ELEVENTH EDITION

Environmental SCIENCE

A Global Concern

William P. Cunningham
University of Minnesota

Mary Ann Cunningham
Vassar College

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ENVIRONMENTAL SCIENCE: A GLOBAL CONCERN, ELEVENTH EDITION

This book is printed on acid-free paper.

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

ISBN 978–0–07–338321–7
MHID 0–07–338321–X

Publisher: *Janice Roerig-Blong*
Executive Editor: *Margaret J. Kemp*
Director of Development: *Kristine Tibbetts*
Marketing Manager: *Heather Chase Wagner*
Senior Project Manager: *April R. Southwood*
Lead Production Supervisor: *Sandy Ludovissy*
Lead Media Project Manager: *Judi David*
Design Coordinator: *Brenda A. Rolwes*
Cover Designer: *Studio Montage, St. Louis, Missouri*
(USE) Cover Image: *Getty Images*
Senior Photo Research Coordinator: *Lori Hancock*
Photo Research: *LouAnn K. Wilson*
Compositor: *S4Carlisle Publishing Services*
Typeface: *10/12 Times Roman*
Printer: *Quebecor World Dubuque, IA*

Library of Congress Cataloging-in-Publication Data

Cunningham, William P.
Environmental science : a global concern. — 11th ed. / William P. Cunningham, Mary Ann Cunningham.
p. cm.
Includes index.
ISBN 978–0–07–338321–7 — ISBN 0–07–338321–X (hard copy : alk. paper)
1. Environmental sciences—Textbooks. I. Cunningham, Mary Ann. II. Title.

GE105.C86 2010
363.7—dc22 2009016505

www.mhhe.com

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, 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 coauthored 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.

Professor Cunningham's hobbies include photography birding, hiking, gardening, and traveling. He lives in St. Paul, Minnesota with his wife, Mary. He has three children (one of whom is coauthor of this book) and seven grandchildren.

Both authors have a long-standing interest in the topic in this book. Nearly half the photos in the book were taken on trips to the places we discuss.

Mary Ann Cunningham

Mary Ann Cunningham is an associate professor of geography at Vassar College. 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 nonscience 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 coauthor of this book since its seventh edition. She is also coauthor of *Principles of Environmental Science* (now in its fifth 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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Preface

Environmental Science Has Never Been More Important

"These were the best of times. These were the worst of times." The opening lines from Charles Dicken's *A Tale of Two Cities* provide a good description of our current global environmental situation. We see increasing signs of global warming. Arctic sea ice is disappearing at a frightening rate. Most commercial marine fisheries are either declining or exploited at unsustainable levels. Droughts and catastrophic wildfires threaten many parts of the world. Habitat destruction threatens an ever increasing number of species and ecosystems. In spite of warnings about the environmental, social, and economic costs of our dependence of fossil fuels, we continue to use ever increasing quantities of them.

And yet, there are also signs of hope. Human population growth is slowing almost everywhere. New technologies offer alternatives to fossil fuels. Renewable sources, such as solar, wind, biomass, and geothermal could supply all the energy we need. Conservation measures are reducing wasteful uses of energy, water, and soil. Air and water pollution have been reduced dramatically in many places.

Perhaps most encouraging, governments around the world have become aware of the costs of environmental degradation and are beginning to take steps to reduce their environmental impacts. As you'll read in Chapter 1, China has announced ambitious plans to restore forests, conserve water, reduce air and water pollution, and to move toward sustainable energy supplies. They've even agreed to reduce their greenhouse gas emissions, something they refused to consider when the Kyoto Protocol was signed a decade ago.

In the United States, there's new attitude toward both science and the environment. Experienced scientists are being appointed to governmental posts previously given to political appointees. President Obama has announced plans to use sound, scientific practice and evidence to guide federal policy. He has taken many steps to safeguard our environment and its resources for future generations, and public support for these steps has been overwhelmingly enthusiastic. The economic recovery bill passed in the first weeks of the Obama administration contains at least $86 billion in grants and tax incentives to develop clean and sustainable energy sources and create millions of green jobs. And he promised to take positive steps to reduce greenhouse gas emissions in the United States as well as to work with other governments to control climate change.

Businesses, too, now recognize the opportunities in conservation, recycling, producing nontoxic products, and reducing their ecological footprints. Many are hiring sustainability experts and beginning to recognize environmental impacts in their business accounting. Venture capitalists have increased their investments in "cleantech" (renewable energy, pollution reduction, etc.) from $270 million in 2003 to $4.1 billion in 2008.

This is a good time to study environmental science. Millions of new jobs are being created in environmental fields. Public opinion is shifting toward approval of environmental protection, because of its benefits for health and the economy, and organizations—many of them made up of young people using the tools of modern technology—are having an increasing voice in public policy. As an example, more than 12,000 people—most of them students—gathered in Washington, D.C. in March, 2009 to lobby for renewable energy and climate change control. In nearly every chapter of this book you'll find lists of smaller, but important positive steps individuals can take to help sustain our common environment.

As the British ecologist Norman Meyers said, "The present has a unique position in history. Now, as never before, we have technical, political, and economic resources to solve our global environmental crisis. And if we don't do it now, it may be too late for future generations to do so."

We hope that you'll find information and inspiration in this book to do something to help make the world a better place. Let's get started!

What Sets This Book Apart?

A positive viewpoint

We wrote this book because we think it's important for students to realize the difference they can make in their community. We believe a book focused on gloom and decay provides little inspiration to students, and in this time of exciting change, we think such a gloomy view is inaccurate. Many environmental problems remain severe, but there have been many improvements over past decades including cleaner water and cleaner air for most Americans. The Kyoto Protocol, despite its imperfections, is now pushing nations to reduce their climate impacts. The earth's population exceeds 6 billion people, but birth rates have plummeted as education and health care for women have improved. This book highlights these

developments and presents positive steps that individuals can take, while acknowledging the many challenges we face. Case studies that show successful projects, and "What Can You Do?" boxes are some of the features written to give students an applicable sense of direction. A number of other features also set this book apart.

An integrated, global perspective

Globalization spotlights the interconnectedness of environmental concerns, as well as economies. To remain competitive in a global economy, it is critical that we understand conditions in other countries and cultures. This book provides case studies and topics from regions around the world, as well as maps and data showing global issues. These examples also show the integration between environmental, social, and economic conditions at home and abroad.

A balanced presentation that encourages critical thinking

Environmental science often involves special interests, contradictory data, and conflicting interpretations of data. Throughout the text, one of the most important skills a student can learn is to think analytically and clearly about evidence, weigh the data, consider uncertainty, and skeptically evaluate the sources of information. We give students opportunities to practice critical thinking in brief "Think About It" boxes and in "What Do You Think?" readings. We present balanced evidence, while not suggesting that any opinion is on par with ideas accepted by the community of informed scientists, and we provide the tools for students to discuss and form their own opinions.

Emphasis on science

Science is critical for understanding environmental change. We emphasize principles and methods of science through coverage on uncertainty and probability, new graphing exercises, Data Analysis exercises, and "Exploring Science" readings that show how scientists observe the world and gather data.

Google Earth™ placemarks

Throughout this book, you'll see small globe icons that mark topics particularly suited to exploration in Google Earth™. This online program lets you view amazingly detailed satellite images of the earth that will help you understand the geographic context of these places you're studying. We've created placemarks that will help you find the places being discussed, and we've provided brief descriptions and questions to stimulate a thoughtful exploration of each site and its surroundings. This interactive geographical exploration is a wonderful tool to give you an international perspective on environmental issues.

To download the placemarks, go to http://environmental-science-cunningham.blogspot.com/. You'll also find links there for downloading the free Google Earth™ program as well as suggestions on how to use it effectively. Notice that there are two different sets of placemarks depending on which version of our book you're using.

Overview of Changes to Environmental Science Eleventh Edition

What's new to this edition?

We've updated data throughout the chapters in this book. Information and examples presented are the most recent available as of mid-2009. You'll find an abundance of specific numbers and current events—details that are difficult to keep up-to-date in a textbook.

Specific changes by chapter

- **Learning to Learn** has been revised with the removal of concept maps and quiz and discussion questions to save space.
- **Chapter 1** has a new opening case study: plug-in hybrid cars; an updated list of environmental challenges and signs of hope; revised sections on development of environmental thought, social progress, and environmental ethics; a new Data Analysis exercise on reading graphs; and seven new or revised figures.
- **Chapter 2** has a new opening case study: biodiversity; the ethics section has been removed to chapter 1; an updated discussion of systems; a new Data Analysis exercise on uncertainty in data analysis; and four new or revised figures.
- **Chapter 3** Figure 3.6 (DNA molecular model) has been corrected so that the bonds between bases are accurate.
- **Chapter 6** has a revised discussion of population growth models, with new figures and graphs and a new Data Analysis exercise to build on the new text; discussion of natality and fecundity removed to chapter 7; a BIDE and survivorship section revised; and eight new or revised figures.
- **Chapter 7** has new data on population sizes and growth rates throughout; the data analysis box at the end of the chapter has been revised with better questions; and there are five new figures.
- **Chapter 8** has a new discussion of climate change and emergent diseases together with the emerging threat of methicillin-resistant *Staphylococcus aureus* (MRSA) infections, and controversy over the U.S. federal endocrine disrupter screening program.
- **Chapters 9 and 10** have been extensively reorganized. Chapter 9 is on food resources and hunger and chapter 10 is on farming resources. There is a new opening case study on environmental costs of protein, and sustainable food

production; nine new or revised figures; and a new Data Analysis exercise on examining relative values.

- **Chapter 10** is almost completely revised to combing the previous edition's Pesticides chapter with the topics of soils and other resources for agriculture. Extensive new sections cover soil components, erosion and land degradation, pests, and pesticides. The pesticide section is reorganized and updated to reflect recent changes in transgenic crop uses; the section on integrated pest management is revised; and there is a new What Do You Think? box: Amazonian Terra Preta Soils and nine new or revised figures.
- **Chapter 11** opens with a new case study based on the recently released Northern Spotted Owl Recovery Plan. This case study serves as a reference for much of the subsequent discussion in the chapter. For example, habitat destruction, endangered species recovery, captive breeding, invasive species incursions, and critical habitat designation all have bearing on spotted owl protection. The numbers of known and estimated species by major group has been updated with new data. This chapter has six new figures.
- **Chapter 12** has extensive revisions that present new information on world forest status as well as specific descriptions of the status of tropical and temperate forests. It has a brief introduction to the huge areas protected in new U.S. National Monuments in the Pacific. People use many different descriptions for relatively undamaged forests, including virgin, native, old-growth, or frontier forests. Although we sometimes use one of these terms to provide student familiarity with this vocabulary, we've adopted the terminology suggested by the U.N. Food and Agriculture Organization, and use the term *primary* forest throughout the text. This chapter also has eight new figures.
- **Chapter 14** has a new Data Analysis exercise on tectonic plate margins.
- **Chapter 15** is substantially revised to reflect new data on climate change. There is a new opening case study on climate wedge analysis; revised discussion of climate processes; revised discussion of the Intergovernmental Panel on Climate Change (IPCC), including several new figures from the IPCC's fourth assessment report; a new section discussing how we know climate change is human-caused; new or extensively revised sections on different greenhouse gases, on why we should care about climate change, and the observed effects of climate change, and on strategies for reducing greenhouse gas emissions; thirteen new or revised figures; and a new Data Analysis using IPCC data.
- **Chapter 16** has a new discussion of airborne mercury sources, with new figure.
- **Chapter 17** has a new case study on water-sharing in the Klamath basin in California. After years of bitterly contentious (and overtly political) controversy, it's encouraging that the major stakeholders in this debate have finally found common ground and are working out ways to share the dwindling resource. This case study provides a positive example of dispute mediation and also ties in very well with extensive new sections of the chapter on droughts, water shortages, shrinking rivers, and water conservation. It also connects with a new What Do You Think? box on the benefits and problems associated with dam removal. It turns out that proposals for destruction of four dams on the Klamath provide a good share of the incentive for bringing together warring constituencies.
- **Chapter 18** has new material on wetlands protection, water pollution in developing countries (particularly India), and the positive impact of constructing of rain gardens. It also has a rewritten (and improved) Data Analysis box at the end of the chapter.
- **Chapter 19** has new sections on global oil imports, the problems and benefits of carbon capture and storage, oil and gas leases in the western United States, and a new photo and brief discussion of the Trans-Alaska pipeline. The discussion of nuclear power has been significantly shortened. Because nuclear plants don't release greenhouse gases (although the mining and processing of fuel is another issue), utilities are seeking permission to build new nuclear power plants in the United States for the first time in nearly 40 years. Recent economic analysis, however, shows that new nuclear plants have become far too costly to make sense. As the *Economist* magazine put it. "Nuclear power has gone from too cheap to meter to too costly to matter."
- **Chapter 20** has extensive new material on green buildings, plug-in hybrid vehicles, biomass energy, renewable-energy programs at colleges, and ethanol production; biofuels from plant oils, cellulosic material, and algae; and plans to upgrade the electrical transmission grid. Altogether, about half the chapter is new or revised. There's a new What Do You Think? box on the sustainability of grain-based and cellulosic ethanol, using recent analysis from ecologists and economists at the University of Minnesota that evaluates the health effects and climate-change costs of different fuel types.
- **Chapter 21** has updated sections on e-waste and marine plastic debris, with a new figure.
- **Chapter 24** is rewritten to simplify and prioritize students' understanding of major policies and policy formation. There is a new opening case study on the Clean Water Act, with new figures; a new discussion highlighting major environmental laws, a new boxed reading on philosophical views about government size; and a revised section on lawmaking, case law, public action, courts, and mediation. There is also a new Data Analysis exercise about examining environmental laws on the EPA website, and five new or revised figures.

Acknowledgements

We owe a great debt to the hardworking, professional team that has made this the best environmental science text possible. We express special thanks for editorial support to Marge Kemp, Janice Roerig-Blong, Ashley Zellmer, and Wendy Langerud. We are grateful to the excellent production team led by April Southwood and marketing leadership by Heather Wagner. We also thank Kandis Elliot for her outstanding artwork, and Cathy Conroy for copy-editing. We also thank Dr. Kim Chapman for essays that contributed to the text. Finally, we thank the many contributions of careful reviewers who shared their ideas with us during revisions.

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Guided Tour

A global perspective is vital to learning about environmental science.

Case Studies

In the front of each chapter, case studies utilize stories to portray real-life global issues that affect our food, our quality of life, and our future. Seventeen new case studies have been added to further focus on current events and the success stories of environmental protection progress.

Case Study Farming the Cerrado

A soybean boom is sweeping across South America. Inexpensive land, availability of new crop varieties, and government policies that favor agricultural expansion have made South America the fastest growing agricultural area in the world. The center of this rapid expansion is the Cerrado, a huge area of grassland and tropical forest stretching from Bolivia and Paraguay across the center of Brazil almost to the Atlantic Ocean (fig. 10.1). Biologically, this rolling expanse of grasslands and tropical woodland is the richest savanna in the world, with at least 130,000 different plant and animal species, many of which are threatened by agricultural expansion.

Until recently, the Cerrado, which is roughly equal in size to the American Midwest, was thought to be unsuitable for cultivation. Its red iron-rich soils are highly acidic and poor in essential plant nutrients. Furthermore, the warm, humid climate harbors many destructive pests and pathogens. For hundreds of years, the Cerrado was primarily cattle country with many poor-quality pastures producing low livestock yields.

In the past few decades, however, Brazilian farmers have learned that modest applications of lime and phosphorus can quadruple yields of soybeans, maize, cotton, and other valuable crops. Researchers have developed more than 40 varieties of soybeans—mostly through conventional breeding, but some created with molecular techniques—specially adapted for the soils and climate of the Cerrado. Until about 30 years ago, soybeans were a relatively minor crop in Brazil. Since 1975, however, the area planted with soy has doubled about every four years, reaching more than 25 million ha (60 million acres) in 2006. Although that's a large area, it represents only one-eighth of the Cerrado, more than half of which is still occupied by pasture.

Brazil is now the world's top soy exporter, shipping some 50 million metric tons per year, or about 10 percent more than the United States. With two crops per year, cheap land, low labor costs, favorable tax rates, and yields per hectare equal to those in the American Midwest, Brazilian farmers can produce soybeans for less than half the cost in America. Agricultural economists predict that, by 2020, the global soy crop will double from the current 160 million metric tons per year, and that South America could be responsible for most of that growth. In addition to soy, Brazil now leads the world in beef, corn (maize), oranges, and coffee exports. This dramatic increase in South American agriculture helps answer the question of how the world may feed a growing human population.

A major factor in Brazil's current soy expansion is rising income in China. With more money to spend, the Chinese are consuming more soy, both directly as tofu and other soy products, and indirectly as animal feed. A decade ago, China was self-sufficient in soy production. Now, China imports about 30 million tons of soy annually. About half that amount comes from Brazil, which passed the United States in 2007 as the world's leading soy exporter. In 1997, Brazil shipped only 2 million tons of soy. A decade later, exports reached 28 million tons.

The outbreak of mad cow disease (or BSE, see chapter 8) in Europe, Canada, and Japan has fueled increased worldwide demand for Brazilian beef. With 175 million free-range, grass-fed (and presumably BSE-free) cattle, Brazil has become the world's largest beef exporter.

Increasing demand for both soybeans and beef create land conflicts in Brazil. The pressure for more cropland and pasture is a leading cause of deforestation and habitat loss, most of which is occurring in the "arc of destruction" between the Cerrado and the Amazon. Small family farms are being gobbled up, and farm workers, displaced by mechanization, often migrate either to the big cities or to frontier forest areas. Increasing conflicts between poor farmers and big landowners have led to violent confrontations. The Landless Workers Movement claims that 1,237 rural workers died in Brazil between 1985 and 2000 as a result of assassinations and clashes over land rights. In 2005, a 74-year-old Catholic nun, Sister Dorothy Stang, was shot by gunmen hired by ranchers who resented her advocacy for native people, workers, and environmental protection. Over the past 20 years, Brazil claims to have resettled 600,000 families from the Cerrado. Still, tens of thousands of landless farm workers and displaced families live in unauthorized squatter camps and shantytowns across the country awaiting relocation.

As you can see, rapid growth of beef and soy production in Brazil have both positive and negative aspects. On one hand, more high-quality food is now available to feed the world. The 2 million km^2 of the Cerrado represents one of the world's last opportunities to open a large area of new, highly productive cropland. On the other hand, the rapid expansion and mechanization of agriculture in Brazil is destroying biodiversity and

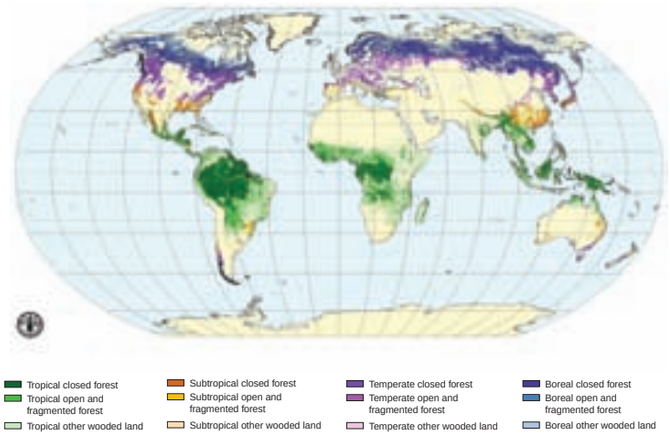
Arc of destruction
BRAZIL
CERRADO
BOLIVIA
PARAGUAY
BRAZIL
ATLANTIC RAINFOREST

FIGURE 10.1 Brazil's Cerrado, 2 million ha of savanna (grassland) and open woodland, is the site of the world's fastest growing soybean production. Cattle ranchers and agricultural workers, displaced by mechanized crop production, are moving northward into the "arc of destruction" at the edge of the Amazon rainforest, where the continent's highest rate of forest clearing is occurring.

CHAPTER 10 Farming: Conventional and Sustainable Practices 197

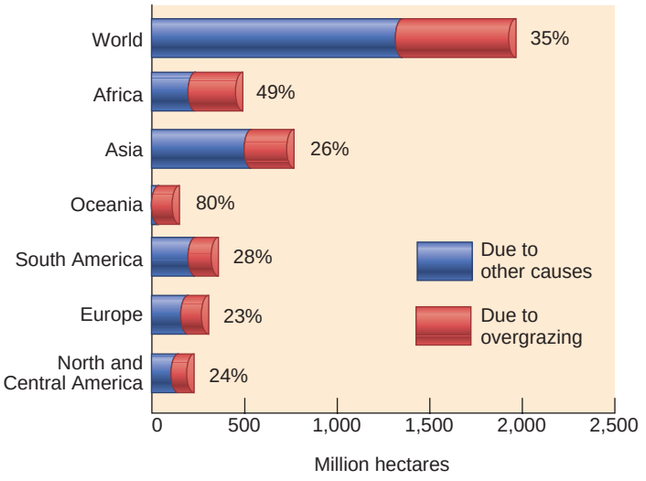
Google Earth™ Placemarks

This feature provides interactive satellite imagery of the earth to give students a geographic context of places and topics in the text. Students can zoom in for detail or they can zoom out for a more global perspective. Placemark links can be found on the website http://www.mhhe.com/cunningham11e.



The Latest Global Data

Easy to follow graphs, charts, and maps display numerous examples from many regions of the world. Students are exposed to the fact that environmental issues cross borders and oceans.



Critical thinking skills support understanding of environmental change.

Exploring Science

Real-life environmental issues drive these readings as students learn about the principles of scientific observation and proper data-gathering techniques.

Exploring Science — Predators Help Restore Biodiversity in Yellowstone

In the past dozen years, Yellowstone National Park has been the site of a grand experiment in managing biodiversity. The park is renowned for its wildlife and wilderness. But between about 1930 an 1990, park managers and ecologists observed that growing elk populations were overbrowsing willow and aspen. Plant health and diversity were declining, and populations of smaller mammals, such as beaver, were gradually dwindling. Most ecologists blamed these changes on the eradication of one of the region's main predators, the gray wolf (*Canis lupus*). Now, a project to restore wolves has provided a rare opportunity to watch environmental change unfold.

Wolves were once abundant in the Greater Yellowstone ecosystem. In the 1890s, perhaps 100,000 wolves roamed the western United States. Farmers and ranchers, aided by government programs to eradicate predators, gradually poisoned, shot, and trapped nearly all the country's wolves. In the northern Rocky Mountains, elk and deer populations expanded rapidly without predators to restrain their numbers. Yellowstone's northern range elk herd grew to about 20,000 animals. Some ecologists warned that without a complete guild of predators, the elk, bison, and deer could damage one of our best-loved parks. After much controversy, 31 wolves were captured in the Canadian Rockies and relocated to Yellowstone National Park in 1995 and 1996.

Wolves expanded quickly in their new home. With abundant elk for prey, as well as occasional moose and bison, the wolves tripled their population in just three years. The population now exceeds 100 animals in over 20 packs, well beyond the recovery goal of 10 packs.

Following the wolf reintroductions, elk numbers have fallen, and regenerating willow and aspen show signs of increased stature and abundance. Elk carcasses left by wolves provide a feast for scavengers, and wolves appear to have driven down numbers of coyotes, which prey on small mammals. Many ecologists see evidence of more songbirds, hawks, foxes, voles, and ground squirrels, which they attribute to wolf reintroductions. Other ecologists caution that Yellowstone is a complex system, and wolves are one of many factors that may influence regeneration. For example, recent mild winters may have allowed elk to find alternate food sources, reducing browsing pressure on willows and aspen, and drought may have contributed to declining elk numbers. Debate on the exact impact of wolves underscores the difficulty of interpreting change in complex ecosystems. Whether or not wolves are driving ecological change, most ecologists agree that wolves contribute to a diverse and healthy ecosystem.

Wolves reintroduced to Yellowstone National Park help to restore biodiversity and ecosystem health.

New Technology

How do ecologists study these changes? For years, ecologists have skiied and snowshoed out to remote observation posts to record wolf kills and observe wolf behavior. But the difficulty of this field work has limited the amount of data that could be collected. One of the exciting new alternatives involves a remotely controlled video camera that allows researchers to monitor wolf ecology and behavior without intruding on the wolves.

Ecologist Dan MacNulty, of the University of Minnesota, together with Glenn Plumb of the National Park Service, has installed a pair of computer-controlled video cameras in an open meadow near hot springs where bison gather to seek exposed grass in the winter. Wolves, hoping to prey on the bison, frequent the area as well. Instead of skiing long, cold miles to the site, MacNulty can now turn on a camera from his office desktop. The camera scans an area of 17 km^2, and it can zoom in to identify individual animals up to 9.5 km away. In the past, his team was lucky to get a few weeks of winter wolf observation in a year, but now MacNulty and his 12 undergraduate research assistants can watch for wolves year-round, any time it's light enough to see them. Working in shifts, the group records sightings and behavior of wolves, bears, elk, bison, coyotes, and fox.

Because they can observe the animals at length without disturbing them, MacNulty's group has made some intriguing observations. Wolves are masterful at detecting when a bison is vulnerable. They almost never attack a large bull, unless it has wandered from the group or gotten into deep snow, where bison quickly get bogged down. Bison will also work together to fend off wolves—if they can avoid leaving the snow-free areas. Wolves can also be surprisingly persistent: in one case MacNulty says wolves harassed a vulnerable bison for 36 hours before finally killing it. All these observations help ecologists understand how wolves hunt, select their prey, and avoid injury in the chase.

Dan MacNulty observes wolves from his office.

What Do You Think?

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

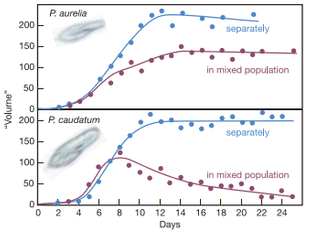
Data Analysis

At the end of every chapter, these exercises ask students to graph and evaluate data while critically analyzing what they observe.

Data Analysis: Species Competition

In a classic experiment on competition between species for a common food source, the Russian microbiologist G. F. Gause grew populations of different species of ciliated protozoans separately and together in an artificial culture medium. He counted the number of cells of each species and plotted the total volume of each population. The organisms were *Paramecium caudatum* and its close relative, *Paramecium aurelia*. He plotted the aggregate volume of cells rather than the total number in each population because P. caudatum is much larger than *P. aurelia* (this size difference allowed him to distinguish between them in a mixed culture). The graphs in this box show the experimental results. As we mentioned earlier in the text, this was one of the first experimental demonstrations of the principle of competitive exclusion. After studying these graphs, answer the following questions.

1. How do you read these graphs? What is shown in the top and bottom panels?
2. How did the total volume of the two species compare after 14 days of separate growth?
3. If *P. caudatum* is roughly twice as large as *P. aurelia*, how did the total number of cells compare after 14 days of separate growth?
4. How did the total volume of the two species compare after 24 days of growth in a mixed population?
5. Which of the two species is the more successful competitor in this experiment?
6. Does the larger species always win in competition for food? Why not?



Growth of two *paramecium* species separately and in combination.
Source: Gause, Georgyi Frantsevitch. 1934 *The Struggle for Existence.* Dover Publications, 1971 reprint of original text.

For Additional Help in Studying This Chapter, please visit our website at www.mhhe.com/cunningham11e. You will find additional practice quizzes and case studies, flashcards, regional examples, place markers for Google Earth™ mapping, and an extensive reading list, all of which will help you learn environmental science.

What Do You Think?

Should We Revise Mining Laws?

In 1872, the U.S. Congress passed the General Mining Law intended to encourage prospectors to open up the public domain and promote commerce. This law, which has been in effect more than a century, allows miners to stake an exclusive claim anywhere on public lands and to take—for free—any minerals they find. Three-forths of the Beartrack Mine, for example, is on public land. Claim holders can "patent" (buy) the land for $2.50 to $5 per acre (0.4 hectares) depending on the type of claim. Once the patent fee is paid, the owners can do anything they want with the land, just like any other private property. Although $2.50 per acre may have been a fair market value in 1872, many people regard it as ridiculously low today, amounting to a scandalous give-away of public property.

In Nevada, for example, a mining company paid $9,000 for federal land that contains an estimated $20 billion worth of precious metals. Similarly, Colorado investors bought about 7,000 ha (17,000 acres) of rich oil-shale land in 1986 for $42,000 and sold it a month later for $37 million. You don't actually have to find any minerals to patent a claim. A Colorado company paid a total of $400 for 65 ha (160 acres) it claimed would be a gold mine. Almost 20 years later, no mining has been done, but the property—which just happens to border the Keystone Ski Area—is being subdivided for condos and vacation homes.

According to the Bureau of Land Management (BLM), some $4 billion in minerals are mined each year on U.S. public lands. Under the 1872 law, mining companies don't pay a penny for the ores they take. Furthermore, they can deduct a depletion allowance from taxes on mineral profits. Former Senator Dale Bumpers of Arkansas, who calls the 1872 mining law "a license to steal," has estimated that the government could derive $320 million per year by charging an 8 percent royalty on all minerals and probably could save an equal amount by requiring larger bonds to be posted to clean up after mining is finished. The Meridian Gold Company, for example, has posted a $2 million bond for cleaning up the Beartrack Mine (a larger than normal amount). Reclamation, however, is expected to cost 15 times that amount. Chapter 13 has more information on how reclamation and restoration can return damaged sites to beneficial uses.

On the other hand, mining companies argue they would be forced to close down if they had to pay royalties or post larger bonds. Many people would lose jobs and the economies of western mining towns would collapse if mining becomes uneconomic. We provide subsidies and economic incentives to many industries to stimulate economic growth. Why not mining for metals essential for our industrial economy? Mining is a risky and expensive business. Without subsidies, mines would close down and we would be completely dependent on unstable foreign supplies.

Thousands of abandoned mines on public lands poison streams and groundwater with acid, metal-laced drainage. This old mine in Montana drains into the Blackfoot River, the setting of Norman Maclean's book. *A River Runs Through It.*

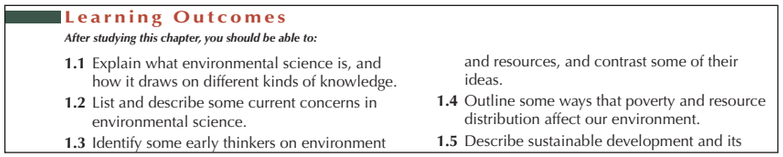
Mining critics respond that other resource-based industries have been forced to pay royalties on materials they extract from public lands. Coal, oil, and gas companies pay 12.5 percent royalties on fossil fuels obtained from public lands. Timber companies—although they don't pay the full costs of the trees they take—have to bid on logging sales and clean up when they are finished. Even gravel companies pay for digging up the public domain. Ironically, we charge for digging up gravel, but give gold away free.

Over the past decade, numerous mining bills have been introduced in Congress. Those supported by environmental groups generally would require companies mining on federal lands to pay a higher royalty on their production. They also would eliminate the patenting process, impose stricter reclamation requirements, and give federal managers authority to deny inappropriate permits. In contrast, bills offered by Western legislators, and enthusiastically backed by mining supporters, tend to leave most provisions of the 1872 bill in place. They would charge a 2 percent royalty, but only after exploration, production, and other costs were deducted. Permit processes would consider local economic needs before environmental issues in this version. What do you think we should do about this mining law? How could we separate legitimate public-interest land use from private speculation and profiteering? Are current subsidies necessary and justifiable or are they just a form of corporate welfare?

Sound pedagogy encourages science inquiry and application.

Learning Outcomes

Found at the beginning of each chapter, and organized by major headings, these outcomes give students an overview of the key concepts they will need to understand.



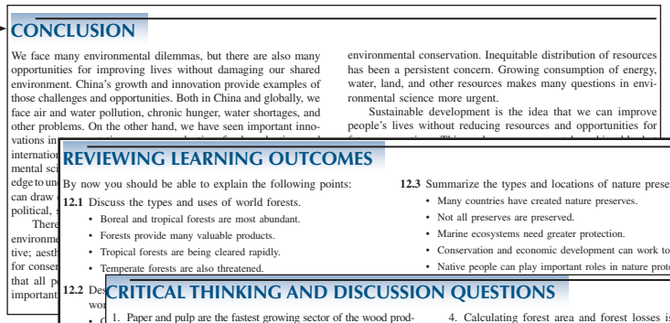
Learning Outcomes

After studying this chapter, you should be able to:

1.1 Explain what environmental science is, and how it draws on different kinds of knowledge.
1.2 List and describe some current concerns in environmental science.
1.3 Identify some early thinkers on environment and resources, and contrast some of their ideas.
1.4 Outline some ways that poverty and resource distribution affect our environment.
1.5 Describe sustainable development and its

Conclusion

This section summarizes the chapter by highlighting key ideas and relating them to one another.



CONCLUSION

We face many environmental dilemmas, but there are also many opportunities for improving lives without damaging our shared environment. China's growth and innovation provide examples of those challenges and opportunities. Both in China and globally, we face air and water pollution, chronic hunger, water shortages, and other problems. On the other hand, we have seen important inno-

environmental conservation. Inequitable distribution of resources has been a persistent concern. Growing consumption of energy, water, land, and other resources makes many questions in environmental science more urgent.

Sustainable development is the idea that we can improve people's lives without reducing resources and opportunities for

Reviewing Learning Outcomes

Related to the Learning Outcomes at the beginning of each chapter, this review clearly restates the important concepts associated with each outcome.

REVIEWING LEARNING OUTCOMES

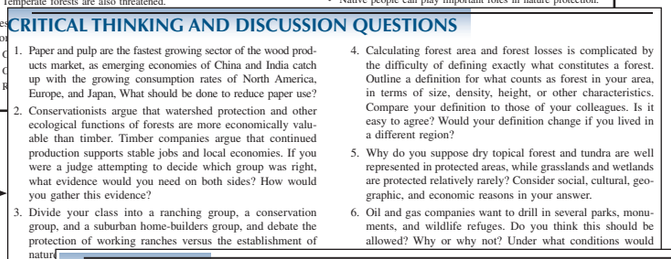
By now you should be able to explain the following points:

12.1 Discuss the types and uses of world forests.
- Boreal and tropical forests are most abundant.
- Forests provide many valuable products.
- Tropical forests are being cleared rapidly.
- Temperate forests are also threatened.

12.3 Summarize the types and locations of nature preserves.
- Many countries have created nature preserves.
- Not all preserves are preserved.
- Marine ecosystems need greater protection.
- Conservation and economic development can work together.
- Native people can play important roles in nature protection.

Critical Thinking and Discussion Questions

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



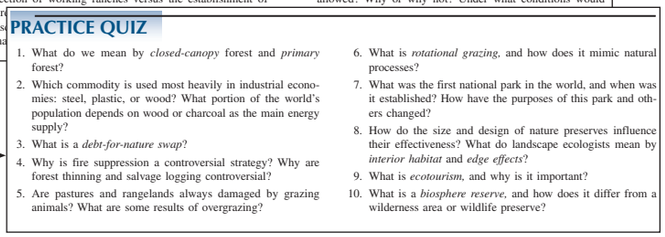
CRITICAL THINKING AND DISCUSSION QUESTIONS

1. Paper and pulp are the fastest growing sector of the wood products market, as emerging economies of China and India catch up with the growing consumption rates of North America, Europe, and Japan. What should be done to reduce paper use?
2. Conservationists argue that watershed protection and other ecological functions of forests are more economically valuable than timber. Timber companies argue that continued production supports stable jobs and local economies. If you were a judge attempting to decide which group was right, what evidence would you need on both sides? How would you gather this evidence?
3. Divide your class into a ranching group, a conservation group, and a suburban home-builders group, and debate the protection of working ranches versus the establishment of

4. Calculating forest area and forest losses is complicated by the difficulty of defining exactly what constitutes a forest. Outline a definition for what counts as forest in your area, in terms of size, density, height, or other characteristics. Compare your definition to those of your colleagues. Is it easy to agree? Would your definition change if you lived in a different region?
5. Why do you suppose dry topical forest and tundra are well represented in protected areas, while grasslands and wetlands are protected relatively rarely? Consider social, cultural, geographic, and economic reasons in your answer.
6. Oil and gas companies want to drill in several parks, monuments, and wildlife refuges. Do you think this should be allowed? Why or why not? Under what conditions would

Practice Quiz

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

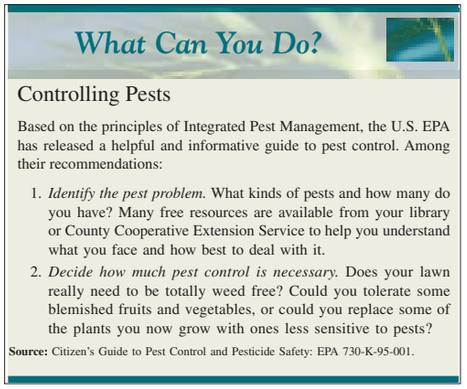


PRACTICE QUIZ

1. What do we mean by *closed-canopy* forest and *primary* forest?
2. Which commodity is used most heavily in industrial economies: steel, plastic, or wood? What portion of the world's population depends on wood or charcoal as the main energy supply?
3. What is a *debt-for-nature swap*?
4. Why is fire suppression a controversial strategy? Why are forest thinning and salvage logging controversial?
5. Are pastures and rangelands always damaged by grazing animals? What are some results of overgrazing?
6. What is *rotational grazing*, and how does it mimic natural processes?
7. What was the first national park in the world, and when was it established? How have the purposes of this park and others changed?
8. How do the size and design of nature preserves influence their effectiveness? What do landscape ecologists mean by *interior habitat* and *edge effects*?
9. What is *ecotourism*, and why is it important?
10. What is a *biosphere reserve*, and how does it differ from a wilderness area or wildlife preserve?

What Can You Do?

This feature gives students realistic steps for applying their knowledge to make a positive difference in our environment.



What Can You Do?

Controlling Pests

Based on the principles of Integrated Pest Management, the U.S. EPA has released a helpful and informative guide to pest control. Among their recommendations:

1. *Identify the pest problem.* What kinds of pests and how many do you have? Many free resources are available from your library or County Cooperative Extension Service to help you understand what you face and how best to deal with it.
2. *Decide how much pest control is necessary.* Does your lawn really need to be totally weed free? Could you tolerate some blemished fruits and vegetables, or could you replace some of the plants you now grow with ones less sensitive to pests?

Source: Citizen's Guide to Pest Control and Pesticide Safety: EPA 730-K-95-001.

Think About It

These boxes provide several opportunities in each chapter for students to review material, practice critical thinking, and apply scientific principles.

Think About It

Examine figure 1.16. Describe in your own words how increasing wealth affects the three kinds of pollution shown. Why do the trends differ?

Online Teaching and Study Tools

Text Website: http://www.mhhe.com/cunningham11e

McGraw-Hill offers various tools and technology products to support *Environmental Science: A Global Concern*. Instructors can obtain teaching aids by calling the Customer Service Department at 1-800-334-7344.

Presentation Center (ISBN-13: 978-0-07-332806-5;
ISBN-10:0-07-332806-5)
ARIS Presentation Center is an online digital library containing assets such as photos, artwork, PowerPoints, animations, and other media types that can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, and attractive printed support materials. The following digital assets are grouped by chapter:

- **Color Art** Full-color digital files of illustrations in the text can be readily incorporated into lecture presentations, exams, or custom-made classroom materials. These include all of the 3-D realistic art found in this edition, representing some of the most important concepts in environmental science.
- **Photos** Digital files of photographs from the text can be reproduced for multiple classroom uses.
- **Tables** Every table that appears in the text is provided in electronic format.
- **Videos** This special collection of 69 underwater video clips displays interesting habitats and behaviors of many animals in the ocean.
- **Animations** One hundred full-color animations that illustrate many different concepts covered in the study of environmental science are available for use in creating classroom lectures, testing materials, or online course communication. The visual impact of motion will enhance classroom presentations and increase comprehension.
- **Test Bank** A computerized test bank that uses testing software to quickly create customized exams is available on for this text. The user-friendly program allows instructors to search for questions by topic or format, edit existing questions or add new ones; and scramble questions for multiple versions of the same test. Word files of the test bank questions are provided for those instructors who prefer to work outside the test-generator software.
- **Global Base Maps** Eighty-eight base maps for all world regions and major subregions are offered in four versions: black-and-white and full-color, both with labels and without labels. These choices allow instructors the flexibility to plan class activities, quizzing opportunities, study tools, and PowerPoint enhancements.
- **PowerPoint Lecture Outlines** Ready-made presentations that combine art and photos and lecture notes are provided for each of the 25 chapters of the text. These outlines can be used as they are or tailored to reflect your preferred lecture topics and sequences.
- **PowerPoint Slides** For instructors who prefer to create their lectures from scratch, all illustrations, photos, and tables are preinserted by chapter into blank PowerPoint slides for convenience.
- **Course Delivery Systems** With help from WebCT and Blackboard, professors can take complete control of their course content. Course cartridges containing website content, online testing, and powerful student tracking features are readily available for use within these platforms.

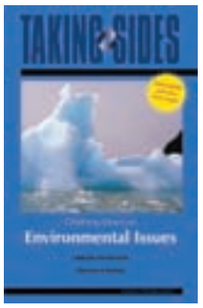
Electronic Textbook

CourseSmart is a new way for faculty to find and review eTextbooks. It's also a great option for students who are interested in accessing their course materials digitally and saving money. CourseSmart offers thousands of the most commonly adopted textbooks across hundreds of courses from a wide variety of higher education publishers. It is the only place for faculty to review and compare the full text of a textbook online, providing immediate access without the environmental impact of requesting a print exam copy. At CourseSmart, students can save up to 50 percent off the cost of a print book, reduce their impact on the environment, and gain access to powerful web tools for learning including full text search, notes and highlighting, and email tools for sharing notes between classmates. www.CourseSmart.com

Learning Supplements for Students

Website (www.mhhe.com/cunningham11e)
The *Environmental Science: A Global Concern* website provides access to resources such as multiple-choice practice quizzes with immediate feedback and grade, Google Earth links and questions. Interactive maps, animation quizzes and a case study library.

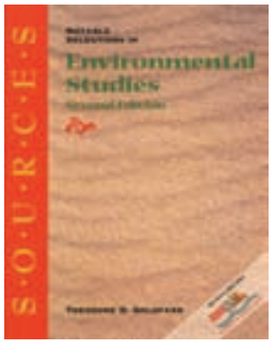
***Annual Editions: Environment 09/10* by Sharp**
(MHID: 0-07-351549-3)
This Twenty-Eighth Edition provides convenient, inexpensive access to current articles selected from some of the most respected magazines, newspapers, and journals published today. Organizational features include: an annotated listing of selected World Wide Web sites; an annotated table of contents; a topic guide; a general introduction; brief overviews for each section; and an instructor's resource guide with testing materials. *Using Annual Editions in the Classroom* is also offered as a practical guide for instructors.



Taking Sides: Clashing Views on Controversial Environmental Issues,
Expanded Thirteenth Edition by Easton
(MHID: 0-07-351445-4)
This Expanded Thirteenth Edition of *Taking Sides: Environmental Issues* presents two additional current controversial issues in a debate-style format designed to stimulate student interest and develop critical thinking skills. Each issue is thoughtfully framed with an issue summary, an issue introduction, and a postscript. *Taking Sides* readers also feature annotated listings of selected World Wide Web sites. An instructor's resource guide with testing material is available for each volume. *Using Taking Sides in the Classroom* is also an excellent instructor resource.

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.

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 stay current on every nation's capital, type of government, currency, major languages, population, religions, political structure, climate, economics, and more, this book is intended to help students to understand these essential facts in order to make useful applications.



Sources: Notable Selections in Environmental Studies, Second Edition, by Goldfarb
(ISBN: 978-0-07-303186-6; MHID: 0-07-303186-0)
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.