines, if the rules can be agreed upon and enforced.

Enforcement is relatively easy in a small community like Apo Island, where the benefits of the marine sanctuary are obvious and widely shared. The island's rich marine life and spectacular coral reefs have made Apo an international destination for scuba diving and snorkeling. Hotels and dive shops provide jobs for island residents. Villagers sell food and souvenirs to visitors. Fees charged to tourists for diving and snorkeling have been used to build schools, improve island water supplies, provide electricity to the island's households, and pay local people to patrol the sanctuary. Fishing is still a primary occupation, and fish are the mainstay of local diets, but it's no longer necessary to travel as far or work as hard to catch the fish. Now fishers have time for other activities, such as guiding diving tours.

Higher family incomes now allow most island children to attend high school on nearby Negros Island, and many continue on to college or technical schools. Education has greatly expanded the islanders' economic opportunities. Just as important, villagers are empowered by seeing that they can take action to improve their environment and their living conditions at the same time.

Environmental scientists often point out that crisis and opportunity go hand in hand. Faced with loss of their livelihoods, Apo Island's residents discovered new ways to cooperate and to manage their resources better than they had done before. Often the best solutions to our problems involve rethinking our accustomed approaches and actions. The idea of MPAs draws on basic ideas of ecology and population biology. Ideas of governance and economics are also essential. In this book we'll examine these and other concepts that can help us resolve the environmental, economic, and social challenges we face. That is the challenge that faces all of us. With creativity and commitment we may find strategies to rebuild the living systems that sustain us. ■

FIGURE 1.1 Coral reefs are among the most beautiful, species-rich, and productive biological communities on the planet. They serve as the nurseries for many open-water species. At least half the world's reefs are threatened by pollution, global climate change, destructive fishing methods, and other human activities, but they can be protected and restored if we care for them.

> *Today we are faced with a challenge that calls for a shift in our thinking, so that humanity stops threatening its life-support system.*
>
> —WANGARI MAATHAI, WINNER OF 2004 NOBEL PEACE PRIZE

1.1 UNDERSTANDING OUR ENVIRONMENT

Reversing the depletion of Apo Island's fishery required a scientific understanding of many aspects of the environment. Knowledge about population biology, reef ecology, the cultural history of fishing, and even economics of fishing all contributed to explaining this question of resource conservation. Similarly, the field of environmental science draws on many disciplines to help us understand pressing problems of resource supply, ecosystem stability, and sustainable living.

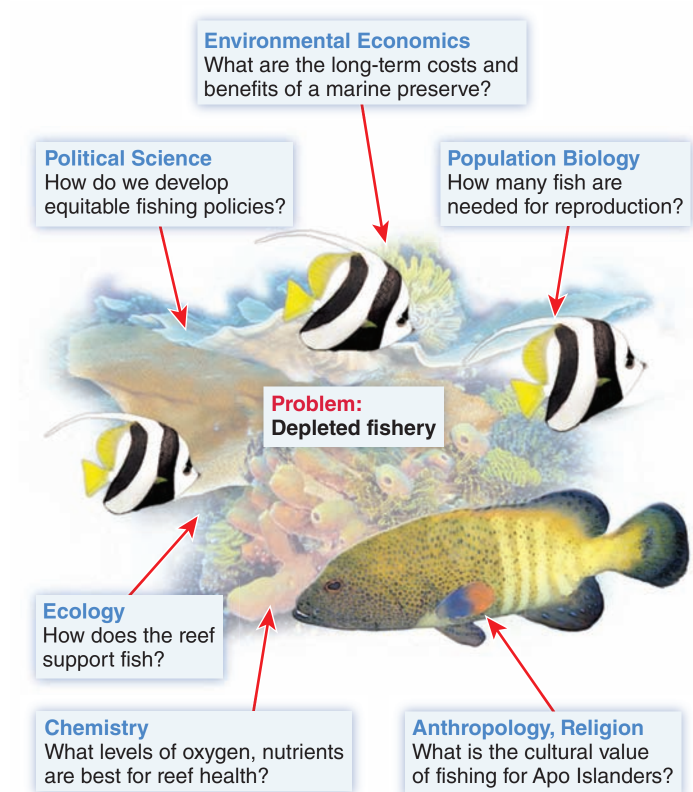
In this chapter we examine some of the serious challenges in environmental science and some promising signs of progress. We also explore the nature of science. What makes the scientific method different from other forms of inquiry? Why do scientists like to answer questions with numbers? Finally we review some of the fundamental ideas that have shaped the ways we think about the environment and our place in it.

What is environmental science?

We inhabit two worlds. One is the natural world of plants, animals, soils, air, and water that preceded us by billions of years and of which we are a part. The other is the world of social institutions and artifacts that we create for ourselves using science, technology, culture, and political organization. Both the natural world and the "built" or technological, social, and cultural world make up our environment (from the French *environner*, "to encircle or surround").

Environmental science is the systematic study of our environment and our place in it. Because environmental problems involve complex, interacting systems, environmental science draws on many fields of knowledge (fig. 1.2). Sciences such as biology, chemistry, earth science, and geography are central. Social sciences and humanities, from political science and economics to art and literature, help us understand how society responds to environmental challenges and opportunities. Solutions to these problems increasingly involve both social systems and natural science. One of your tasks in this class may be to discover where your knowledge and interests contribute to understanding questions in environmental science (see Active Learning, p. 4). Finding your particular interest will help you do better in this class, because you'll have more reason to explore the ideas you encounter.

Is environmental science the same thing as environmentalism? Not necessarily. Environmental science is the use of scientific methods to study processes and systems in the environment in which we live. Environmentalism is working to influence attitudes and policies that affect our environment. The two are often separate goals. Hydrologists, for example, are environmental scientists who study water, often in order to ensure ready supplies to cities and farms. They may work to increase access to water, but their work may or may not involve broader attention to environmental quality. On the other hand ecologists might actively work to defend the ecosystems they study. Many environmental scientists work in the public interest, to promote public health by reducing water contamination, for example, without necessarily being interested in nature or biodiversity. Whether we use science to pursue public health, economic success, environmental quality, or other goals depends on issues outside of science, such as worldviews and ethics.



▲ **FIGURE 1.2** Many types of knowledge are needed in environmental science. A few examples are shown here.

Environmental science is a global subject

You are already aware of our global dependence on resources and people in faraway places, from computers built in China to oil extracted in Iraq or Venezuela. These interdependencies become clearer as we learn more about global and regional environmental systems. Often the best way to learn environmental science is to see how principles play out in real places. Familiarity with the world around us will help you understand the problems and their context. Throughout this book we've provided links to places you can see in Google Earth, a free online mapping program that you can download from googleearth.com. When you see a blue globe in the margin of this text, like the one at left, you can go to Connect and find place marks that let you virtually visit places discussed. In Google Earth you can also save your own placemarks and share them with your class.

Active LEARNING

Finding Your Strengths in This Class

A key strategy for doing well in this class is to figure out where your strengths and interests intersect with the subjects you will be reading about. As you have read, environmental science draws on many kinds of knowledge (fig. 1.2). Nobody is good at all of these, but everyone is good at some of them. Form a small group of students, then select one of the questions in section 1.2. Explain how each of the following might contribute to understanding or solving that problem:

artist, writer, politician, negotiator, chemist, mathematician, hunter, angler, truck driver, cook, parent, builder, planner, economist, speaker of multiple languages, musician, business person.

ANSWERS: All of these provide multiple insights; answers will vary.

We inhabit a remarkable planet

Before turning to focus on current challenges, we should pause to consider the extraordinary natural world that we inherited and that we hope to pass on to future generations in a condition as good as—or perhaps even better than—we found it in.

Imagine that you are an astronaut returning to the earth after a trip to the moon or Mars. What a relief it would be, after the silent void of outer space, to return to this beautiful, bountiful planet (fig. 1.3). We live in an incredibly prolific and colorful world that is, as far as we know, unique in the universe. Compared with other planets in our solar system, temperatures on the earth are mild and relatively constant. Plentiful supplies of clean air, fresh water, and fertile soil are regenerated endlessly and spontaneously by biogeochemical cycles and biological communities (discussed in chapters 2 and 3). The value of these ecological services is almost incalculable, although economists estimate that they account for a substantial proportion of global economic activity (chapter 16).

Perhaps the most amazing feature of our planet is its rich diversity of life. Millions of beautiful and intriguing species populate the earth and help sustain a habitable environment (fig. 1.4). This vast multitude of life creates complex, interrelated communities where towering trees and huge animals live together with, and depend upon, such tiny life-forms as viruses, bacteria, and fungi. Together, all these organisms make up delightfully diverse, self-sustaining ecosystems, including dense, moist forests; vast, sunny savannas; and richly colorful coral reefs.

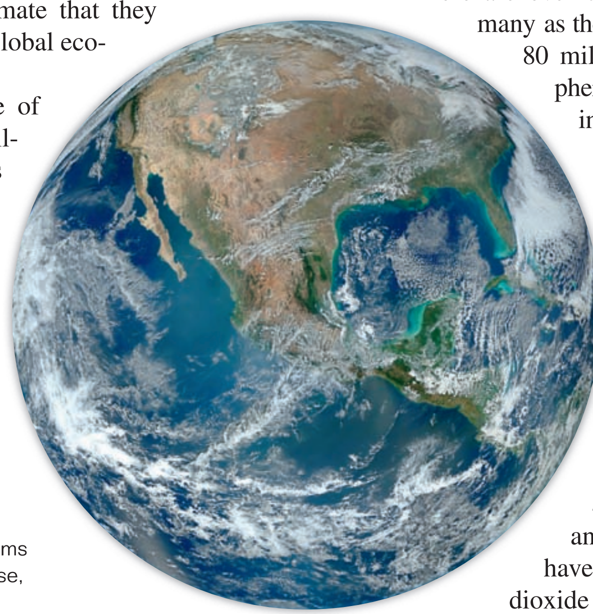


FIGURE 1.3 The life-sustaining ecosystems on which we all depend are unique in the universe, as far as we know.

FIGURE 1.4 Perhaps the most amazing feature of our planet is its rich diversity of life.

From time to time we should pause to remember that, in spite of the challenges of life on earth, we are incredibly lucky to be here. We should ask ourselves what we can do, and what we *ought* to do, to ensure that future generations have the same opportunities to enjoy this bounty.

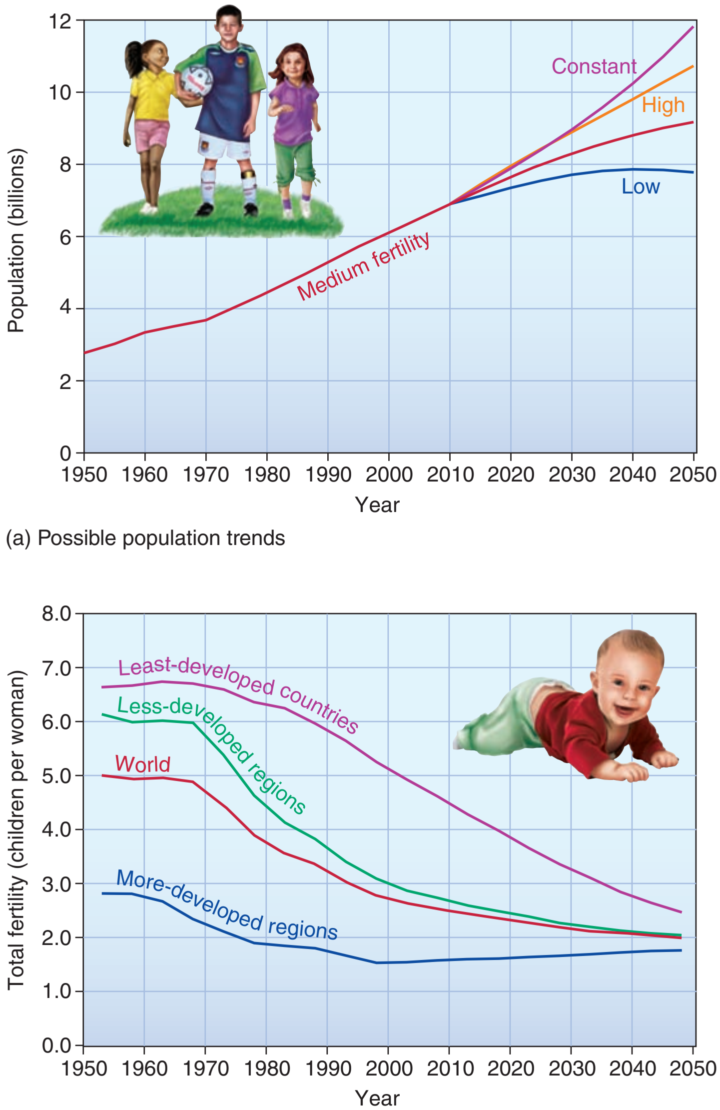
1.2 CRISES AND OPPORTUNITIES

As we have noted, crisis and opportunity often go hand in hand, because serious problems can drive us to seek better solutions. A first step in understanding environmental science is to understand some of the principal challenges we face and some of the recent changes in environmental quality and environmental health. We give a brief overview here, and we explore each topic in detail in later chapters. Most of these issues are influenced by multiple factors. As you read, consider what those factors are and what steps might be taken to resolve some of these problems.

What persistent challenges do we face?

There are over 7 billion people on earth, about twice as many as there were 40 years ago. We are adding about 80 million more each year. Although demographers report a transition to slower growth rates in most countries, with improved education and health care, present trends project a population between 8 and 10 billion by 2050 (fig. 1.5). The impact of that many people on our natural resources and ecological systems strongly influences many of the other problems we face.

Climate Change The atmosphere normally captures heat near the earth's surface, which is why it is warmer here than in space. But human activities such as burning fossil fuels, clearing forests and farmlands, and raising ruminant animals have greatly increased concentrations of carbon dioxide and other "greenhouse gases." In the past



(a) Possible population trends

(b) Fertility rates

▲ **FIGURE 1.5** Bad news and good news: globally, populations continue to rise (a), but our rate of growth has plummeted (b). Some countries are below the replacement rate of about two children per woman. SOURCE: United Nations Population Program, 2011.

200 years, atmospheric CO_2 concentrations have increased about 30 percent. Climate models indicate that by 2100, if current trends continue, global mean temperatures will probably increase by 2° to 6°C compared to 1990 temperatures (3.6° and 12.8°F: fig. 1.6a), far warmer than the earth has been since the beginning of human civilization. For comparison, the last ice age was about 4°C cooler than now. Increasingly severe droughts and heat waves are expected in many areas. Greater storm intensity and flooding are expected in other places. Disappearing mountaintop glaciers and snowfields threaten the water supplies on which cities such as Los Angeles and Delhi depend. Canadian Environment Minister David Anderson said that global climate change is a greater threat than terrorism because it could force hundreds of millions of people from their homes and trigger an economic and social catastrophe.

Hunger Over the past century, global food production has increased faster than human population growth, but hunger remains a chronic problem because food resources are unevenly distributed. At the same time, soil scientists report that about two-thirds of all agricultural lands show signs of degradation. The biotechnology and intensive farming techniques responsible for much of our recent production gains are too expensive for many poor farmers. Can we find ways to produce the food we need without further environmental degradation? And can we distribute food more equitably? In a world of food surpluses, currently more than 850 million people are chronically undernourished, and at least 60 million people face acute food shortages due to weather, politics, or war (fig. 1.6b).

Clean Water Water may be the most critical resource in the twenty-first century. Already at least 1.1 billion people lack access to safe drinking water, and twice that many don't have adequate sanitation. Polluted water contributes to the death of more than 15 million people every year, most of them children under age 5. About 40 percent of the world population lives in countries where water demands now exceed supplies, and the UN projects that by 2025 as many as three-fourths of us could live under similar conditions (fig. 1.6c).

Energy Resources How we obtain and use energy will greatly affect our environmental future. Fossil fuels (oil, coal, and natural gas) presently provide around 80 percent of the energy used in industrialized countries. Supplies of these fuels are diminishing, however, and the costs of extracting and using these fuels are high in terms of air and water pollution, mining damage, political conflicts, and of course climate change. Energy conservation and cleaner, renewable energy resources—solar, wind, geothermal, and biomass power—could give us cleaner, less destructive options if we decide to invest in them.

Air Quality Air quality has worsened dramatically in newly industrializing areas, including much of China and India. An "Asian brown cloud," a 3-km (2-mile)-thick toxic haze of ash, acids, aerosols, dust, and photochemical smog, regularly covers the entire Indian subcontinent for much of the year. Nobel laureate Paul Crutzen estimates that at least 3 million people die each year from diseases triggered by air pollution. Worldwide, the United Nations estimates, more than 2 billion metric tons of air pollutants (not including carbon dioxide or wind-blown soil) are released each year. These air pollutants travel easily around the globe. On some days 75 percent of the smog and airborne particulates in California originate in Asia; mercury, polychlorinated biphenyls (PCBs), and other industrial pollutants accumulate in arctic ecosystems and in the tissues of native peoples in the far north.

Biodiversity Loss Biologists report that habitat destruction, overexploitation, pollution, and the introduction of exotic organisms are eliminating species as quickly as the great extinction that marked the end of the age of dinosaurs. The UN Environment Programme reports that over the past century more than 800 species have disappeared, and at least 10,000 species are now considered threatened. This includes about half of all primates and freshwater fish, together with around 10 percent of all plant species. Top